

# OncoKB™ Curation Standard Operating Procedure

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## Changes or Updates in Version 4.1 of the OncoKB™ SOP from Version 4.0

1. Version 4.0, p 206, the addition of: [Chapter 8: The OncoKB™ website](#).

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# I. Introduction

OncoKB is a Precision Oncology Knowledgebase that contains information about the biological effects and treatment implications of specific cancer genes and their somatic alterations. OncoKB is developed and maintained by the Knowledge Systems group in the Marie Josée and Henry R. Kravis Center for Molecular Oncology at Memorial Sloan Kettering Cancer Center (MSK).

In OncoKB, genes are classified as either oncogenes or tumor suppressors based on the curated evidence. Alterations included in OncoKB are protein-level changes that arise as a result of DNA-level variants in cancer: non-synonymous mutations, translocations, rearrangements / fusions, copy number amplifications and deletions. This document uses “Alterations”, “Mutations” and “Variants” interchangeably. All alterations in OncoKB are classified according to 1) their oncogenic effect and 2) their biological effect, based on the curated evidence (discussed in [Chapter 1: Protocol 2: Variant Curation](#)). In OncoKB, the oncogenic effect of an alteration is an evidence-based assertion that classifies whether the mutation is oncogenic, likely oncogenic, neutral or inconclusive. Additionally, in OncoKB, the biological effect of an alteration is an evidence-based assertion that classifies whether the mutation is gain-of-function, loss-of-function, neutral or inconclusive.

A subset of oncogenic alterations in cancer may act as biomarkers that may be diagnostic of a specific cancer, have prognostic implications or may be predictive of response to specific targeted therapies in specific cancer indications. If a cancer alteration in OncoKB is associated with clinical implications, these implications are also curated in OncoKB (discussed in [Chapter 2: Curation of variant and tumor type specific clinical implications](#)). Alterations with clinical implications are further assigned a Therapeutic (Chakravarty et al., 2017), level of evidence. Each Level of Evidence assignment in OncoKB defines the strength of the evidence that supports the alteration as being a therapeutic biomarker.

## A. OncoKB Oversight and Governance

Oversight and governance of OncoKB is under the purview of the Lead Scientist and the Clinical Genomics Annotation Committee (CGAC). The Lead Scientist and CGAC are responsible for establishing standards and oversight of all processes in the scope of OncoKB. CGAC provides expertise in cancer variant interpretation, and, in particular, the assignment of the OncoKB Levels of Evidence to specific alterations. CGAC consists of “Core” members and “Extended” members. Core CGAC members guide OncoKB development, are at the forefront of clinical management and research and have translational cancer biology expertise in their respective major disease entities. Extended members are selected physicians and scientists who represent the broader MSK clinical leadership across departments and services, including service chiefs, physicians with clinical expertise in their fields, and scientists with specific gene or pathway expertise. Core members, in addition to responding to requests regarding clinical consensus, also maintain an active and responsive dialogue with the Lead Scientist, providing insight or updates regarding genomic biomarker-based clinical data.

## B. OncoKB Staff

The OncoKB staff consists of the following:

1. **The OncoKB Lead Scientist** creates and maintains general oversight and governance procedures for the OncoKB staff including the development, approval, and coordination of all variant assessment

activities. The Lead Scientist also liaises between the variant curation processes and their oversight and governance by CGAC. The OncoKB Lead Scientist does not have any relevant conflicts of interest.

2. **Lead Scientist, Knowledge Systems** creates and maintains the systems, programs and computational aspects of OncoKB and its deployment to the various OncoKB outputs while overseeing and coordinating the software engineering staff. The Lead Scientist of the Knowledge Systems liaises between the software engineers and the OncoKB Lead Scientist. The Lead Scientist of Knowledge Systems does not have any relevant conflicts of interest.
3. **The Scientific Content Management Team (SCMT)** is made up of three Ph.D-level and one M.S.-level scientists with translational cancer biology expertise that provide day-to-day guidance and management of the OncoKB Curators regarding appropriate curation, and who also provide editorial and scientific content review. No member of the SCMT has any relevant conflicts of interest.
4. **Lead Software Engineer** executes the systems, programs and computational aspects of OncoKB and its deployment to the various OncoKB outputs, while providing day-to-day guidance and management of the software engineers. The Lead Software Engineer does not have any relevant conflicts of interest.
5. **Software Engineer** undertakes tasks within the systems, programs and computational aspects of OncoKB under the guidance of the Lead Software Engineer. The Software Engineer does not have any relevant conflicts of interest.
6. **Data and Software Liaison** acts as a bridge between the software team and the scientific team. The data and software liaison executes computational data analysis, provides computational assistance to the scientific team and works with the software team to implement systems for data curation. The data and software liaison does not have any relevant conflicts of interest.
7. **OncoKB Curators** include pre-doctoral graduate students, postdoctoral fellows and clinical fellows. They assess and curate alterations, their biological effects, and their oncogenic effects in cancer in compliance with the procedures described by the OncoKB SOP. OncoKB Curators are specifically trained in evaluating evidence from various sources and entering the appropriate information into the curation platform.

## C. OncoKB Data Sources

Four primary data sources are used to identify and curate cancer variants and their biological and clinical therapeutic implications (See [Chapter 1: Sub-protocol 2.1: Variant Sources](#)):

1. Public cancer variant databases of alterations identified in tumor sequencing studies, e.g., cBioPortal and COSMIC (Catalogue of Somatic Mutations in Cancer).
2. Statistically significant and recurrent variants identified based on 24,592 sequenced tumors using methods described in [Chang et al., 2018](#).
3. Disease-specific treatment guidelines such as those provided by the National Cancer Compendium Network (NCCN) and proceedings of major scientific and/or clinical conferences such as the American Society of Clinical Oncology (ASCO) and the American Association of Cancer Research (AACR).
4. General scientific literature, accessed through PubMed.

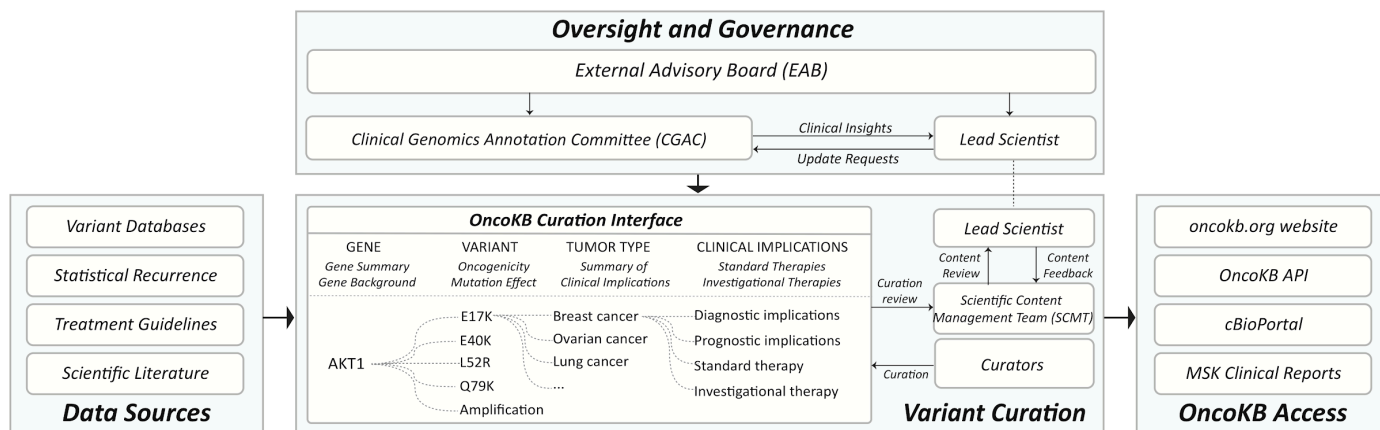
The external databases that we use as reference for curation are: 1) IARC TP53 (<https://p53.iarc.fr/>) 2) BRCA Exchange (<https://brcaexchange.org/>), 3) Cancer Hotspots ([www.cancerhotspots.org](http://www.cancerhotspots.org)). These databases are NOT used as primary curation sources. Rather, they are used for variant candidate selection by downloading the comprehensive list of alterations in each database and comparing them to the mutations curated in OncoKB. Post candidacy, each variant is independently curated using the processes specified in [Chapter 1: Protocol 2: Variant curation](#), and undergo necessary review ([Chapter 3: Data review and release](#)), reanalysis, and re-review ([Chapter 5: Re-analysis and reevaluation](#)) as needed. Thus far, we have selected candidate alterations from the IARC and BRCA Exchange (at the time, known as BIC) databases once in August 2015. Since then, manual review of publications with BRCA and TP53 variants has been our primary process of curation. For cancerhotspots.org, two publications in 2016 and 2018 provided a variant candidate list which we reviewed per [Chapter 1: Protocol 2: Variant curation](#). Variants that had supporting scientific literature were classified as “Oncogenic” per [Chapter 1: Sub-Protocol 2.5: Assertion of the oncogenic effect of a VPS](#) and variants which were considered hotspots based purely on statistical recurrence per [Chang et al., 2018](#) were considered “Likely Oncogenic” per [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#). The Cancer Hotspots website has a static list based on the 2018 publication and has not been updated since.

## D. OncoKB Access

Data from OncoKB is used in four ways ([Figure 1: Summary of OncoKB processes](#)):

1. OncoKB data is publicly available for personal and research purposes through an interactive website at [www.oncokb.org](http://www.oncokb.org). Usage terms of OncoKB are specified at <https://www.oncokb.org/terms>.
2. The curated data is also available programmatically through the OncoKB application program interface (API). The different ways to access OncoKB data are documented at [www.oncokb.org/DataAccess](http://www.oncokb.org/DataAccess).
3. The cBioPortal for Cancer Genomics (<https://www.cbioportal.org>) uses the OncoKB API for annotating cancer variants in its database.
4. OncoKB data is used to annotate the patient reports of the results from MSK-IMPACT, a targeted tumor sequencing test available to MSK patients.

Additionally, this document, a version-controlled OncoKB SOP v2 describing all processes and protocols involved in the maintenance of OncoKB, is publicly available on our website.



**Figure 1: Summary of OncoKB processes.**

The schematic shows a summary of the data sources, knowledgebase architecture and processes that compose the OncoKB workflow.

## E. Conflicts of Interest

Evidence-based assertions of the oncogenic and biological effect of an alteration (as described in [Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS](#) and [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)) are not considered to be subject to conflicts of interest (COI). The evidence used to support specific assertions of oncogenic and biological effects is displayed on the website and linked to the appropriate references in PubMed or to the scientific abstract website. Variant assertions are re-analyzed and re-evaluated by the OncoKB team in specific review cycles ([Chapter 5: Protocol 1: Variant re-analysis and re-evaluation](#)) and any new content or inconsistencies are corrected at that time. Additionally feedback regarding updated content or inconsistencies reported from users of OncoKB either through the website or via cBioPortal are addressed within 72 hours of receipt (refer to [Chapter 1: Sub-protocol 2.1: Variant Sources](#) and [Chapter 5: Variant reanalysis and re-evaluation](#)).

A subset of alterations in OncoKB are considered biomarkers that are predictive of response to certain drugs (Variants of potential clinical significance) and are asserted an OncoKB level of evidence in accordance with [Chapter 2: Protocol 1: Curation of tumor-type specific variant clinical implications](#). Some of these drugs are FDA-approved and the biomarker is a consideration in standard care. In these cases, the biomarker is associated with either Level of Evidence 1 or 2 (refer to [Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels](#) and [Chapter 2: Sub-Protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)) and are not subject to COI. However, some of these drugs are either 1) FDA-approved, but the biomarker is in an off-label setting or 2) not FDA-approved and instead are being tested in clinical trials, and for these, COI may arise. In both of the latter scenarios, the biomarkers and drugs are considered investigational and are associated with a Level of Evidence, 3A, 3B or 4 (refer to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) and [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#)).

To address and resolve potential COI, any new level assignments or changes to an existing level have to be approved unanimously by all CGAC members and there are at minimum 3 affirmative verifications from CGAC (please refer to [Chapter 2: Protocol 2: CGAC approval of OncoKB leveled associations](#)). The affirmative verifications from CGAC that must be received in order for a proposed change to the levels of evidence to be entered into OncoKB are the following:

1. From the Director of the Center for Molecular Oncology, Dr. David Solit
2. From a Disease Management Team Chief in the indication of the proposed level of evidence change
3. A miscellaneous member of CGAC

Members of CGAC who may have COI with respect to the introduction or change of the levels of evidence assigned to a specific variant are allowed to provide advice and information regarding the assertion, but are excluded from the 3 CGAC member verification committee.

Financial conflicts of interest for all OncoKB personnel including CGAC are disclosed publicly on the OncoKB website, [www.oncokb.org/team](http://www.oncokb.org/team) and reported in publications or in conferences as appropriate. In the event of a conflict of interest arising for a specific CGAC member with regards to a Level of Evidence assignment, he or she is asked to recuse themselves from the consensus request. In the event that consensus cannot be immediately reached, the Lead Scientist is responsible for mediating between conflicting advice to resolve any discrepancy. The Lead Scientist can request the input from the External Advisory Board to resolve conflicting

advice from CGAC. Should consensus still not be reached, the proposed change in the Level of Evidence is rejected.

## F. External Advisory Board

To further mitigate issues of conflicts of interest (COI), we have convened an External Advisory Board (EAB), which consists of four leaders in the clinical oncology and genomics community: Dr. Victor Velculescu from Johns Hopkins University, Dr. Lillian Siu from Princess Margaret Hospital, Dr. Eliezer Van Allen from the Dana Farber Cancer Center and Dr. Alexander Lazar from MD Anderson Cancer Center. As part of the OncoKB EAB, these members have agreed to meet once a year via WebEx to review summarized OncoKB content, comment on any notable process or content changes based on the FDA-approval and clinical trial landscape, assess productivity of the OncoKB team, and advise on improvements to the OncoKB infrastructure, process, or content as necessary. Furthermore they will help mitigate and resolve any COI issues that may arise among members of CGAC.

# II. Definitions

## **Alterations:**

Alterations included in OncoKB are genetic changes that arise as a result of DNA-level variants in cancer: non-synonymous mutations, translocations, rearrangements/fusions, copy number amplifications and deletions. This document uses “alterations”, “mutations” and “variants” interchangeably. OncoKB describes alterations by their effect on the protein using the indicated RefSeq and not at the DNA level. All alterations in OncoKB are classified according to 1) their oncogenic effect and 2) their biological effect, based on the curated evidence.

## **cBioPortal for Cancer Genomics**

The cBioPortal for cancer genomics (herein referred to as “cBioPortal” or “portal”) is a web-based software system originally developed at MSKCC. The cBioPortal was designed to provide simple and intuitive access to cancer genomics data and allows exploratory data analysis of large data sets and visualization of alterations in individual tumor samples. Like OncoKB, cBioPortal is also housed by the CMO at MSKCC and utilizes OncoKB to annotate the functional and clinical effects of alterations.

## **Clinical Genomics Annotation Committee (CGAC):**

A Clinical Genomics Annotation Committee (CGAC) member is an MD or MD/PhD who is an attending physician at MSKCC and who is considered an expert in their field and disease specialty. CGAC provides oversight and governance of OncoKB while setting and maintaining standards for the database, especially the assignment of the OncoKB Levels of Evidence to specific alterations.

## **Curators:**

Curators (also referred to as biocurators) are individuals who meet the qualifications as listed in Chapter 7 of this document and who are chosen by the SCMT to evaluate primary literature sources, identify variants of potential interest, interpret the scientific data for these variants, suggest biological and clinical effects, and enter such information into the OncoKB curation platform.

## **Center for Molecular Oncology (CMO):**

The Center for Molecular Oncology (CMO) at MSKCC is the department under which OncoKB operates. Scientists in the CMO conduct large-scale translational research involving molecular characterization of archival tumor specimens and patient tissues from clinical trials in order to identify correlations between genomic features and clinical outcomes. OncoKB is part of the knowledge systems in the CMO and data from OncoKB is used internally to annotate the MSK-IMPACT clinical sequencing reports.

## **Emerging Biomarker:**

Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations EGFR exon 20 insertions in NSCLC based on a basket study of Ado-Trastuzumab Emtansine

## **Expert guidelines:**



Expert guidelines (or **expert panels**) are recommendations from known, well-accepted resources in the field of oncology which make consensus recommendations for what should be considered standard of care. Examples of expert guidelines are those from the National Comprehensive Cancer Network (NCCN) and the World Health Organization (WHO).

#### **External Advisory Committee:**

The OncoKB External Advisory Committee is made up of four researchers from institutions outside of MSKCC who oversee the OncoKB practices, evidence levels, and COI on an annual basis. The EAB may suggest changes to existing practices or evidence levels, and is an important check of OncoKB COI.

#### **FDA recognized alterations:**

A list of tumor-type specific gene alterations and the corresponding FDA Level of Evidence that assigns their clinical significance. The assigned FDA level of evidence is based on these alterations being tested in Formalin Fixed Paraffin Embedded (FFPE) specimen types, except in cases where specimen type is not specified.

#### **Hotspot:**

For the purpose of OncoKB and the SOP, a hotspot is defined as a variant that is found recurrently in cancer in a statistically significant manner as defined in [Chang et al. 2017](#).

#### **Investigational Biomarker:**

In contrast to a standard care biomarker that is mentioned in either the FDA drug label or the NCCN as being predictive of response to a targeted drug, investigational biomarkers are those which are associated with off-label use of an FDA-approved drug or use of a non-FDA-approved drug that is currently being tested in clinical trials and is predicted based on preclinical evidence to be associated with response to the drug.

#### **OncoKB Curation Platform:**

The OncoKB Curation Platform (herein referred to as “the curation platform” or “the platform”) is located at <http://oncokb.mskcc.org> and is an internal website that contains structured, itemized, hierarchical means in which all OncoKB data is entered, organized, edited, and maintained. The curation platform is accessible by only those who are approved for access, namely the OncoKB staff and curators. Outputs of the curation platform are MSK-IMPACT clinical reports, cBioPortal, and the OncoKB public website.

#### **OncoKB Public Website:**

The OncoKB public website (herein referred to as “the public website”, “the OncoKB website”, or “the website”) is located at <http://www.oncokb.org> and is a publically accessible website that contains reviewed and accepted data in the OncoKB curation platform, including annotated variants of all genes in the OncoKB curation platform, therapeutics associated with a level of evidence for any biomarker in the OncoKB curation platform, and sources for any OncoKB assertion. Registration for a license with OncoKB allows access to the OncoKB Annotator and the OncoKB API, which are also accessible through the public website.

#### **Oncogenic mutations:**

In OncoKB, the heading “oncogenic mutations” includes all OncoKB-defined oncogenic and likely oncogenic variants per [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#). **If a gene has “Amplification” curated as “Oncogenic” or “Likely Oncogenic”, this alteration will NOT be associated with the tumor-type specific information captured by the term “Oncogenic Mutations.”**

**OncoTree:**

OncoTree (<http://oncotree.info>) is a cancer classification system that was developed and is updated by a cross-institutional committee of oncologists, pathologists, and scientists and is accessible via an open-source web user interface and an application programming interface (API). All tumor types in OncoKB follow the nomenclature, coding, and node structure found in OncoTree.

**Pathognomonic Alterations:**

Pathognomonic alterations are defined as those which are specifically characteristic or indicative of a particular disease or condition and are present in more than 90-95% of tumors. For example, NF1 alterations are considered pathognomonic to neurofibromatosis type 1 (NF1).

**Rare driver:**

A mutation that is statistically recurrent (as defined in [Chang et al., 2018](#)) and/or experimentally determined as functional (as defined in [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)) and that is present in  $\leq 3\%$  of cancers.

**Standard Care Biomarker:**

A subset of alterations in OncoKB are biomarkers that are predictive of response to targeted drugs. When the alteration is specifically mentioned in an FDA-approved targeted drug's label or specified in the NCCN, the alteration is considered by OncoKB as a standard care biomarker.

**Trial-defined clinical benefit:**

The definition of clinical benefit is dependent on the type of trial in question. Clinical benefit for each type of clinical trial used or referenced in OncoKB is defined in [Chapter 2: Supplemental Material: Table S4: Examples of trial-defined clinical benefit or pathological response that may be used to assess clinical benefit in a defined patient population](#)

**Tumor Mutational Burden-High (TMB-H):**

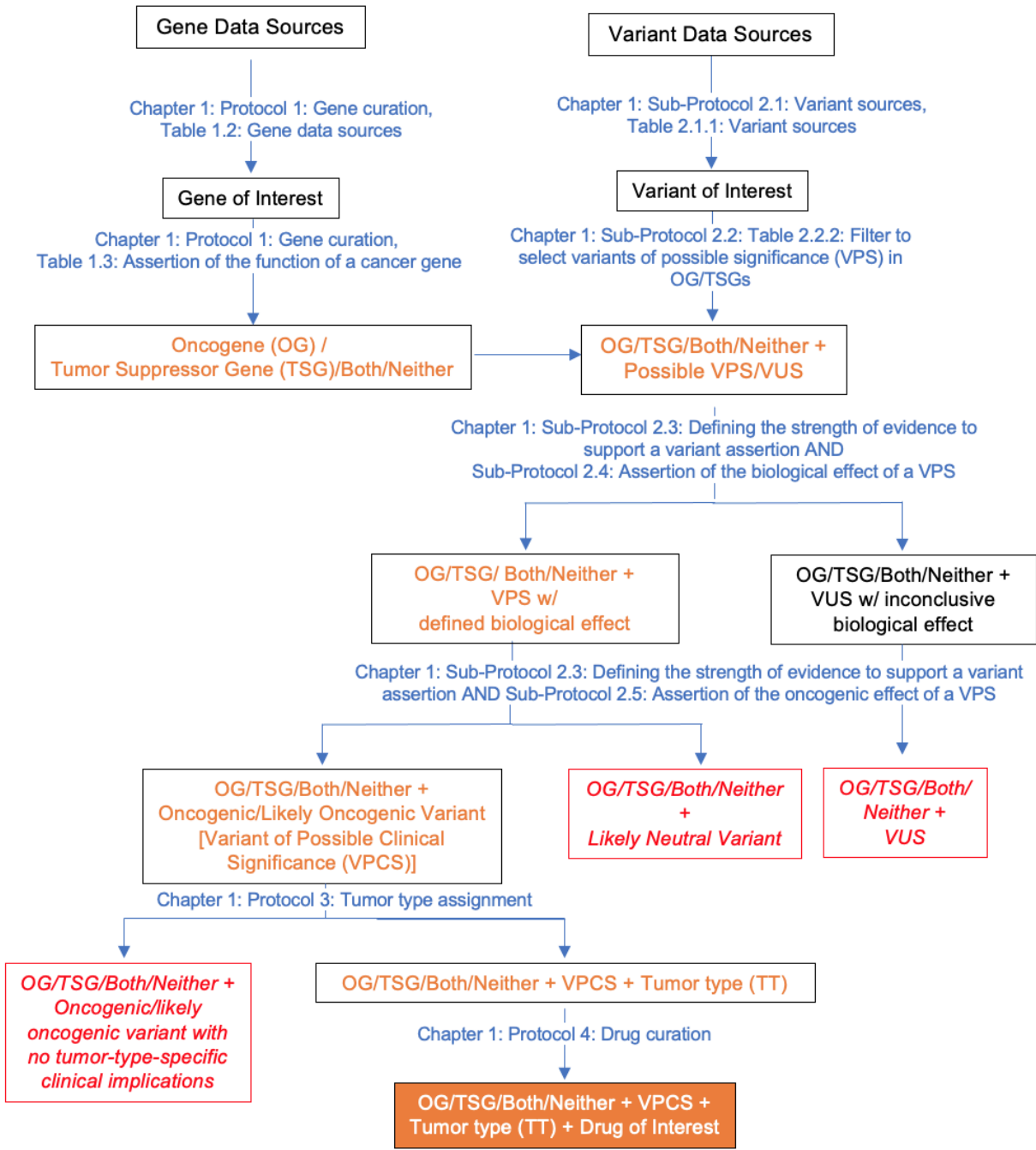
Tumor Mutational Burden (TMB) is defined as the number of somatic mutations per megabase (mut/Mb) of genome sequenced. Importantly, the assignment of TMB-H and validity of these calls is left under jurisdiction of the sequencing assay and is not executed by OncoKB. OncoKB annotates these calls with the appropriate OncoKB and FDA Level of Evidence as outlined in [Chapter 2: Curation of variant and tumor type specific clinical implications](#).

## III. Workflow Summaries

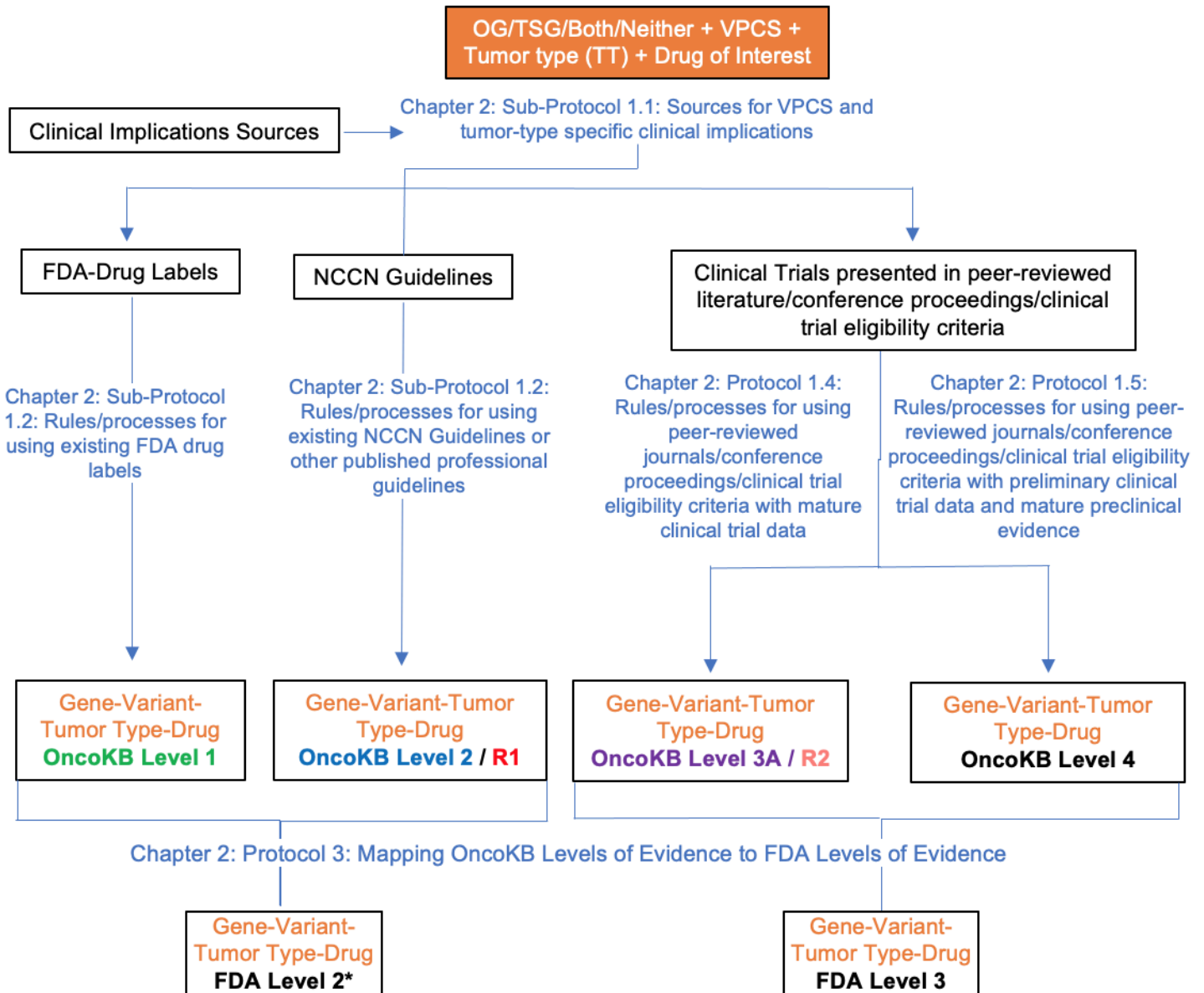
### A. Flowchart summarizing processes to assign a Level of Evidence (OncoKB or FDA) to a variant

Below is a two part flowchart that provides an overview of the OncoKB curation process from gene and variant data sources to FDA and OncoKB leveled gene-VPCS-tumor type-drug associations.

A.



B.



**Figure 2: End-to-end curation.**

For each step in the workflow, the corresponding protocol/sub-protocol in the OncoKB SOP V2 is noted. Red boxes indicate end points in the curation process. The end point of flowchart part (A) is the OUTPUT of Chapter 1 (indicated in the orange box and white text) is also the starting point of flowchart part (B) and the INPUT for Chapter 2. Note that following curation of an FDA/OncoKB leveled gene-VPCS-tumor type-drug associations, the data needs to be reviewed: by the Clinical Genomics Annotation Committee (CGAC) (per [Chapter 2: Protocol 2: CGAC approval of OncoKB leveled associations](#)) and internally by a member of the OncoKB team (per [Chapter 3: Protocol 1: Data review](#)).

## B. End-to-end curation workflow

1. All curation is performed in the OncoKB Curation Platform using formatting rules defined and visualized in [Chapter 6: OncoKB formatting and nomenclature in the curation platform](#).
2. Required **INPUT** to map a variant to an **OncoKB and FDA-level of Evidence**:
  - a. **Gene + Variant + Tumor type + Drug**
3. Define the **Gene** as Oncogene or Tumor Suppressor or Both or Neither as outlined in [Chapter 1: Table 1.3: Assertion of the function of a gene](#) from **Gene Data Sources** described in [Chapter 1: Table 1.2: Gene Data Sources](#).
4. Is the **Variant**<sup>1</sup> (from the **Variant Data Sources** described in [Chapter 1: Table 2.1.1: Variant Data Sources](#)) a **Variant of Possible Significance (VPS)** or **Variant of Uncertain Significance (VUS)** per [Chapter 1: Table 2.2.2: Filter to select Variants of Possible Significance \(VPS\) in OG/TSGs?](#)
  - a. If the variant is defined as Variant of Possible Significance (VPS), *proceed to Step 5*.
  - b. If the variant is defined as Variant of Uncertain Significance (VUS), *proceed to Step 16*.
5. Define the **biological effect** per [Chapter 1: Sub-Protocol 2.4: Assertion of the biological effect of a VPS](#) and **oncogenicity** per [Chapter 1: Sub-Protocol 2.5: Assertion of the oncogenic effect of a VPS](#) of the VPS.
  - a. If VPS is defined as “Oncogenic” or “Likely Oncogenic”, per OncoKB definition, *proceed to Step 6*.
  - b. If VPS is NOT defined as “Oncogenic” or “Likely Oncogenic”, per OncoKB definition, *proceed to Step 16*.
6. Determine if there is **tumor-type specific clinical implications** from data sources outlined in [Chapter 2: Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources](#)
  - a. If tumor type-specific clinical implications exist, the variant is now defined as a **Variant of Possible Clinical Significance (VPCS)**. *Proceed to Step 7*.
  - b. If tumor type-specific clinical implications do NOT exist, *proceed to Step 16*.
7. Define the **tumor type** per [Chapter 1: Protocol 3: Tumor type assignment](#)
8. Define the **drug** per [Chapter 1: Protocol 4: Drug curation](#)

<sup>1</sup>So as to not distract from the overall workflow presented here, and since the process of variant curation has several of its own specific protocols, these are provided separately in summary form in the SOP Chapter III, Section C: Variant curation workflow.

9. Return to **INPUT** and utilizing the data source from which tumor type-specific clinical implications was obtained (**see Step 6**) and using [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) can the VPCS be assigned an **OncoKB Level of Evidence 1 or R1**?
  - a. **YES:** *Proceed to Step 13*
  - b. **NO:** *Proceed to Step 10*
10. Return to **INPUT** and utilizing the data source from which tumor type-specific clinical implications was obtained (**see Step 6**) and using [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#) can the VPCS be assigned an **OncoKB Level of Evidence 2 or R1**?
  - a. **YES:** *Proceed to Step 13*
  - b. **NO:** *Proceed to Step 11*
11. Return to **INPUT** and utilizing the data source from which tumor type-specific clinical implications was obtained (**see Step 6**) and using [Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) can the VPCS be assigned an **OncoKB Level of Evidence 3A or R2**?
  - a. **YES:** *Proceed to Step 13*
  - b. **NO:** *Proceed to Step 12*
12. Return to **INPUT** and utilizing the data source from which tumor type-specific clinical implications was obtained (**see Step 6**) and using [Chapter 2: Sub-protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) can the VPCS be assigned an **OncoKB Level of Evidence 4**?
  - a. **YES:** *Proceed to Step 13*
  - b. **NO:** *Proceed to Step 16*
13. Assign the VPCS an **FDA Level of Evidence** using [Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence](#). *Proceed to Step 14.*
14. **Review all leveled assertions internally** (per [Chapter 3: Protocol 1: Data review](#)). If there is no conflicting data or assertions *proceed to Step 16.*
  - a. If **conflicting data** arises during Steps 2-3 above, follow the process outlined in [Chapter 4: Protocol 1: Resolving conflicting data](#) and then *Proceed to Step 15.*
  - b. If **conflicting assertions (interpretation of the data)** arise during internal review, follow the process outlined in [Chapter 4: Protocol 2: Resolving conflicting assertions](#) and then *Proceed to Step 15.*



15. Obtain **CGAC approval** for the leveled assertion following [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#)
  - a. If CGAC approval is met, *proceed to Step 16.*
  - b. If there NOT is majority consensus or conflicting interpretation of data among CGAC members, follow the process outlined in [Chapter 4: Protocol 2: Resolving conflicting assertions](#) to determine if the leveled association is accepted into OncoKB or rejected (not leveled) and therefore not accepted into OncoKB
  
16. Enter the variant and its assigned levels of evidence (if any) into the OncoKB curation platform by following the appropriate protocols in [Chapter 6: OncoKB formatting and nomenclature in the curation platform](#). *Proceed to Step 17.*
  - Refer to [Chapter 6: Protocol 3: Variant curation](#) to enter variant-specific information
  - Refer to [Chapter 6: Protocol 4: Tumor type curation](#) to enter tumor type-specific information
  - Refer to [Chapter 6: Protocol 5: Therapy curation](#) to enter drug-specific information, including the OncoKB associated Level of Evidence
  
17. Review/accept data in *Review Mode* in the OncoKB curation platform per [Chapter 3: Protocol 1: Data review](#)). *Proceed to Step 18.*
  - Data must be reviewed by a member of the OncoKB staff who did not enter the data into the curation platform
  - Reviewed data is released internally at MSK for inclusion in clinical patient reports and to the cBioPortal for Cancer Genomics
  
18. Perform data validation and release the data to the public OncoKB website ([www.oncokb.org](http://www.oncokb.org)) (per [Chapter 3: Protocol 2: Data release](#))
  - An overview of the data validation process performed by the Data Validation tool on the OncoKB curation website and reviewed by a member of the OncoKB staff is detailed in [Chapter 3: Table 2.1: Data validation procedure](#)

## C. Variant curation workflow

1. Determine if **functional evidence** exists in peer-reviewed publications for the specified variant in the defined OncoKB data source. Functional evidence is defined in [Chapter 1: Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion](#)
  - a. If **YES**: The specified variant is a Variant of Possible Significance (VPS). *Proceed to Step 4*
  - b. If **NO**: *Proceed to Step 2*
2. Determine whether the variant is a **statistically significant hotspot** as defined in ([Chang et al, 2016](#); [Chang et al. 2018](#)). Specifically, check if the variant is defined as a hotspot on [www.cancerhotspots.org](http://www.cancerhotspots.org).
  - a. If **YES**: The specified variant is a Variant of Possible Significance (VPS). *Proceed to Step 4*
  - b. If **NO**: The variant is a possible Variant of Uncertain Significance (VUS). *Proceed to Step 3*
3. Note whether the variant-associated gene is an oncogene, tumor suppressor, both or neither using [Chapter 1: Protocol 1: Gene curation](#). Confirm the specified variant is a VUS using [Chapter 1: Table 2.2.2: Filter to select Variants of Possible Significance \(VPS\) in OG/TSGs](#)
  - a. If variant is **confirmed to be a VUS**: *Proceed to Chapter 6: Sub-Protocol 3.2: VUS curation*
  - b. If variant is **NOT confirmed to be a VUS (i.e., it is a VPS)**: *Proceed to Step 4*
4. If functional data exists for the VPS in the defined data source, determine the **strength of the evidence** using [Chapter 1: Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion](#)
  - a. **If the VPS is novel** (not already in OncoKB), *proceed to Step 5*
  - b. **If the VPS is already curated in OncoKB**, *proceed to Step 7*
5. Assign the VPS a **biological effect** using [Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS](#)
  - a. *Proceed to Step 6*
6. Assign the VPS an **oncogenic effect** using [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)
  - a. *Proceed to Step 9*
7. For variants already in OncoKB that are undergoing re-analysis and re-evaluation, re-assess and re-assign (if applicable) the **biological effect** of the variant given the new evidence using [Chapter 5: Table 1.2: Process for determining the biological effect of a variant following variant re-analysis and re-evaluation](#)
  - a. *Proceed to Step 8*
8. Re-assess and re-assign (if applicable) the **oncogenic effect** of the variant given the new evidence using [Chapter 5: Table 1.3: Process for determining the oncogenic effect of a variant following variant re-analysis and re-evaluation](#)

- a. *Proceed to Step 9*
9. Generate a **mutation effect description** for the VPS, defined in [Chapter 6: Table 3.2: Generation and formatting of mutation effect description](#)
  - a. For variants undergoing re-analysis and re-evaluation, edit the mutation effect description accordingly and add in the appropriate references
  - b. *Proceed to Step 10*
10. For each VPS, enter the variant name, biological effect, oncogenic effect and description of mutation effect into the OncoKB curation platform utilizing the nomenclature and formatting described in [Chapter 6: Sub-Protocol 3.1: Mutation header and mutation effect](#)
  - a. *Proceed to Step 11*
11. **If Variant of Possible Significance is defined as “Oncogenic” or “Likely Oncogenic”**, proceed to [Chapter 1: Protocol 3: Tumor type assignment](#), to determine if there are tumor type-specific clinical implications for the specified variant (***Step 7 in End-to-end Curation workflow***)

## D. Clinical Implications Curation Workflow:

All protocols from [Chapter 1: OncoKB curation of tumor type specific gene-variants and drugs](#) (Protocols 1 - 4) must be completed prior to execution of any Chapter 2 protocols.

The **INPUT** for all protocols of [Chapter 2: Curation of variant and tumor type specific clinical implications](#) MUST be:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
  - D. **Drug**: must be a targeted therapy (refer to [Chapter 1: Protocol 4: Drug curation](#))
1. Identify an **INPUT** of OG, TSG, Both or Neither + VPCS + Tumor type + Drug of Interest that may qualify for an OncoKB and FDA Level of Evidence using **Protocols 1-4** in [Chapter 1: OncoKB curation of tumor type specific gene-variants and drugs](#)  
--Refer to [Chapter 2: Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources](#)
  2. Follow the process outlined in the [End-to-end curation workflow](#) and refer to the following protocols in [Chapter 2: Curation of variant and tumor type specific clinical implications](#) to assign an OncoKB Level of Evidence
    - a. Use [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) to assign an OncoKB Level of Evidence 1 or R1
    - b. Use [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#) to assign an OncoKB Level of Evidence 2 or R1
    - c. Use [Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) to assign an OncoKB Level of Evidence 3A or R2
    - d. Use [Chapter 2: Sub-protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assign an OncoKB Level of Evidence 4
  3. If the VPCS is assigned an OncoKB Level of Evidence, the VPCS must be assigned an **FDA Level of Evidence** using [Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence](#)
  4. All leveled assertions must be **reviewed internally** (per [Chapter 3: Protocol 1: Data review](#))  
--If **conflicting data** arises during Steps 2-3 above, follow the process outlined in [Chapter 4: Protocol 1: Resolving conflicting data](#)

--If **conflicting assertions (interpretation of the data)** arises during internal review, follow the process outlined in [Chapter 4: Protocol 2: Resolving conflicting assertions](#)

5. For all leveled associations, obtain **CGAC approval** following [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#)
  - a. If CGAC approval is met, *proceed to Step 6*
  - b. If there is majority consensus or conflicting interpretation of data among CGAC members, follow the process outlined in [Chapter 4: Protocol 2: Resolving conflicting assertions](#) to determine if the leveled association is accepted into OncoKB or rejected (not leveled) and therefore not accepted into OncoKB ([www.oncokb.org](http://www.oncokb.org)).
6. Enter the leveled association into the OncoKB curation platform by following the appropriate protocols in [Chapter 6: OncoKB formatting and nomenclature in the curation platform](#)
  - a. Use [Chapter 6: Protocol 3: Variant curation](#) to enter variant-specific information
  - b. Use [Chapter 6: Protocol 4: Tumor type curation](#) to enter tumor type-specific information
  - c. Use [Chapter 6: Protocol 5: Therapy curation](#) to enter drug-specific information, including the OncoKB associated Level of Evidence
7. Review the curated association in the OncoKB curation platform using *Review Mode* (per [Chapter 3: Protocol 1: Data review](#))

--Data must be reviewed by a member of the OncoKB staff who did not enter the data into the curation platform

8. Validate and release the data from the OncoKB curation platform to the public OncoKB website ([www.oncokb.org](http://www.oncokb.org)) (per [Chapter 3: Protocol 2: Data release](#))

# Chapter 1: OncoKB curation of tumor type specific gene-variants and drugs

## Introduction

OncoKB uses the following standardizations for each gene:

- The HUGO gene symbols are used for gene names. We update the latest HUGO symbols periodically.
- For each gene, one canonical transcript is selected for annotation. Both Ensembl and RefSeq transcript IDs are provided per gene.

The OncoKB Gene Curation Page contains the biological and clinical implications of each gene and its alterations. Sections of the Gene Curation Page are outlined in [Chapter 6: Protocol 2: Gene Curation](#).

Alterations included in OncoKB are genetic changes that arise as a result of DNA-level variants in cancer: non-synonymous mutations, translocations, rearrangements / fusions, copy number amplifications and deletions. This document uses “alterations”, “mutations” and “variants” interchangeably. OncoKB describes alterations by their effect on the protein and not at the DNA level (refer to [Chapter 1: Table 2.2.2: Filter to select Variants of Possible Significance \(VPS\) in OG/TSGs](#)). All alterations in OncoKB are classified according to 1) their oncogenic effect (refer to [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)) and 2) their biological effect, (refer to [Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS](#)) based on the curated evidence.

The oncogenic and biological effects of a mutation are curated based on data highlighting the properties of transformed cells as described in the second edition of “The Biology of Cancer” by Robert Weinberg and the Hallmarks of Cancer described by Douglas Hanahan and Robert Weinberg in their manuscript “Hallmarks of cancer: the next generation” published in Cell in 2011 ([Hanahan and Weinberg, 2011](#)) (refer to [Chapter 1: Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion](#)).

Below each alteration in the curation interface, the user must choose one or multiple Tumor Type(s) for the purpose of curating alteration- and tumor type-specific clinical implications, if any (refer to [Chapter 1: Protocol 3: Tumor type assignment](#)). OncoKB uses OncoTree (<http://oncotree.mskcc.org>) to manage the precise vocabulary of tumor types. Currently, OncoTree version *oncotree\_latest\_stable* is being used. The user may choose a main cancer type and/or subtype from the dropdown list on the gene page (refer to [Chapter 6: Protocol 4: Tumor type curation](#)).

Below each cancer type, the user has the option of curating standard or investigational therapeutic associations for sensitivity or resistance, if any (refer to [Chapter 6: Sub-Protocol 5.1: Therapy Selection](#)). OncoKB uses the NCI thesaurus to standardize all drug names. If a drug is entered, it must be associated with an OncoKB Level of Evidence (refer to [Chapter 2: Figure 1: OncoKB Levels of Evidence V2](#)) and a valid reference from a peer-reviewed source (refer to [Chapter 2: Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources](#)).

# Protocol 1: Gene curation

This protocol specifies the data sources and methods used to curate a cancer gene.

1. Identify a **Gene of Interest (GOI)** from [Chapter 1: Table 1.2: Gene data sources](#) and enter into the OncoKB Curation Platform (refer to [Chapter 6: Protocol 2: Gene curation](#))
2. Evaluate whether the GOI is an **oncogene (OG)**, **tumor suppressor gene (TSG)**, **Both** or **Neither** using [Chapter 1: Table 1.3: Assertion of the function of a cancer gene](#)

## Table 1.1: Protocol 1 INPUTS and OUTPUTS

An overview of Protocol 1 INPUTs and OUTPUTs. OUTPUTs from Protocol 1 serve as INPUTs for Protocol 2.

Protocol 1 INPUT	INPUT to OUTPUT Process Location (from Chapter 1)	Protocol 1 OUTPUT
Gene data sources	<a href="#">Table 1.2: Gene data sources</a>	Gene of Interest
Gene of Interest	<a href="#">Table 1.3: Assertion of the function of a cancer gene</a>	Oncogene (OG) or Tumor Suppressor Gene (TSG) or Both or Neither

## Table 1.2: Gene data sources

The various sources (and the priority of each source) used by OncoKB staff to identify potential cancer genes for inclusion in OncoKB. Sources and the evidence presented in each may be investigated by OncoKB curators, SCMT members or the Lead Scientist.

Source Type	Specific Sources in Type	Priority
MSK NGS Panels	IMPACT HemePACT ARCHER	High
External NGS Panels	Foundation One CDx Foundation One Heme	Moderate
External Databases/Publications	Sanger Cancer Gene Census <a href="#">Vogelstein et al. (2013)</a>	Moderate
Other	Feedback from users	High
Other	Biomarker in clinical trial	Low

**Table 1.3: Assertion of the function of a cancer gene**

Assertion of OG or TSG or Both requires at least 1 criteria from Evidence I or Evidence II. If the evidence is weak and/or/conflicting, or if there is insufficient evidence to classify a gene as an OG or TS, that gene will not be labeled as an OG or TS.

Evidence	ASSERTIONS		
	Oncogene (OG)	Tumor Suppressor (TSG)	Both
I. Weinberg, p.G:20, 2014 Vogelstein et al., 2013	<p><b>RULE OG-1</b> Any of the following features as demonstrated by the scientific literature in ≥1 studies. (1) A cancer-inducing gene when activated by mutation OR (2) A gene that can transform cells by increasing the selective growth advantage of the cell in which it resides as demonstrated by the scientific literature in ≥1 studies.</p>	<p><b>RULE TSG-1</b> Any of the following features as demonstrated by the scientific literature in ≥1 studies. (1) A gene whose partial or complete inactivation by mutation, occurring in either the germline or the genome of a somatic cell, leads to an increased likelihood of cancer development by increasing the selective growth advantage of the cell in which it resides OR (2) A gene that is responsible for constraining cell proliferation OR (3) A gatekeeper, a gene that operates to hinder cell multiplication or to further cell differentiation or cell death and in this way prevents the appearance of populations of neoplastic cells 4) Mutated through protein-truncating alterations throughout their length</p>	<p><b>RULE TSGOG-1</b> Meets at least one of the criteria for both OG and TSG</p>
II. Davoli et al., 2013	<p><b>RULE OG-2</b> A gene that, in tumor samples, has i) higher functional impact as defined by the PolyPhen2 Hum-Var prediction model and higher amplification frequency in comparison to those observed in neutral genes, AND ii) lower loss-of-function mutations, splicing mutations and frequency of deletions and increased frequency of amplification compared to tumor suppressors</p>	<p><b>RULE TSG-2</b> A gene that, in tumor samples, has i) higher frequencies of loss-of-function and splicing mutations, higher functional impact, and higher frequency of deletions compared to those found in neutral genes, AND ii) higher frequencies of loss-of-function and splicing mutations, higher deletion frequency and lower amplification frequency compared to those found in oncogenes</p>	<p><b>RULE TSGOG-2</b> Meets OG AND TSG criteria</p>

**Note:** If the gene does not meet the specific criteria for either an oncogene or a tumor suppressor, then the gene is not classified as either.



## Protocol 2: Variant curation

This protocol specifies the data sources and methods used to determine if a specified gene-variant is a Variant of Possible Significance (VPS).

- Prior to execution of this protocol, [Chapter 1: Protocol 1: Gene Curation](#) must have been completed
- The **INPUT** of this protocol MUST be a **gene defined as an OG, TSG, Both or Neither**

### Table 2.1: Protocol 2 INPUTS and OUTPUTS

An overview of Protocol 2 INPUTs and OUTPUTs. OUTPUTs from Protocol 2 serve as INPUTs for Protocol 3.

Step	INPUT	INPUT to OUTPUT Process Location		OUTPUT
		Protocols (from Chapter 1)	Table (if applicable; from Chapter 1)	
1	Variant data sources	<a href="#">Sub-Protocol 2.1: Variant sources</a>	<a href="#">Table 2.1.1 Variant data sources</a>	Variant of Interest
2	Gene defined as OG/TSG/Both/Neither (from <a href="#">Chapter 1: Protocol 1: Gene curation</a> )  AND  Variant of Interest	<a href="#">Sub-Protocol 2.2: Defining Variant Type</a>	<a href="#">Table 2.2.1 Definitions of variant types and their molecular consequences</a>  AND  <a href="#">Table 2.2.2 Filter to select Variants of Possible Significance (VPS) in OG/TSGs</a>	Candidate Variant of Possible Significance (VPS)/Variant of Uncertain Significance (VUS)
3	Gene defined as OG/TSG/Both/Neither  AND  Candidate VPS/VUS	<a href="#">Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion</a>	<a href="#">Table 2.3.1 Types of experimental evidence to support VPS biological or oncogenic assertion</a>	Gene defined as OG/TSG/Both/Neither  <b>AND</b>  Candidate VPS/VUS with defined biological effect
			<a href="#">Table 2.3.2 Definition of the strength of functional (experimental) evidence</a>	
		<a href="#">Sub-Protocol 2.4: Assertion of the biological effect of a VPS</a>	NA	

4	Gene defined as OG/TSG/Both/Neither  <b>AND</b>  Candidate VPS/VUS with defined biological effect	<a href="#">Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion</a>	<a href="#">Table 2.3.1 Types of experimental evidence to support VPS biological or oncogenic assertion</a>	Oncogenic Variant with defined biological effect == <b>Variant of Possible Clinical Significance (VPCS)</b>
			<a href="#">Table 2.3.2 Definition of the strength of functional (experimental) evidence</a>	OR  Likely Oncogenic Variant with defined biological effect == <b>VPCS</b>
		<a href="#">Sub-Protocol 2.5: Assertion of the oncogenic effect of a VPS</a>	NA	OR  Likely Neutral Variant with defined biological effect == <b>Likely Neutral Variant<sup>1</sup></b>  OR Variant with Inconclusive biological and oncogenic effect == <b>VUS<sup>1</sup></b>

<sup>1</sup>These variants are not associated with curation of clinical implications.

## Sub-Protocol 2.1: Variant sources

### Table 2.1.1: Variant data sources

The various sources (and the priority of each source) used by OncoKB staff to identify potential cancer variants for inclusion in OncoKB (Variants of Possible Significance). Sources and the evidence presented in each may be investigated by OncoKB curators, SCMT members or the Lead Scientist.

Data source type	Source examples	Frequency of assessment of sources by OncoKB team
Public cancer variant databases of alterations identified in tumor sequencing studies	cBioPortal COSMIC	Weekly
Statistically significant and recurrent variants	Cancerhotspots.org ( <a href="#">Chang et al. 2017</a> )	Weekly
Disease-specific treatment guidelines	NCCN Guidelines ( <a href="http://www.nccn.org">www.nccn.org</a> )	Monthly
Conference proceedings	AACR Annual Meeting ASCO Annual Meeting ESMO Annual Meeting IASLC WCLC SABCS AACR-EORTC-NIH MTCT ASH Annual Meeting	Within six weeks of conference date
Peer-reviewed literature	Cell Cancer Discovery JAMA Oncology Nature Nature Medicine Nature Review Clinical Oncology JCI Lancet Oncology Nature Review Cancer Cancer Cell Annals of Oncology Clinical Cancer Research Cancer Research JAMA Lancet Blood New England Journal of Medicine Science Science Translational Medicine JCO JCO PO J Thoracic Oncol Target Oncol Lung Cancer BMC Cancer Haematologica Leukemia Hematology Oncology American Journal of Hematology	Monthly
External Variant Databases <sup>1</sup>	BRCA Exchange ClinVar IARC TP53	Ad hoc
Other	CGAC recommendation	Members of CGAC can nominate gene-alteration-tumor type-drug associations for

		<p>OncoKB Level 3A or 4 status based on their knowledge and expertise in the field. CGAC members have first-hand knowledge of new biomarker-tumor type-drug associations that may qualify for an OncoKB level of evidence, specifically those that may qualify as an OncoKB Level 3A/3B or Level 4 association since qualification for these levels is based on clinical trial enrollment criteria, preclinical biomarker-drug studies, and results from case studies and larger clinical trials.</p>
	<p>User feedback Biomarkers in clinical trials</p>	<p>Ad hoc</p>

<sup>1</sup> Data is never imported automatically (e.g. from external databases) but rather checked routinely and incorporated on a case-by-case basis after evaluation of the merit of the evidence presented by the OncoKB curator or SCMT member. Merit of evidence is determined using [Chapter 1: Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion](#). All sources are evaluated with the same priority and assertions made using such evidence are reviewed per [Chapter 3: Protocol 1: Data review](#). External databases are never cited as the source of information, but rather are used to find the primary literature for the variant, which in turn is independently evaluated and cited in OncoKB. As these external databases are never cited as the data source, tracking of versioning is obsolete.

## Sub-Protocol 2.2: Defining variant type

### Table 2.2.1: Definitions of variant types and their molecular consequences

The specific variant types as defined by their molecular consequences that are curated in OncoKB. The molecular consequence for each variant type can be found at:

<https://uswest.ensembl.org/info/genome/variation/prediction/classification.html> and [https://uswest.ensembl.org/info/genome/variation/prediction/predicted\\_data.html](https://uswest.ensembl.org/info/genome/variation/prediction/predicted_data.html).

Variant Type <sup>1</sup>	Description
Nonsense	A sequence variant which causes a disruption of the translational reading frame, because the number of nucleotides inserted or deleted is not a multiple of three
Frameshift	A sequence variant which causes a disruption of the translational reading frame, because the number of nucleotides inserted or deleted is not a multiple of three
Splicing	A splice variant that changes the 2 base region at the 3' end of an intron or a splice variant that changes the 2 base region at the 5' end of an intron
Missense	A sequence variant, that changes one or more bases, resulting in a different amino acid sequence but where the length is preserved
In-frame insertion	An inframe non synonymous variant that inserts bases into in the coding sequence
In-frame deletion	An inframe non synonymous variant that deletes bases from the coding sequence
Duplication	An insertion which derives from, or is identical in sequence to, nucleotides present at a known location in the genome.
Amplification	Increases the copy number of a given region
Deletion	Decreases the copy number of a given region
Fusion	A fusion gene is a hybrid gene formed from two previously independent genes. It can occur as a result of translocation, interstitial deletion, or chromosomal inversion.

<sup>1</sup>**Assignment of variant types and the validity of variant calls is left under jurisdiction of the sequencing assay and is not executed by OncoKB.** For MSK-IMPACT, the variant type is defined by TCGA MAF format for variant classification. Details on this variant classification are found at the following links: (<https://uswest.ensembl.org/info/genome/variation/prediction/classification.html>) ([https://uswest.ensembl.org/info/genome/variation/prediction/predicted\\_data.html](https://uswest.ensembl.org/info/genome/variation/prediction/predicted_data.html)). Upon receiving a variant call, OncoKB associates the appropriate biological function and clinical information to the called variant.

## Table 2.2.2: Filter to select Variants of Possible Significance (VPS) in OG/TSGs

This table is an initial filter for variants to prioritize their investigation by an OncoKB curator, SCMT member or Lead Scientist, and is not an endpoint for variant curation. If functional data exists that describes the biological and/or oncogenic effect of a variant, that variant is prioritized for investigation using the protocols outlined in [Chapter 1: Protocol 2: Variant Curation](#).

Classification	Oncogene	Tumor Suppressor Gene
Variants of Possible Significance (VPS) (Requires curation employing <a href="#">Chapter 1: Protocol 2: Variant Curation</a> )	Missense	Nonsense
	Amplification	Missense
	Fusion	
	In-frame insertion	Splice-site mutation
	In-frame deletion	Deletion
	Duplication	
Possible VUS (May not require curation)	Nonsense	Amplification
	Frameshift	Fusion
	Splice-site mutation	
	Deletion	

**Note:** There may be instances where this table's rules may be incorrect and further curation steps detailed in this chapter are necessary. For example, in the MET oncogene, splice-site mutations in MET exon 14 are not VUS but are in fact functional and oncogenic.

**Note:** If a gene is defined as a tumor suppressor, there must be sufficient functional evidence in the literature to curate all truncating mutations and all in-frame deletions as likely oncogenic (note exceptions can be made and curated independently at the allele-level).

## Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion

### Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion

Peer-reviewed experimental assays that may be assessed when investigating the biological or oncogenic effect of a cancer gene variant. Investigation of variants and their mutation effect may be performed by OncoKB curators, SCMT members or the Lead Scientist.

Evidence type	Specific experimental assays
Functional evidence	<ul style="list-style-type: none"> <li>● 3D Structural Assay compared to wildtype</li> <li>● Altered cell death (apoptosis) compared to wildtype</li> <li>● Altered Binding to Known Partner compared to wildtype</li> <li>● Altered Known Biochemical Function (homologous recombination assay, DNA damage repair assay etc) compared to wildtype</li> <li>● Growth Factor Independence compared to wildtype</li> <li>● Statistically significant recurrence of an alteration as defined by <a href="#">Chang et al 2018</a>.</li> <li>● Increased Cell Invasion compared to wildtype</li> <li>● Altered Immune Invasion compared to wildtype</li> <li>● Altered Kinase Activity compared to wildtype</li> <li>● Increased Metastasis in vivo compared to wildtype</li> <li>● Altered Metabolic Function compared to wildtype</li> <li>● Other model-organism-specific assay (zebrafish embryo elongation, drosophila eye phenotype, etc) compared to wildtype</li> <li>● Increased Cell Proliferation/Growth in vitro compared to wildtype</li> <li>● Downstream Pathway Activation as measured by western blot compared to wildtype</li> <li>● Altered Protein Localization compared to wildtype</li> <li>● Altered Protein Stability compared to wildtype</li> <li>● Failed rescue experiment compared to wildtype</li> <li>● Increased Transforming Potential in vitro (Foci Formation, Growth in Soft Agar), etc. compared to wildtype</li> <li>● Transcriptional Activation of Target Genes (Luciferase Promoter Activation Assay) compared to wildtype</li> <li>● Tumor Growth in vivo (tumor xenografts) compared to wildtype</li> <li>● Altered Transcriptional Profile compared to wildtype</li> </ul>
In silico evidence	<ul style="list-style-type: none"> <li>● Evolutionary conservation</li> <li>● Structural prediction</li> <li>● Prediction algorithms (SIFT, Polyphen, etc)</li> </ul>
Preclinical evidence	<ul style="list-style-type: none"> <li>● Resistance to Targeted Inhibitors in vitro/vivo compared to wildtype</li> <li>● Sensitivity to Targeted Inhibitors in vitro/vivo compared to wildtype</li> </ul>





## Table 2.3.2: Definition of the strength of functional (experimental) evidence that supports an assertion

This table defines the requirements for classifying functional (experimental) evidence as strong, moderate or weak. Functional evidence is assessed when assigning the biological and oncogenic effect of variants and determining the validity of preclinical tumor response data. Types of functional (experimental) evidence that may be assessed during OncoKB variant curation are described in [Chapter 1: Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion](#). Preclinical (experimental) evidence that may be assessed when investigating the sensitivity of a cancer gene variant to a targeted therapy are described in [Chapter 1: Table 4.1: Preclinical \(experimental\) evidence that may be used to support an assertion of drug sensitivity \(for OncoKB Levels 3A, 4 and R2\)](#).

Strength of evidence	Evidence requirements for this classification
<b>Strong</b>	Functional evidence from <a href="#">Chapter 1: Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion</a> that fulfills the following requirements (journal standards <sup>1</sup> ): <ol style="list-style-type: none"> <li>1. Wildtype controls</li> <li>2. Biological replicates <math>\geq 3</math></li> <li>3. Performed in genomically controlled model systems (e.g. genomically characterized patient cells, organoids, isogenic cell lines, strain-controlled mice)</li> <li>4. Contains appropriate statistical analyses, when applicable (e.g. p-value)</li> </ol>
<b>Moderate</b>	Functional evidence from <a href="#">Chapter 1: Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion</a> that meets journal standards and has: <ol style="list-style-type: none"> <li>1. Controls other than wildtype controls</li> <li>2. No evidence of control for genomic background of model system</li> <li>3. Absent statistical analysis when otherwise warranted</li> </ol>
<b>Weak</b>	In Silico <sup>2</sup> or preclinical or functional evidence from <a href="#">Table 2.3.1: Types of experimental evidence to support VPS biological or oncogenic assertion</a> without appropriate controls or without biological replicates  Germline information including population frequency, gnomAD score, etc. (when used to characterize a somatic alteration)

<sup>1</sup>Journal standards refer to the data analysis and reporting standards of the top-tier journals used as data sources for OncoKB. An example is the standards reported for the AACR journals (<https://aacrjournals.org/content/authors/editorial-policies>).

<sup>2</sup>In silico evidence is considered weak evidence due to the lack of functional characterization in these studies. Thus, in silico evidence is the least prioritized among all the evidence types evaluated by OncoKB.

## Sub-protocol 2.4: Assertion of the biological effect of a VPS

Assertion of the biological effect of an alteration requires **at least 1 of criteria** from Assertion Type I (only 1 Assertion Type I (A, B, C, D or E) can be chosen for each variant) and **at least 1 criteria** from Assertion Type II (only 1 Assertion Type II can be chosen for each variant (A or B))

<b>ASSERTION TYPE I</b> Choose from A, B, C, D or E; *Based on any of the following criteria in each	<b>ASSERTION TYPE II</b> If Type I = A / B / C / D choose from A or B; *Based on any of the criteria in each	<b>FINAL ASSERTION<sup>1</sup></b>
<b>A: Gain of function</b> <ol style="list-style-type: none"> <li>The alteration is associated with Increased function of the protein</li> <li>Increased gene dosage</li> <li>Increased/ectopic mRNA expression</li> <li>Increased/constitutive protein activity</li> <li>Dominant negative</li> <li>Structural protein</li> <li>Toxic protein</li> </ol>	<b>A: Known function</b> <ol style="list-style-type: none"> <li>Compelling experimental data in one or more studies directly establishing the function of the mutation.</li> <li>Multiple lines of data in one or more studies including but not limited to experimental data and statistical recurrence that together provide strong evidence establishing the function of the mutation.</li> <li>The alteration is a known hotspot (<a href="#">Chang et al., 2016</a>, <a href="#">Chang et al., 2018</a>) AND at least one experimental study provides strong evidence that the alteration confers gain-, loss-, or switch-of or neutral function.</li> <li>Rescue experiment provides evidence that the alteration is neutral. (Neutral)</li> <li>The alteration has been identified in a patient who responded to a targeted inhibitor AND at least one experimental study provides strong evidence that the alteration confers gain-, loss-, or switch-of or neutral function.</li> <li>Strong evidence-based data demonstrating that there is no difference in measurable cell attributes expressing either the wildtype or mutant form of the gene (Neutral).</li> </ol>	<b>IA.IIA</b> Known Gain of function
<b>B: Loss of function</b> <ol style="list-style-type: none"> <li>The alteration is associated with decreased function of the protein</li> <li>Haploinsufficiency</li> </ol>		<b>IB.IIA</b> Known Loss of function
<b>C: Switch of function</b> <ol style="list-style-type: none"> <li>The alteration is associated with a novel function of the protein</li> <li>New protein</li> <li>Altered substrate specificity</li> </ol>	<b>IC.IIA</b> Known Switch of function	
<b>D: Neutral function</b> <ol style="list-style-type: none"> <li>The function of the protein is unchanged by the alteration</li> <li>There is no difference in measurable cell attributes expressing either the wildtype or mutant form of the gene.</li> </ol>	<b>ID.IIA</b> Known Neutral function	
<b>E: Inconclusive function</b> <ol style="list-style-type: none"> <li>Conflicting data exists as to the mutational effect of the alteration.</li> <li>Data is limited to “weak” experimental data describing the mutational effect of the alteration (small, under-powered experimental studies in one or multiple publications).</li> <li>Data is limited to studies demonstrating patient and/or in vitro sensitivity/resistance to a drug.</li> <li>Data is limited to in silico studies that predict the mutation effect of the alteration.</li> </ol>	<b>B: Likely function</b> <ol style="list-style-type: none"> <li>A single or multiple experimental studies from one publication including but not limited to experimental data or statistical recurrence establishing the function of the mutation</li> <li>The alteration is a known hotspot (<a href="#">Chang et al., 2016</a>, <a href="#">Chang et al., 2018</a>), and there are no known functional studies describing the mutation effect of the alteration.</li> <li>The alteration is in the same known domain in an infrequently altered gene as the domain in a paralogous gene that is established to be oncogenic</li> <li>While conflicting evidence may exist, there is a reasonable assumption based on the data suggesting the alteration confers gain-, loss-, or switch-of or neutral function.</li> <li>The alteration has been identified in a patient who responded to a targeted inhibitor AND at least one experimental study provides limited evidence that the alteration confers gain-, loss-, or switch-of-function.</li> <li>Probable, possible, and/or evidence-based data suggesting that there is no difference in measurable cell attributes expressing either the wildtype or mutant form of the gene (Likely neutral).</li> </ol>	<b>IA.IIB</b> Likely Gain of function
		<b>IB.IIB</b> Likely Loss of function
		<b>IC.IIB</b> Likely Switch of function
		<b>ID.IIB</b> Likely Neutral function
		<b>IE</b> Inconclusive

<sup>1</sup>Discord between evidence sources is resolved by comparing the strength of the evidence as defined in [Chapter 1: Table 2.3.2: Definition of the strength of functional \(experimental\) evidence that supports an assertion](#), and following the protocols in [Chapter 4: Conflicting data and conflicting assertions](#).

## Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS

Assertion of the oncogenic effect of an alteration (A-E) **requires at least 1 of criteria** from the corresponding evidence column.

Assertion	Definition	Criteria	Evidence (the alteration meets any of the following criteria)
<b>A. Oncogenic</b>	Strong evidence shows that the alteration is established in the literature as promoting cell proliferation or other hallmark of cancer as defined by Douglas Hanahan and Robert Weinberg (Hanahan and Weinberg, 2011).	1	Compelling experimental data (e.g., genetically engineered mouse data with the mutation) in one or more studies directly demonstrating that the alteration is oncogenic and is associated with at least one hallmark of cancer as defined by Hanahan and Weinberg
		2	The alteration is a known hotspot ( <a href="#">Chang et al., 2018</a> ) AND there is at least one experimental study suggesting the alteration is oncogenic.
		3	The alteration has been identified in a patient who responded to a targeted inhibitor, AND at least one experimental study provides strong evidence that the alteration is oncogenic.
		4	The alteration is classified as either known gain/loss/switch-of-function AND there is at least one experimental study suggesting the alteration is oncogenic.
<b>B. Likely Oncogenic</b>	Evidence suggests the alteration likely promotes cell proliferation or other hallmarks of cancer as defined by Douglas Hanahan and Robert Weinberg (Hanahan and Weinberg, 2011).	1	Representative experimental lines of data (e.g., downstream activation/inactivation of a signaling target/a hit in a high-throughput screen) in one or more studies pointing to possible oncogenic function or mutation associated with known germline syndrome.
		2	At least one experimental study provides reasonable evidence suggesting the alteration is oncogenic.
		3	The alteration is a known hotspot ( <a href="#">Chang et al., 2018</a> ) AND there are no known functional studies describing the oncogenic potential of the alteration.
		4	The gene is a tumor suppressor and the variant is a truncating mutation (i.e. nonsense/frameshift/deletion/splice site mutation)
		5	The mutation is a resistance mutation supported by demonstrating either patient and/or in vitro sensitivity/resistance to a targeted drug.
		6	The variant qualifies as likely oncogenic based on gene-specific criteria outlined in <a href="#">Table 2.5.1: Gene-specific criteria for defining a variant as likely oncogenic.</a>
<b>C. Likely Neutral</b>	Evidence suggests the alteration does not alter protein activity or does not confer growth or survival advantage when expressed in cells.	1	The mutation effect of the alteration is neutral or likely neutral.
		2	At least one experimental study provides reasonable evidence suggesting the alteration is likely neutral.

<b>D. Inconclusive</b>	There is conflicting and/or weak data describing the oncogenic effect of the mutant alteration	1	Conflicting data exists as to the oncogenic effect of the alteration.
		2	Data is limited to “weak” experimental data describing the oncogenic effect of the alteration (small, under-powered experimental studies in one or multiple publications).
		3	Data is limited to in silico studies that predict the oncogenic effect of the alteration.

**Table 2.5.1: Gene-specific criteria for defining a variant as likely oncogenic**

This table describes unique gene-specific criteria for defining variants as likely oncogenic. The criteria in this table is specific to individual gene(s) and falls outside the evidence specified in [Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#).

Gene	Mutations	Rule for Oncogenicity	Example	Evidence
POLE	Select missense mutations	POLE mutations that result in an ultra-mutated phenotype are considered likely oncogenic (no additional functional data is required to make this assertion)	POLE P286H	The POLE P286H mutation is recurrent in colorectal and endometrial carcinoma and is located in a conserved residue in the exonuclease domain of the protein. This alteration likely perturbs its native proofreading function, as shown in in vitro experiments, leading to large numbers of point mutations throughout the genome (PMID: 25228659). Whole genome sequencing data analysis from colorectal cancer samples harboring POLE P286H demonstrates that the mutation is inactivating as measured by sample mutational patterns, such as high mutation density and mutational strand asymmetry, that indicate proofreading deficiency (PMID: 32012149).

**Table 2.5.2: Types of VPS that upon curation are considered VPCS based on the gene classification**

This table lists types of variants in oncogenes or tumor suppressor genes that upon review by an OncoKB curator, SCMT member or Lead Scientist are evidence-based oncogenic or likely oncogenic VPCS. For tumor suppressor genes, deleterious or suspected deleterious variants are considered oncogenic or likely oncogenic variants.

Classification	Oncogene	Tumor Suppressor Gene	
Oncogenic or Likely Oncogenic Variants of Possible Clinical Significance (VPCS)	Missense	Nonsense	Deleterious or suspected deleterious mutations
	Amplification	Missense	
	Fusion	Frameshift	
	In-frame insertion	Splice-site mutation	
	In-frame deletion	Deletion	
	Duplication		



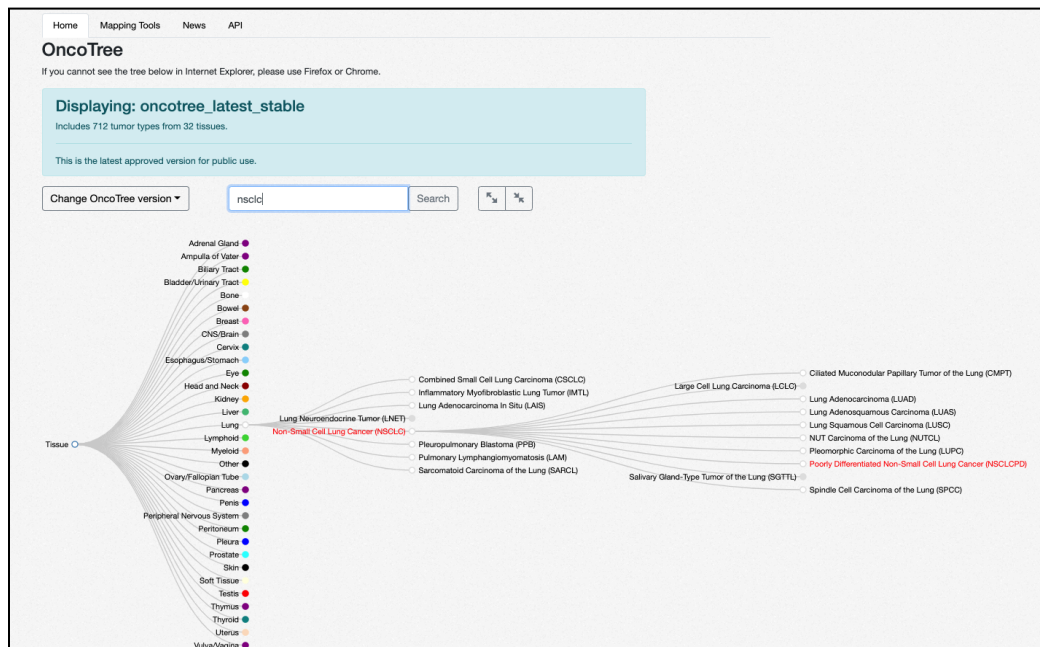
# Protocol 3: Tumor type assignment

This protocol specifies how tumor types are assigned when a variant of possible clinical significance (VPCS) is associated with tumor type-specific clinical implications.

- Prior to execution of this protocol, [Chapter 1: Protocol 1: Gene curation](#) and [Chapter 1: Protocol 2: Variant curation](#) must have been completed.
- The **INPUT** of this protocol MUST be a **gene defined as an OG, TSG, Both or Neither + VPCS**

Curation of tumor types for OncoKB utilize the nomenclature found in OncoTree (<http://oncotree.info>) to describe tumor types as a subtype of a specific tumor maintype ([Kundra et al., JCO Clinical Cancer and Informatics, 2021](#)) as outlined in [Chapter 1: Figure 3: OncoTree Homepage and tree structure](#). OncoTree (<http://oncotree.info>) is a cancer classification system that was developed and is updated by a cross-institutional committee of oncologists, pathologists, and scientists and is accessible via an open-source web user interface and an application programming interface (API).

1. Tumor type associated with a gene, variant, and a therapeutic implication is identified from an OncoKB data source as defined in [Chapter 2: Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources](#)
2. Tumor type is entered into the curation platform as outlined in [Chapter 6: Protocol 4: Tumor type curation](#)
3. OncoTree API is used internally to map the tumor type to the appropriate OncoTree Code, which is a unique identifier of each node on the tree and which identifies the tumor type with a main type and a subtype
4. OncoTree Codes in OncoKB are then translated to the tumor name and are adopted by the OncoKB database and website



**Figure 3.1: OncoTree homepage and tree structure.**

All cancer types are represented by a node on the tree. All sub-classifications are connected to parent nodes through branches. The location of the cancer is based on the cell of origin and histologic architecture. This

structure of the tree not only allows grouping of tumor types under the tissue of origin but also connecting nodes across branches based on histology.

# Protocol 4: Drug curation

This protocol specifies how drugs are curated when a variant of possible clinical significance (VPCS) is associated with tumor type-specific clinical implications.

- Prior to execution of this protocol, [Chapter 1: Protocol 1: Gene curation](#), [Protocol 2: Variant curation](#), and [Protocol 3: Tumor type assignment](#) must have been completed.
  - The **INPUT** of this protocol MUST be **gene defined as an OG, TSG, Both or Neither + VPCS + Tumor type**
1. Is the drug a **targeted therapy**?
    - a. **YES:** *Proceed to Step 2*
    - b. **NO:** This does not qualify as a drug of interest (DI)
  2. Is the drug FDA-approved for patients with the specified tumor type harboring the specified genetic alteration?
    - a. **YES:** This qualifies as a DI
    - b. **NO:** *Proceed to Step 3*
  3. Is the drug NCCN-compendium listed for patients with the specified tumor-type harboring the specified genetic alteration?
    - a. **YES:** This qualifies as a DI
    - b. **NO:** *Proceed to Step 4*
  4. Is there strong experimental evidence (defined in [Chapter 1: Table 4.1. Preclinical \(experimental\) evidence that may be used to support an assertion of drug sensitivity \(for OncoKB Levels 3A, 4 and R2\)](#)) demonstrating the DI or a drug in the DI family has anti-cancer effects in cells harboring the specified genetic alteration?
    - a. **YES:** This qualifies as a DI
    - b. **NO:** *Proceed to Step 5*
  5. Is there compelling clinic evidence that patients with the specified tumor type harboring the specified genetic alteration responded that the DI or a drug in the DI family?
    - a. **YES:** This qualifies as a DI
    - b. **NO:** This does not qualify as a DI



### Table 4.1: Preclinical (experimental) evidence that may be used to support an assertion of drug sensitivity (for OncoKB Levels 3A, 4 and R2)

Experimental assays that may be assessed when investigating the sensitivity of a cancer gene variant to a targeted therapy. Investigation of variants and their drug sensitivities may be performed by OncoKB curators, SCMT members or the Lead Scientist.

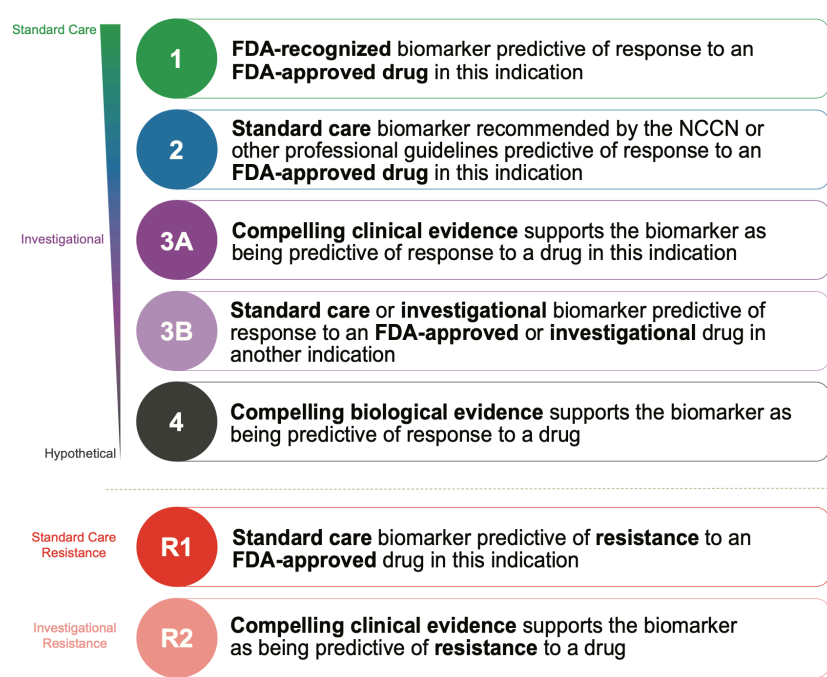
Evidence type	Specific experimental assays
<p><b>Strong evidence</b> (in vivo)</p> <p>*Must meet criteria for Strong evidence outlined in <a href="#">Chapter 1: Table 2.3.2: Definition of the strength of functional (experimental) evidence that supports an assertion</a></p>	<ul style="list-style-type: none"> <li>• Decreased Metastasis in vivo in the presence of drug compared to wildtype</li> <li>• Decreased Tumor Growth in vivo (tumor xenografts) in the presence of drug compared to wildtype</li> <li>• Decreased tumor formation or tumor growth in vivo (genetically engineered mouse models) in the presence of the drug compared to wildtype</li> </ul>
<p><b>Moderate evidence</b> (in vitro)</p> <p>*Must meet criteria for Moderate evidence outlined in <a href="#">Chapter 1: Table 2.3.2: Definition of the strength of functional (experimental) evidence that supports an assertion</a></p>	<ul style="list-style-type: none"> <li>• Increased cell death (apoptosis) in the presence of drug in vitro compared to wildtype</li> <li>• Decreased Growth Factor Independence in the presence of drug compared to wildtype</li> <li>• Decreased Cell Invasion in the presence of drug compared to wildtype</li> <li>• Decreased Kinase Activity in the presence of drug compared to wildtype</li> <li>• Decreased Metabolic Function in the presence of drug compared to wildtype</li> <li>• Decreased Cell Proliferation/Growth in the presence of drug in vitro compared to wildtype</li> <li>• Decreased downstream Pathway Activation in the presence of drug as measured by western blot compared to wildtype</li> <li>• Decreased Protein Stability in the presence of drug compared to wildtype</li> <li>• Decreased Transforming Potential in vitro (Foci Formation, Growth in Soft Agar, etc) in the presence of drug compared to wildtype</li> <li>• Decreased Transcriptional Activation of Target Genes (Luciferase Promoter Activation Assay) in the presence of drug compared to wildtype</li> <li>• Other model-organism-specific assay (zebrafish embryo elongation, drosophila eye phenotype, etc) in the presence of drug compared to wildtype</li> </ul>
<p><b>Weak evidence</b> (in silico)</p>	<ul style="list-style-type: none"> <li>• Structural prediction of drug binding</li> </ul>

# Chapter 2: Curation of variant and tumor type specific clinical implications

## Introduction

A subset of alterations in OncoKB are considered biomarkers that are predictive of response to certain drugs. Some of these drugs are FDA-approved and the biomarker is a consideration in standard care. Alternatively, some of these drugs are either 1) FDA-approved, but the biomarker is in an off-label setting or 2) not FDA-approved and instead are being tested in clinical trials. In both of the latter scenarios, the biomarkers and drugs are considered investigational.

The OncoKB Therapeutic Levels of Evidence system, [Chapter 2: Figure 1: OncoKB Levels of Evidence V2](#), (originally published in 2017 and updated in December 2019, [Chapter 2: Figure S1: Mapping between OncoKB Levels of Evidence V1 and OncoKB Levels of Evidence V2](#)) was developed to rank the therapeutic implications associated with an alteration found in a patient tumor sample by the relative weight of the evidence ([Chakravarty et al., 2017](#)), and are consistent with the Joint Consensus Recommendation by AMP, ASCO and CAP ([Li et al., 2017](#)) ([Chapter 2: Figure S2: Mapping between the OncoKB Levels of Evidence V2 and the AMP-ASCO-CAP Consensus Recommendation Variant Categorizations](#)) and the ESMO Scale for Clinical Actionability of molecular Targets (ESCAT) ([Mateo et al., 2018](#)). The highest levels of evidence, Levels 1 and 2, refer to the standard implications for sensitivity to an FDA-approved drug. Additionally, Level R1 refers to the standard implications for resistance to an FDA-approved drug. Levels 3A, 3B and 4 refer to the investigational implications for sensitivity to either an FDA-approved or investigational drug (in the off-label setting, Level 3B) or an investigational drug (Levels 3A and 4). Level R2 includes investigational implications for resistance to either an FDA-approved or investigational drug.



**Figure 1. OncoKB Levels of Evidence V2.**

The OncoKB levels of evidence system was originally published in JCO-PO in 2017. Since its publication, this system was refined to deprioritize the significance of standard care biomarkers when present in indications outside of the FDA-approved/NCCN listed indication. This change was based on clinical data demonstrating that patients with investigational predictive biomarkers for a specific tumor type based on compelling clinical evidence presented in phase 3 clinical trials (currently Level 3A) are more likely to experience clinical benefit compared to patients with predictive biomarkers that are considered standard care in a different tumor type (previously Level 2B, currently Level 3B) and is consistent with guidelines published by ASCO/AMP/CAP and ESMO.



# Protocol 1: Curation of tumor type specific variant clinical implications

This protocol (which includes Sub-protocols 1.1 - 1.5) specifies 1) the data sources from which information is reviewed and critically assessed when assigning gene-alteration-tumor type-drug associations an OncoKB and FDA Level of Evidence and 2) the detailed processes for assigning a Variant of Possible Clinical Significance (VPCS) an OncoKB Level of Evidence for sensitivity (Levels 1-4) or resistance (Levels R1 and R2).

**Table 1.1: Protocol 1 INPUTS and OUTPUTS**

An overview of Protocol 1 INPUTs and OUTPUTs. OUTPUTs from Protocol 1 serve as INPUTs for Protocol 2.

Protocol 1 INPUT	INPUT to OUTPUT Process Location (from Chapter 2)	Protocol 1 OUTPUT
Sources for variants of possible clinical significance (VPCS)	<a href="#">Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources</a>	VPCS + potential tumor type-specific clinical implications
VPCS + potential tumor type-specific clinical implications	<a href="#">Sub-protocol 1.2: Rules and processes for using existing FDA drug labels</a>	OncoKB Level 1 or R1 VPCS (FDA level of evidence 2) OR OncoKB Level 3B VPCS (No FDA level of evidence) OR VPCS is NOT assigned an OncoKB Level of Evidence (No FDA level of evidence)
	<a href="#">Sub-Protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines</a>	OncoKB Level 2 or R1 VPCS (FDA level of evidence 2) OR OncoKB Level 3B VPCS (No FDA level of evidence) OR VPCS is NOT assigned an OncoKB Level of Evidence (No FDA level of evidence)
	<a href="#">Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a>	OncoKB Level 3A or R2 VPCS (FDA level of evidence 3) OR OncoKB Level 3B VPCS (No FDA level of evidence)

		<p>OR</p> <p>VPCS is NOT assigned an OncoKB Level of Evidence <i>(No FDA level of evidence)</i></p>
	<p><a href="#"><u>Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence</u></a></p>	<p>OncoKB Level 4 VPCS <i>(FDA level of evidence 3)</i></p> <p>OR</p> <p>OncoKB Level 3B VPCS <i>(No FDA level of evidence)</i></p> <p>OR</p> <p>VPCS is NOT assigned an OncoKB Level of Evidence <i>(No FDA level of evidence)</i></p>

## Sub-protocol 1.1: VPCS and tumor type-specific clinical implications sources

**Table 1.1.1: Data sources for VPCS- and tumor type-specific clinical implications**

Data sources from which information is reviewed and critically assessed when assigning gene-alteration-tumor type-drug associations an OncoKB and FDA Level of Evidence.

Data source type that contains evidence for a leveled association	Data source example or clarification	FDA Level of Evidence	OncoKB Level of Evidence																										
FDA Drug Label	Specific sections of the FDA drug label to investigate are: Section 1: Indications and Usage Section 2.1: Patient Selection Section 14: Clinical Section 12.1: Mechanism of Action	2	1 or R1																										
NCCN Guidelines	<a href="http://www.nccn.org">www.nccn.org</a>	2 or 3 <sup>1</sup>	2 or R1																										
Peer Reviewed Journals <sup>2</sup> See <a href="#">Chapter 2: Table 1.4.1: Types of biomarker-based studies or analyses evaluated by OncoKB</a>	<table border="0"> <tr> <td>Cell</td> <td>JAMA</td> </tr> <tr> <td>Cancer Discovery</td> <td>New England Journal of Medicine</td> </tr> <tr> <td>JAMA Oncology</td> <td>Science</td> </tr> <tr> <td>Nature</td> <td>Science Translational Medicine</td> </tr> <tr> <td>Nature Medicine</td> <td>JCO</td> </tr> <tr> <td>Nature Reviews Clinical Oncology</td> <td>JCO PO</td> </tr> <tr> <td>Journal of Clinical Investigation</td> <td>J Thoracic Oncol</td> </tr> <tr> <td>Lancet Oncology</td> <td>Target Oncol</td> </tr> <tr> <td>Nature Reviews Cancer</td> <td>Lung Cancer</td> </tr> <tr> <td>Cancer Cell</td> <td>BMC Cancer</td> </tr> <tr> <td>Annals of Oncology</td> <td>Haematologica</td> </tr> <tr> <td>Clinical Cancer Research</td> <td>Leukemia</td> </tr> <tr> <td>Cancer Research</td> <td>Hematology</td> </tr> </table>	Cell	JAMA	Cancer Discovery	New England Journal of Medicine	JAMA Oncology	Science	Nature	Science Translational Medicine	Nature Medicine	JCO	Nature Reviews Clinical Oncology	JCO PO	Journal of Clinical Investigation	J Thoracic Oncol	Lancet Oncology	Target Oncol	Nature Reviews Cancer	Lung Cancer	Cancer Cell	BMC Cancer	Annals of Oncology	Haematologica	Clinical Cancer Research	Leukemia	Cancer Research	Hematology	3	3A, 4 or R2
Cell	JAMA																												
Cancer Discovery	New England Journal of Medicine																												
JAMA Oncology	Science																												
Nature	Science Translational Medicine																												
Nature Medicine	JCO																												
Nature Reviews Clinical Oncology	JCO PO																												
Journal of Clinical Investigation	J Thoracic Oncol																												
Lancet Oncology	Target Oncol																												
Nature Reviews Cancer	Lung Cancer																												
Cancer Cell	BMC Cancer																												
Annals of Oncology	Haematologica																												
Clinical Cancer Research	Leukemia																												
Cancer Research	Hematology																												
Conference Proceedings (Abstracts, Posters or Presentations)	<table border="0"> <tr> <td>AACR Annual Meeting</td> <td>IASLC WCLC</td> </tr> <tr> <td>ASCO Annual Meeting</td> <td>SABCS</td> </tr> <tr> <td>ESMO Annual Meeting</td> <td>AACR-EORTC-NIH MTCT</td> </tr> <tr> <td>ASH Annual Meeting</td> <td></td> </tr> </table>	AACR Annual Meeting	IASLC WCLC	ASCO Annual Meeting	SABCS	ESMO Annual Meeting	AACR-EORTC-NIH MTCT	ASH Annual Meeting																					
AACR Annual Meeting	IASLC WCLC																												
ASCO Annual Meeting	SABCS																												
ESMO Annual Meeting	AACR-EORTC-NIH MTCT																												
ASH Annual Meeting																													
Clinical Trial Eligibility Criteria	Biomarkers must be specified in patient inclusion or exclusion criteria																												

<sup>1</sup> Emerging biomarkers in the NCCN guidelines are mapped to FDA Level 3 (see [Chapter 2: Protocol 3: Mapping OncoKB levels of Evidence to FDA Levels of Evidence](#)). Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

<sup>2</sup> Notes the most prevalent journals referenced in OncoKB. OncoKB does not discriminate when evaluating evidence in peer-reviewed journals. All evidence is evaluated independent of journal name, corresponding author and/or institution. It is the quality and strength of the evidence (defined in [Chapter 1: Table 4.1: Preclinical \(experimental\) evidence that may be used to support an assertion of drug sensitivity \(for OncoKB Levels 3A, 4 and R2\)](#)) that is considered when assigning an OncoKB and FDA Level of Evidence.

## Sub-protocol 1.2: Rules and processes for using existing FDA drug labels

This protocol describes the process for determining FDA Level 2 (OncoKB Level 1 or R1) associations. The protocol specifically details the approach for evaluating and interpreting the different sections of the FDA Drug label, including *Section 1: Indications and Usage*, *Section 2.1: Patient Selection*, *Section 12.1: Mechanism of Action*, and *Section 14: Clinical Studies* when evaluating a potential FDA Level 2 (OncoKB Level 1 or R1) association.

- Please also refer to:
  - [Chapter 2: Table 1.2.3: Sections of the FDA drug label that are reviewed by OncoKB to determine the FDA Level 2 \(OncoKB Level 1 or R1\) Association](#)
  - [Chapter 2: Table S1: FDA Level 2 \(OncoKB Level 1\) Variants of Possible Clinical Significance \(VPCS\) and the information in FDA drug labels that was utilized to define them](#)

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
  - D. **Drug**: must correspond to the drug or drug combination listed in the *Indication and Usage* section of the FDA drug label (refer to [Chapter 1: Protocol 4: Drug curation](#))
- Note that **GREEN** and **RED** text refer to terminal endpoints in which the Variant of Possible Clinical Significance (VPCS) qualifies or does not qualify, respectively, as a FDA and OncoKB leveled variant.
1. Use the **INPUT Drug** as a search term in [Drugs@FDA.gov](#) obtain the most up-to-date version of the FDA drug label and *Proceed to Step 2*
  2. Review **Section 1: Indications and Usage** of the FDA drug label. Does INPUT Tumor Type match the tumor type referenced in the FDA drug label?
    - a. **YES**: *Proceed to Step 3*
    - b. **NO**: This VPCS does not qualify as an FDA Level 2 (OncoKB Level 1) variant. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*
  3. Is the INPUT association being evaluated in the context of:
    - a. Sensitivity: *Proceed to Step 4*
    - b. Resistance: *Proceed to Step 16*

4. Does **Section 1: Indications and Usage** of the FDA drug label indicate the specified genetic alteration is germline?
  - a. **YES:** This VPCS (specified in the germline setting) does not qualify as an FDA Level 2 (OncoKB Level 1) variant. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*
  - b. **NO:** *Proceed to Step 5*
  
5. Does **Section 1: Indications and Usage** of the FDA drug label state that patient selection is based on the identification of a genetic alteration “as detected by an FDA-approved test”?
  - a. **YES:** *Proceed to Step 6*
  - b. **NO:** *Proceed to Step 10*
  
6. Review the **FDA CDx website:** [www.fda.gov/CompanionDiagnostics](http://www.fda.gov/CompanionDiagnostics)
  - Search for the drug and tumor type listed in **Section 1: Indications and Usage** of the FDA drug label
  - Click on the Premarket Approval (PMA) link - review the information listed under “Approval Order Statement” to determine the alteration(s) detected by the test in the specified indication (drug + tumor type).
  - If the information is not present, click on and review the following links on the PMA page:
    - i. *Approval Order*
    - ii. *Labeling*
  - Record the genes + alteration(s) specifically detected by the CDx test

Is the CDx test based on a DNA detection method?

  - a. **YES:** Proceed to Step 9
  - b. **NO:** Proceed to Step 7
  
7. Is this CDx test IHC- or FISH-based?
  - a. **YES:** Proceed to Step 8
  - b. **NO:** *This VPCS does not qualify as an FDA Level 2 (OncoKB Level 1) association*
  
8. Can the FDA-specified biomarker (corresponding to INPUT VPCS) be detected by a DNA-based method?
  - a. **YES:** *The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant*
  - b. **NO:** *This VPCS does not qualify as an FDA Level 2 (OncoKB Level 1) association*
  
9. Is the INPUT VPCS specifically listed in the corresponding CDx test?
  - a. **YES:** *The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant.*



- a. **NO:** This VPCS does not qualify as an FDA Level 2 (OncoKB Level 1) association. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*
10. Is the **INPUT VPCS** specifically listed in **Section 1: Indications and Usage** of the FDA drug label?  
-- Refer to [Chapter 2: Table 1.2.1: Genetic alterations specified in the FDA drug label or other professional guidelines that may qualify an INPUT Variant\(s\) of Potential Clinical Significance \(VPCS\) as an FDA Level 2 \(OncoKB Level 1 or 2\) variant](#) for examples of genetic alterations that are clearly defined in the FDA drug label and that may themselves qualify as OncoKB Level 1 variants
- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant.
  - b. **NO:** *Proceed to Step 11*
11. Is the INPUT VPCS pathognomonic to the INPUT Tumor Type (and tumor type referenced in the FDA drug label)?
- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant.
  - b. **NO:** *Proceed to Step 12*
12. Is the INPUT VPCS a required genetic eligibility criteria for patient selection in the clinical trial referenced in **Section 14: Clinical Trials** of the FDA drug label and present in >90% of the specified tumor type?
- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant.
  - b. **NO:** *Proceed to Step 13*
13. Is the VPCS TMB-H?
- Refer to the OncoKB definition of TMB-H and note <sup>1</sup> provided in [Chapter 2: Table 1.2.2: Defining the VPCS when the variant is in the FDA drug label or other professional guidelines under non-specific language](#)
- a. **YES:** This is an FDA Level 2 (OncoKB Level 1) variant.
  - b. **NO:** *Proceed to Step 14*
14. Is the VPCS MSI-H?
- Refer to the OncoKB definition of MSI-H and note <sup>2</sup> provided in [Chapter 2: Table 1.2.2: Defining the VPCS when the variant is in the FDA drug label or other professional guidelines under non-specific language?](#)
- a. **YES:** This is a FDA Level 2 (OncoKB Level 1) variant.
  - b. **NO:** *Proceed to Step 15*
15. Could the INPUT VPCS be included under an umbrella term listed in **Section 1: Indications and**

**Usage** of the FDA drug label?

-- Refer to [Chapter 2: Table 1.2.2: Defining the VPCS when the variant is in the FDA drug label or other professional guidelines under non-specific language](#) for how to define the specific variant in the data source when the terminology is vague (including when umbrella terms are used)

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 1) variant and the FDA/OncoKB leveled VPCS is that which is specified in [Chapter 2: Table 1.2.2: Defining the VPCS when the variant is in the FDA drug label or other professional guidelines under non-specific language](#)
- b. **NO:** This VPCS does not qualify as an FDA Level 2 (OncoKB Level 1) variant. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*

16. Does **Section 1: Indications and Usage** of the FDA drug label include a “Limitation of Use” clause?

- a. **YES:** *Proceed to Step 17*
- b. **NO:** *Proceed to Step 18*

17. Does the “Limitation of Use” clause exclude a patient from treatment if their tumor harbors the INPUT VPCS, either by direct mention of the VPCS or indicating that patients must be wildtype for the Gene in which the VPCS is associated?

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level R1) variant
- b. **NO:** This VPCS does not qualify as an FDA Level 2 (OncoKB Level R1) variant per this protocol. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*

18. Does **Section 2.1: Patient Selection** of the FDA drug label specify that patients with the INPUT VPCS are not eligible for the drug, either by direct mention of the VPCS or indicating that patients must be wildtype for the Gene in which the VPCS is associated?

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level R1) variant
- b. **NO:** *Proceed to Step 19*

19. Review **Section 12.1: Mechanism of Action** of the FDA drug label. Is the INPUT VPCS specified as being a clinically acquired resistance mutation?

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level R1) variant
- b. **NO:** This VPCS does not qualify as an FDA Level 2 (OncoKB Level R1) variant per this protocol. *Proceed to [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines](#)*

**Table 1.2.1: Genetic alterations specified in the FDA drug label or other professional guidelines that may qualify an INPUT Variant(s) of Potential Clinical Significance (VPCS) as an FDA Level 2 (OncoKB Level 1 or 2) variant**

Genetic alterations that may be specified in *Section 1: Indications and Usage* of the FDA drug label or in the NCCN and other professional guidelines and that may qualify the INPUT VPCS as an FDA Level 2 (OncoKB Level 1 or 2) variant. *Section A.* of this table shows examples of genetic alterations specified in *Section 1: Indications and Usage* of the FDA drug label that are clearly defined and may themselves qualify as an FDA Level 2 (OncoKB Level 1) variant. *Section B.* of this table shows examples where the genetic alteration specified in *Section 1: Indications and Usage* of the FDA drug label is vague and requires clarification to define the FDA Level 2 (OncoKB Level 1 or 2) variant. For example, the FDA drug label for Alpelisib lists “PIK3CA-mutated...as detected by an FDA-approved test.” In this case, it is the alterations specified in the FDA-approved test that are the relevant variants and that may qualify an INPUT VPCS as an FDA Level 2 (OncoKB Level 1) variant (as outlined in [Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels](#)).

A. Genetic alteration(s) specified in <i>Section 1: Indications and Usage</i> of the FDA drug label or in disease-specific NCCN guidelines that may qualify as a VPCS	Oncogene	Tumor Suppressor	Other Biomarkers
	Specific Missense Mutation ex: BRAF V600E or EGFR L858R	Deletion ex: SMARCB1 Deletion	Wildtype
	Specific Fusion ex: BCR-ABL1 Fusion		
	Splice-Site Mutation ex: MET Exon 14 skipping mutations		
	Duplication ex: FLT3-ITD		
	Amplification ex: HER2 overexpressing/amplified		
Range-specified Deletion ex: EGFR exon 19 deletion			
B. Genetic alteration(s) specified in <i>Section 1: Indications and Usage</i> of the FDA drug label or in disease-specific NCCN guidelines that are vague and require clarification to define the VPCS	“Gene”-mutated <sup>1</sup> ex: PIK3CA-mutated (Alpelisib FDA drug label, 05/2019)	Deleterious Mutations <sup>1</sup> ex: BRCA deleterious mutations	Microsatellite Instability-High <sup>1</sup>
	“Gene”-mutant <sup>1</sup> ex: RET-mutant (Pralsetinib FDA drug label, 12/2020)		Tumor Mutational Burden High <sup>1</sup>
	“Gene” Exon X mutations <sup>1</sup> ex: PDGFRA exon 18 mutation (Avapritinib FDA drug label, 2020)		

	“Gene”-positive <sup>1</sup> ex: ALK-positive (Lorlatinib drug label, 11/2018)		
	“Gene”-rearrangement <sup>1</sup> ex: PDGFR gene rearrangement (Imatinib drug label, 08/2020)		
	“Gene” mutations ex: ERBB2 (HER2) mutations (NSCLC NCCN Guidelines v4.2021)		
	“Gene” Translocation ex: ALK Translocation (Soft Tissue Sarcoma NCCN Guidelines v1.2021)		

<sup>1</sup> Refer to [Chapter 2: Table 1.2.2: Defining variants in the FDA drug label or other professional guidelines when non-specific language is used](#)

### Table 1.2.2: Defining variants in the FDA drug label or other professional guidelines when non-specific language is used

Examples of how to define genetic alteration specified in *Section 1: Indications and Usage* of the FDA drug label or in the NCCN or other professional guidelines when the terminology in the data source is vague (including when umbrella terms are used). The corresponding FDA and OncoKB Level of Evidence is listed for each example.

Genetic alteration(s) specified in <i>Section 1: Indications and Usage</i> of the FDA drug label or in the NCCN or other professional guidelines that are vague and require clarification							
Gene of Interest	R U L E  #	Sample non-specific language in the FDA drug label <i>Section 1: Indications and Usage</i> or in professional guidelines	Rules to specify variants in the FDA drug label or professional guidelines with non-specific language	FDA Level of Evidence (LoFE)		OncoKB Level of Evidence (LoFE)	
				<i>Data Source:</i> FDA = FDA drug label NCCN = NCCN or other professional guidelines			
				FDA	NCCN	FDA	NCCN
Oncogene	1	“Gene”-mutated Ex: PIK3CA-mutated (Alpelisib FDA drug label, 05/2019)	<b>Is there a corresponding CDx test?</b> <b>Yes:</b> The VPCS must be matched to those alterations specified in the CDx test  <b>No:</b> The VPCS must be matched to any gene variant considered	FDA LoFE 2	FDA LoFE 2 or LoFE 3 <sup>4</sup>	LoFE 1	LoFE 2
	2	“Gene”-mutant Ex: RET-mutant (Pralsetinib FDA drug label,					

		12/2020)	oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
	3	“Gene”-positive Ex: ALK-positive (Lorlatinib FDA drug label, 11/2018)	The VPCS must be matched to any gene fusion considered oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
	4	“Gene”-rearrangement <sup>1</sup> ex: PDGFR gene rearrangement (Imatinib drug label, 08/2020)	The VPCS must be matched to any gene fusion considered oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
	5	“Gene” mutations ex: ERBB2 (HER2) mutations (NSCLC NCCN Guidelines v4.2021)	The VPCS must be matched to any gene variant considered oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
	6	“Gene” Translocation ex: ALK Translocation (Soft Tissue Sarcoma NCCN Guidelines v1.2021)	The VPCS must be matched to any gene fusion considered oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
<b>Tumor Suppressor</b>	7	Deleterious Mutations ex: BRCA deleterious mutations	The VPCS must be matched to all truncating (nonsense/ frameshift/ deletion/ splice site mutations) mutations and any gene missense variant considered oncogenic or likely oncogenic per <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a> .  Refer to <a href="#">Chapter 6: Protocol 3: Table 3.1: OncoKB alteration nomenclature, style and formatting</a> and <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>				
<b>Other Biomarkers</b>	8	Microsatellite Instability-High (MSI-H)	Refer to <sup>1</sup>				

	9	Tumor Mutational Burden High (TMB-H)	Refer to <sup>2</sup>				
	10	Deleterious or suspected deleterious homologous recombination repair (HRR) gene-mutated (HRR-mutated)	Oncogenic/Likely oncogenic variants in the following genes: BRCA1, BRCA2, ATM, BARD1, BRIP1, CDK12, CHEK1, CHEK2, FANCL, PALB2, RAD51B, RAD51C, RAD51D and RAD54L  Refer to <a href="#">Chapter 1: Sub-Protocol 2.5 Rule B.4</a> and <a href="#">Chapter 1: Table 2.5.1</a>				

<sup>1</sup> It is important to note that the assignment of MSI-H and validity of these calls is left under jurisdiction of the sequencing assay and is not executed by OncoKB. OncoKB annotates these calls with the appropriate OncoKB and FDA Level of Evidence as outlined in [Chapter 2: Curation of variant and tumor type specific clinical implications](#).

<sup>2</sup> It is important to note that the assignment of TMB-H and validity of these calls is left under jurisdiction of the sequencing assay and is not executed by OncoKB. OncoKB annotates these calls with the appropriate OncoKB and FDA Level of Evidence as outlined in [Chapter 2: Curation of variant and tumor type specific clinical implications](#). Tumor Mutational Burden (TMB) is defined as the number of somatic mutations per megabase (mut/Mb) of genome sequenced. As of 02/2021, OncoKB notes that the anti-PD-1 antibody pembrolizumab is FDA-approved for the treatment of adult and pediatric patients with unresectable or metastatic solid tumors with a mutation burden of  $\geq 10$  mut/Mb.

<sup>3</sup> Based on the most recent FDA drug label for Olaparib (12/07/2020), olaparib is indicated for the treatment of adult patients with deleterious or suspected deleterious germline or somatic homologous recombination repair (HRR) gene-mutated metastatic castration-resistant prostate cancer (mCRPC) who have progressed following prior treatment with enzalutamide or abiraterone based on an FDA-approved companion diagnostic for Lynparza. FoundationOne CDx is an FDA-approved test for the detection of Homologous Recombination Repair (HRR) gene (BRCA1, BRCA2, ATM, BARD1, BRIP1, CDK12, CHEK1, CHEK2, FANCL, PALB2, RAD51B, RAD51C, RAD51D and RAD54L) alterations in prostate cancer ([https://www.accessdata.fda.gov/cdrh\\_docs/pdf17/P170019S015C.pdf](https://www.accessdata.fda.gov/cdrh_docs/pdf17/P170019S015C.pdf)). Deleterious or suspected deleterious mutations in a tumor suppressor gene include OncoKB annotated oncogenic and likely oncogenic variants as defined in [Chapter 1: Sub-Protocol 2.5 Rule B.4](#) and [Chapter 1: Table 2.5.1](#)

<sup>4</sup> Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

**Table 1.2.3 Sections of the FDA drug label that are reviewed by OncoKB to determine the FDA Level 2 (OncoKB Level 1 or R1) association**

The different sections of the FDA drug label, the priority/weight assigned to the information in each section, the specific information that is assessed and the rules for determining the FDA Level 2 (OncoKB Level 1 or R1) association.

FDA drug label section	Priority/weight when defining an FDA Level 2 (OncoKB Level 1 or R1) VPCS <sup>1</sup>	Information in the FDA drug label that is assessed by OncoKB	Rules for determining if the INPUT gene-VPCS- tumor type-drug qualifies as an FDA Level 2 (OncoKB Level 1 or R1) association <sup>2</sup> (per <a href="#">Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels</a> )	
			Criteria that must be met from the FDA drug label sections	The FDA Level 2 (OncoKB Level 1 or R1) association
<i>Section 1: Indications and Usage</i>	High	<ul style="list-style-type: none"> <li>• Gene</li> <li>• Alteration</li> <li>• Tumor Type</li> <li>• Drug</li> <li>• Does the section specify “as detected by an FDA-approved test”</li> </ul>	<p>If the INPUT VPCS is specifically listed in <i>Section 1: Indications and Usage</i> of the FDA drug label</p> <p>AND</p> <p>Patient selection is NOT determined by an FDA-approved test (CDx) (per <i>Section 2.1: Patient Selection</i> of the FDA drug label)</p>	<p>The INPUT gene-VPCS-tumor type-drug qualifies as an FDA Level 2 (OncoKB Level 1) association</p>
<i>Section 2.1: Patient Selection</i>	High	<ul style="list-style-type: none"> <li>• Does the section specify “as detected by an FDA-approved test”</li> <li>• If YES - proceed to <a href="http://www.fda.gov/CompanionDiagnostics">http://www.fda.gov/CompanionDiagnostics</a></li> </ul>	<p>If <i>Section 2.1: Patient Selection</i> of the FDA drug label specifies that patient selection must be determined by an FDA-approved test (CDx test)</p> <p>AND</p> <p>the INPUT VPCS is specifically listed in the corresponding CDx test</p>	
<a href="http://www.FDA.gov/CompanionDiagnostics">www.FDA.gov/CompanionDiagnostics</a>	High	<ul style="list-style-type: none"> <li>• Gene</li> <li>• Alteration(s)</li> <li>• Tumor Type</li> <li>• Specimen Type</li> <li>• For a specified CDx test, the specific sections that require review are:               <ol style="list-style-type: none"> <li>1. Premarket Approval (PMA)</li> <li>2. Approval Order</li> <li>3. Labeling</li> </ol> </li> </ul>		

<p><i>Section 14: Clinical Studies</i></p>	<p>Moderate</p>	<ul style="list-style-type: none"> <li>● Clinical Trial Details and Metrics: <ul style="list-style-type: none"> <li>○ Phase</li> <li>○ Drug</li> <li>○ Tumor type</li> <li>○ Total Number of patients</li> <li>○ Patient cohort stratification</li> <li>○ Biomarker-based eligibility criteria</li> <li>○ Primary and Secondary outcomes</li> <li>○ Efficacy Results (for biomarker-based cohort)</li> </ul> </li> </ul>	<p>If patient selection is NOT determined by an FDA-approved test (CDx test) per <i>Section 2.1: Patient Selection</i> of the FDA drug label</p> <p>AND</p> <p>the INPUT VPCS is included under an umbrella term listed in <i>Section 1: Indications and Usage</i> of the FDA drug label</p> <p>AND</p> <p>the INPUT VPCS is specified as being tested in the referenced clinical trial in <i>Section 14.1: Clinical Studies</i></p>	
<p><i>Section 12.1: Mechanism of Action</i></p>	<p>High</p>	<ul style="list-style-type: none"> <li>● Gene</li> <li>● Alteration</li> <li>● Mention of clinically acquired resistance mutation</li> </ul>	<p>If the INPUT association is being evaluated in the context of resistance</p> <p>AND</p> <p><i>Section 12.1: Mechanism of Action</i> of the FDA drug label specifies the VPCS is a clinically acquired resistance mutation</p>	<p>The INPUT gene-VPCS-tumor type-drug qualifies as an FDA Level 2 (OncoKB Level R1) association</p>

<sup>1</sup> *Section 1: Indications and Usage* and *Section 2.1: Patient Selection* of the FDA drug label should be assessed simultaneously and the variants they reference should be directly compared.



## Sub-Protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines

This protocol describes the process for determining FDA Level 2 or Level 3<sup>2</sup> (OncoKB Level 2 or R1) associations. The protocol specifically details the approach for evaluating and interpreting the disease-specific NCCN guidelines when investigating a potential FDA Level 2 or Level 3<sup>2</sup> (OncoKB Level 2 or R1) association.

- Please also refer to:
  - [Chapter 2: Table S3: Examples of FDA Level 2 or 3 \(OncoKB Level 2\) associations](#)

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variants** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
  - D. **Drug**: must correspond to an FDA-approved drug (refer to [Chapter 1: Protocol 4: Drug curation](#))
- *Note that GREEN and RED text refer to terminal endpoints in which the VPCS qualifies or does not qualify, respectively, as a FDA and OncoKB leveled variant.*
1. Determine that the VPCS does not qualify as an FDA Level 2 (OncoKB Level 1 or R1) variant by using [Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels](#)
  2. Obtain the most up-to-date version of the **disease-specific NCCN guidelines**, ensuring that the INPUT Tumor Type matches the tumor type of the NCCN guideline. NCCN Guidelines can be found here: <https://www.nccn.org/>. Note the: 1) Tumor type, 2) NCCN Guideline version and date, 3) Date of last review by OncoKB
  3. Using INPUT Drug as a search term, review the “UPDATES” pages in the NCCN guideline to determine whether the INPUT drug (drug of interest) is **recommended in the treatment-related disease-specific protocols** (Disease-specific protocols are defined as DIS-page number, for example for Colon Cancer, page COL-x or for Breast Cancer page DCIS-x)
    - a. **YES**: *Proceed to Step 4*
    - b. **NO**: *The INPUT VPCS does not qualify as an FDA Level 2 (OncoKB Level 2 or Level R1) variant. Proceed to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)*
  4. Is the drug of interest recommended for patients with a **specified gene-variant(s)**?
    - a. **YES**: *Proceed to Step 5*

- b. **NO:** The INPUT VPCS does not qualify as an FDA Level 2 (OncoKB Level 2 or R1) variant. *Proceed to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)*
- 5. Is the biomarker-specific drug recommendation from Step 4 specified in the germline setting only<sup>1</sup>?
  - a. **YES:** The INPUT gene-VPCS-tumor type-drug (in the somatic setting) does not qualify as an FDA Level 2 (OncoKB Level 2) association. *Proceed to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)*
  - b. **NO:** *Proceed to Step 6*
- 6. Have at least three patients with the tumor type of interest and a **somatic mutation in the gene of interest** demonstrated a RECIST clinical response (CR or PR) to the drug of interest?
  - a. **YES:** *Proceed to Step 9*
  - b. **NO:** *Proceed to Step 7*
- 7. Could the INPUT VPCS be included under an umbrella term (e.g. fusions, “gene” mutated) identified in Step 4?
 

--Refer to [Chapter 2: Table 1.2.2: Defining variants in the FDA drug label or other professional guidelines when non-specific language is used](#) for examples of how to define the specific variant in the data source when the terminology is vague (including when umbrella terms are used)

  - a. **YES:** *Proceed to Step 9*
  - b. **NO:** *Proceed to Step 8*
- 8. Does the INPUT VPCS belong to a group of alterations present in a specific amino acid range (e.g. FLT3 ITD) or functional domain (e.g. DNA binding domain in TP53 or kinase domain in PIK3CA) referenced in the biomarker-based drug recommendation from Step 4?
  - a. **YES:** *Proceed to Step 9*
  - b. **NO:** This VPCS does not qualify as an FDA Level 2 (OncoKB Level 2 or Level R1) variant.
- 9. Is the drug of interest **FDA-approved**?
  - a. **YES:** *Proceed to Step 10*
  - b. **NO:** The INPUT VPCS does not qualify as an FDA Level 2 (OncoKB Level 2 or Level R1) variant. *Proceed to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)*

10. Is the drug of interest recommended at **NCCN Category 2A or higher** and associated with **drug sensitivity**?

- a. **YES:** *Proceed to Step 11*
- b. **NO:** *Proceed to Step 12*

11. Per the data outlined in the data source, is the INPUT VPCS an **emerging biomarker**<sup>2</sup>?

--Refer to [Chapter 2: Table 1.3.1: Emerging biomarkers that are OncoKB Level 2](#)

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 3 (OncoKB Level 2) variant.
- b. **NO:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level 2) variant.

12. Is the drug of interest recommended at **NCCN Category 2A or higher** and associated with **drug resistance**?

- a. **YES:** The INPUT VPCS qualifies as an FDA Level 2 (OncoKB Level R1) variant.
- b. **NO:** The INPUT VPCS does not qualify as an FDA Level 2 (OncoKB Level R1) variant. *Proceed to [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)*

<sup>1</sup> Refer to [Chapter 2: Supplemental Material: Table S2: Examples of using existing FDA drug labels and NCCN Guidelines to assign somatic variants an FDA and OncoKB Level of Evidence when the defined biomarker is in the germline setting](#)

<sup>2</sup> **Emerging biomarkers** are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

## Table 1.3.1 Emerging biomarkers that are OncoKB Level 2

Emerging biomarkers that are OncoKB Level 2 as of 02/01/2021. Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3 For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

OncoKB-associated				NCCN Guidelines						
Gene	Mutation	Tumor Type	Drug	Tumor Type	Version and date	Section and page	NCCN language	Reference	Clinical study trial type	Pt responses (n/N) reported in referenced study
ERBB2	Oncogenic Mutations	NSCLC	Ado-Trastuzumab Emtansine	NSCLC	2.2021 - Dec. 15, 2020	Emerging biomarkers to identify novel therapies for patients with met. NSCLC  NSCL-H 5 of 5	Genetic Alteration ERBB2 (HER2) mutations  Available targeted agents with activity against driver event in lung cancer: Ado-Trastuzumab Emtansine	PMID: 29989854	Basket Study	8/18 pts with RECIST response
EGFR	A763_Y764insFQEA	NSCLC	Erlotinib	NSCLC	2.2021 - Dec. 15, 2020	Principles of Molecular Biomarker Analysis  NSCL-H 2 of 5	A763_Y764insFQEA is associated with sensitivity to TKI therapy	PMID: 28089594	Retrospective analysis of pts diagnosed with NSCLC with EGFR mts	PR: 8/11 pts SD: 2/11 pts PD: 1/11 pts
ALK	Fusions	IMT	Crizotinib	Soft Tissue Sarcoma	1.2021 - Oct. 30, 2020	Systemic Therapy Agents and Regimens with Activity in Soft Tissue Sarcoma Subtypes  SARC-F 5 of 9	IMT with ALK Translocations, Preferred Regimens	PMID: 20979472	Case Report	PR: 1/1
ALK	Fusions	IMT	Ceritinib	Soft Tissue Sarcoma	1.2021 - Oct. 30, 2020	Systemic Therapy Agents and Regimens with Activity in Soft Tissue Sarcoma Subtypes  SARC-F 5 of 9	IMT with ALK Translocations, Preferred Regimens	PMID: 24670165	Phase 1 study - patients with advanced cancers harboring genetic alterations in ALK	Referenced with respect to being successful in NSCLC
BRAF	V600E	Ganglioglioma	Cobimetinib+ Vemurafenib	CNS	3.2021 - Sept. 11,	Principles of brain and spinal	Adjuvant treatments useful under certain	1. PMID: 29380516	1. Case Report	1. 1/1 pt responds to D + T

			Trametinib+D abrafenib		2020	cord tumor systemic therapy  BRAIN-D 1 of 15	circumstances - If BRAF V600E activating mutation	2. PMID: 30351999	2. Phase II VE-basket study	2. 1/3 pts had a PR to Vem
BRAF	V600E	Pilocytic Astrocytoma	Cobimetinib+ Vemurafenib, Trametinib+D abrafenib	CNS	3.2021 - Sept. 11, 2020	Principles of brain and spinal cord tumor systemic therapy  BRAIN-D 1 of 15	Adjuvant treatments useful under certain circumstances - If BRAF V600E activating mutation	PMID: 30351999	Phase II VE-basket study	1/2 pts had a PR to Vem
BRAF	V600E	Pleomorphic Xanthoastrocytoma	Cobimetinib+ Vemurafenib, Trametinib+D abrafenib	CNS	3.2021 - Sept. 11, 2020	Principles of brain and spinal cord tumor systemic therapy  BRAIN-D 1 of 15	Adjuvant treatments useful under certain circumstances - If BRAF V600E activating mutation	1. PMID: 28984141 2. PMID: 26287849 3. PMID: 30351999	1. Case Report 2. Phase II basket study 3. Phase II VE-basket study	1. 2/2 pts respond to D + T 2. 3/4 pts with respond to Vem 3. 3/7 pts with CR or PR to Vem

## Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/ conference proceedings/clinical trial eligibility criteria with mature clinical trial data

This protocol describes the process for determining FDA Level 3 (OncoKB Level 3A or R2) associations. The protocol specifically details the approach for evaluating and interpreting peer-reviewed journals, conference proceedings and clinical trial eligibility criteria with mature clinical data.

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
- B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
- C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
- D. **Drug**: must be a targeted therapy (refer to [Chapter 1: Protocol 4: Drug curation](#))

- Note that **GREEN** and **RED** text refer to terminal endpoints in which the VPCS qualifies or does not qualify, respectively, as a FDA and OncoKB leveled variant.

1. Identify a **clinical trial (or clinical trials) of interest (CTIs)** to be evaluated for inclusion into OncoKB

--Refer to [Chapter 2: Table 1.4.1: Types of biomarker-based studies or analyses evaluated by OncoKB](#) for the types of biomarker-based clinical studies evaluated by OncoKB when investigated a potential FDA/OncoKB leveled association

2. Assess the trial data/results and complete [Chapter 2: Table 1.4.2: Parameters to consider as clinical evidence in biomarker-based clinical studies](#). This table is for internal use only, as it helps the

curator extract, organize, and later assess the information presented in the data source. Does **INPUT** gene, variant, tumor type and drug **match those referenced in the CTI(s)**?

a. **YES:** *Proceed to Step 3*

b. **NO:** This VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. *Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association*

3. Note the different data sources that are used to assign the various FDA and OncoKB Levels of Evidence using [Chapter 2: Table 1.1.1: Data sources for VPCS- and tumor type-specific clinical implications](#). Does the evidence presented in the CTI(s) describe a potential **FDA Level 2 (OncoKB Level 1, 2, or R1) association**?

a. **YES:** *Proceed to:*

i. [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 1 or R1) association OR

ii. [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or guidelines from other expert panels](#) to assess the data for a potential FDA Level 2 or 3<sup>1</sup> (OncoKB Level 2 or R1) association

b. **NO:** *Proceed to Step 4*

4. Is the INPUT drug (drug of interest) FDA-approved in another indication or being tested (or has recently been tested) via enrollment in a clinical trial?

a. **YES:** *Proceed to Step 5*

b. **NO:** The INPUT VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. *Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association*

5. Is the INPUT association being evaluated in the context of:

a. Sensitivity: *Proceed to Step 6*

b. Resistance: *Proceed to Step 15*

6. Is the VPCS a rare variant<sup>2</sup> in the tumor type of interest?

a. **YES:** *Proceed to Step 7*

b. **NO:** *Proceed to Step 8*

7. Has  $\geq 1$  patient with the rare VPCS<sup>2</sup> in the INPUT tumor type demonstrated a RECIST clinical response (CR or PR) or trial-defined clinical benefit<sup>3</sup> to the drug of interest or a drug in the drug of interest family, AND has the mutation been robustly proven in biological studies to sensitize cancer cells to the drug of interest?
  - a. **YES:** The INPUT VPCS qualifies as a potential FDA Level 3 (OncoKB Level 3A) variant.
  - b. **NO:** The INPUT VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association
8. Is the VPCS a hotspot or functionally characterized variant in the tumor type of interest?
  - a. **YES:** Proceed to Step 9
  - b. **NO:** Proceed to Step 10
9. Has  $\geq 3$  patients with the tumor type of interest and a mutation in the gene of interest demonstrated a RECIST clinical response (CR or PR) or trial-defined clinical benefit<sup>3</sup> to the drug of interest or a drug in the drug of interest family?
  - a. **YES:** The INPUT VPCS qualifies as a potential FDA Level 3 (OncoKB Level 3A) variant and the level of evidence can be applied to all oncogenic mutations in the gene of interest
  - b. **NO:** The INPUT VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data to potentially assign the VPCS FDA Level 3 based on OncoKB Level 4.
10. Is the VPCS a fusion?
  - a. **YES:** Proceed to Step 11
  - b. **NO:** Proceed to Step 13
11. Have  $\geq 3$  patients with the tumor type of interest and a functional fusion in the gene of interest demonstrated a RECIST clinical response (CR or PR) or trial-defined clinical benefit<sup>3</sup> to the drug of interest or a drug in the drug of interest family?
  - a. **YES:** The INPUT VPCS qualifies as a potential FDA Level 3 (OncoKB Level 3A) variant and the level of evidence can be applied to all functional fusions in the gene of interest.
  - b. **NO:** Proceed to Step 12
12. Has  $\geq 1$  patient with the tumor type of interest and a functional fusion in the gene of interest demonstrated a RECIST clinical response (CR or PR) or trial-defined clinical benefit<sup>3</sup> to the drug of interest

interest and have >1 fusions and/or other oncogenic mutations in the gene of interest been robustly proven in biological studies to sensitize cancer cells to the drug of interest or a drug in the drug of interest family?

- a. **YES:** The INPUT VPCS qualifies as a potential FDA Level 3 (OncoKB Level 3A) variant and the level of evidence may be applied to all functional fusions in the gene of interest.
- b. **NO:** The INPUT VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association

13. Does the INPUT VPCS belong to a group of alterations present in a specific amino acid range (e.g. FLT3 ITD) or functional domain (e.g. DNA binding domain in TP53 or kinase domain in PIK3CA)?

- a. **YES:** Proceed to Step 14
- b. **NO:** The INPUT VPCS does not qualify as a potential FDA Level 3 (OncoKB Level 3A) variant. Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for potentially assigning the VPCS a FDA Level 3 based on the assignment of a OncoKB Level of evidence 4.

14. Have  $\geq 3$  patients with the tumor type of interest and with a mutation in the specified amino acid range or functional domain demonstrated a RECIST clinical response (CR or PR) or trial-defined clinical benefit<sup>3</sup> to the drug of interest or a drug in the drug of interest family AND have >1 mutations in the specified amino acid range or functional domain in the gene of interest been robustly proven in biological studies to sensitize cancer cells to the drug of interest or a drug in the drug of interest family?

- a. **YES:** The INPUT gene-VPCS-tumor type-drug qualifies as a potential FDA Level 3 (OncoKB Level 3A) association
- b. **NO:** The INPUT gene-VPCS-tumor type-drug does not qualify as a potential FDA Level 3 (OncoKB Level 3A) association. Proceed to [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association

15. Has at least one patient with the tumor type of interest and the VPCS in the gene of interest demonstrated clinical resistance to the drug of interest and has the mutation been robustly proven in biological studies to be resistant to the drug of interest?

- a. **YES:** The INPUT gene-VPCS-tumor type-drug qualifies as a potential FDA Level 3 (OncoKB Level R2) association
- b. **NO:** Proceed to Step 16



16. Have  $\geq 3$  patients with the tumor type of interest and the VPCS in the gene of interest demonstrated clinical resistance to the drug of interest?

- a. **YES:** The INPUT gene-VPCS-tumor type-drug qualifies as a potential FDA Level 3 (OncoKB Level R2) association
- b. **NO:** The INPUT gene-VPCS-tumor type-drug does not qualify as a potential FDA Level 3 (OncoKB Level R2) association

<sup>1</sup> **Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3.** For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

<sup>2</sup> OncoKB defines a rare driver as a mutation that is statistically recurrent (as defined in [Chang et al., 2018](#)) and/or experimentally determined as functional (as defined in [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)) and that is present in  $\leq 3\%$  of cancers.

<sup>3</sup> Trial defined clinical benefit is defined in [Chapter 2: Supplemental Material: Table S4: Examples of trial-defined clinical benefit or pathological response that may be used to assess clinical benefit in a defined patient population](#)

**Table 1.4.1: Types of biomarker-based studies or analyses evaluated by OncoKB**

Defines the types of studies evaluated by OncoKB members when assessing the strength and validity of clinical evidence and determining whether data presented from clinical trials qualifies for an FDA and/or OncoKB Level of Evidence.

Type of Study		Definition	Phase	Significance of evidence	Possible OncoKB level of evidence (FDA level)
Randomized Controlled Study	Prospective	A controlled clinical trial that randomly (by chance) assigns participants to two or more groups	I, II or III	<b>High</b> , depending on significance of association between biomarker and clinical outcomes (see Table 1.4.2) <sup>1</sup>	May comprise evidence for OncoKB Level 1, 2 or 3A (FDA Level 2 or 3)
Single Arm Study	Prospective	A sample of individuals with the targeted medical condition is given the experimental therapy and then followed over time to observe their response	I, II or III	<b>Moderate</b> , depending on significance of association between biomarker and clinical outcomes (see Table 1.4.2) <sup>1</sup>	May comprise evidence for OncoKB Level 2 or 3A (FDA Level 2 or 3)
Case Study or Case Series	Retrospective	A report on a series of patients with an outcome of interest. No control group is involved.	NA	<b>Low</b> depending on significance of association between biomarker and clinical outcomes and number of patients across the number of studies with PR or CR <sup>1</sup>	May comprise evidence for OncoKB Level 3A or 4 (FDA Level 3)
Basket Study	Prospective	A targeted therapy is evaluated on multiple diseases that have common molecular alteration	I, II	<b>Moderate</b> , depending on significance of association between biomarker and clinical outcomes and the denominator of patients with a specific indication <sup>1</sup>	May comprise evidence for OncoKB Level 2 or 3A (FDA Level 2 or 3)
Umbrella Study	Prospective	Evaluates multiple targeted therapies for a single disease that is stratified into subgroups by molecular alteration	I, II	<b>Low</b> , depending on significance of association between biomarker and clinical outcomes and the denominator of patients with a specific indication <sup>1</sup>	May comprise evidence for OncoKB Level 3A or 4 (FDA Level 3)
Meta-analysis	Retrospective	A statistical process that combines the findings from individual research studies	NA	<b>Not considered primary clinical evidence</b>	NA

Retrospective Analysis <sup>2</sup>	Retrospective	Studies used to test etiologic hypotheses in which inferences about an exposure to putative causal factors are derived from data relating to characteristics of persons under study or to events or experiences in their past.	NA	<b>Low</b> , depending on significance of association between biomarker and clinical outcomes and the denominator of patients with a specific indication <sup>1</sup>	May comprise evidence for OncoKB Level 4 (FDA Level 3)
Reviews <sup>3</sup>	NA	Compiles data and evidence from previous studies	NA	<b>Not considered primary clinical evidence</b>	

[www.research.library.gsu.edu/c.php?g=115595&p=755213](http://www.research.library.gsu.edu/c.php?g=115595&p=755213)

<sup>1</sup>The parameters considered to determine the significance of the association between the tumor-type specific biomarker and clinical outcomes are listed in Table 1.4.2 of this chapter.

<sup>2</sup>A retrospective analysis can be performed on a single study or across multiple studies, and can be performed on trials from all Phases (I, II, and III).

<sup>3</sup>Reviews may be assessed by OncoKB staff members for background information and links to primary data sources, but are not themselves used as primary sources when investigating results of clinical trials.

## List 1.4.2: Parameters to consider as clinical evidence in biomarker-based clinical studies

Example of the clinical data that an OncoKB curator or SCMT member must assess and extract when evaluating evidence from peer-reviewed, published biomarker-based clinical studies. Once collected, the data is summarized and reviewed to determine if the VPCS qualifies for an FDA and OncoKB Level of Evidence. Each number represents a column in the Table that is filled in by the OncoKB curator or SCMT member.

To comprehensively curate the clinical data from biomarker based clinical studies Table 1.4.2 is used to document the following information per study (AKT1 E17K in breast cancer is used as an example):

1. Gene e.g. [AKT1](#)
2. Alteration e.g. [E17K](#)
3. Tumor type e.g. [Breast Cancer](#)
4. Drugs e.g. [AZD5363](#)
5. OncoKB Level of Evidence e.g. [3A](#)
6. References e.g. [28489509](#), [23394218](#), [26351323](#), [22294718](#)
7. Other relevant drugs (in the same drug family) e.g. [ARQ 092 \(miransertib\)](#)
8. Number of studies with clinical data e.g. [2](#)
9. Reference study (PMID or Abstract) e.g. [28489509](#)
10. PMID or abstract of additional studies with clinical data (non-reference study) e.g. [26931343](#), [26351323](#)
11. Notes on additional studies (non-reference study) e.g. [1 pt with endometrioid ovarian cancer and AKT1 E17K had a PR](#)

12. Reference study type e.g. Basket Study
13. Reference study drug e.g. AZD5363
14. Trial Name/ID e.g. NCT01226316
15. Phase e.g. Phase 1
16. Disease e.g. Breast Cancer (ER+)
17. Setting e.g. Basket study - pts with histologically confirmed advanced solid tumors refractory to standard therapies, no prior exposure to catalytic AKT inhibitors, and tumors harboring AKT1 mutations but no known concurrent RAS/RAF mutations
18. Total number of patients (N) e.g. 20
19. Number of patients who responded (n) e.g. 17
20. Primary endpoint e.g. Safety
21. Notes on primary endpoint e.g. NA
22. Secondary endpoint e.g. PFS Response (RECIST)
23. Notes on secondary endpoint e.g. NA
24. PFS (experimental group) e.g. 5.5 mos
25. 95% CI (experimental group) e.g. 2.1, 12.8 mos
26. PFS (control group) e.g. NA
27. 95% CI (control group) e.g. NA
28. PFS gain e.g. NA
29. PFS HR e.g. NA
30. OS (experimental group) e.g. NA
31. 95% CI (experimental group) e.g. NA
32. OS (control group) e.g. NA
33. 95% CI (control group) e.g. NA
34. OS gain e.g. NA
35. OS HR e.g. NA
36. ORR e.g. NA
37. Clinical benefit rate e.g. NA
38. CR e.g. 0
39. PR e.g. 4
40. SD e.g. 11
41. PD e.g. 2
42. Not evaluable e.g. 1
43. DOR e.g. NA
44. If case study, describe response e.g. NA
45. Quality of life e.g. NA
46. Toxicity: No. (%) of Grade  $\geq$  3 Adverse Events e.g. Hyperglycemia: 14 (24.1); Diarrhea: 10 (17.2); Rash maculopapular: (15.5%)
47. Notes on toxicity e.g. NA
48. Number or preclinical studies e.g. Drug-related serious adverse events occurred in 15.5% of patients and were consistent with the overall adverse effect profile of AZD5363
49. Preclinical study PMID or abstract e.g. 1
50. Preclinical data summary e.g. In vitro studies of breast cancer explants harboring the AKT E17K mutation have shown that AZD5363 inhibits tumor growth and reduces signaling downstream of AKT, including reduced phosphorylation of PRAS40 and S6

- 51. General notes e.g. 5 pts with TNBC: 1 PR, 1 unconfirmed PR, 1 PD, 2 SD; additional responses in Phase I trial
- 52. Summary of data e.g. 1 Basket Study - Phase 1; N=20 total; 17/20 responded (PR or SD); Drug: AZD5363; Primary Measure is PFS and ORR; Preclinical data is present

## Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/ conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence

This protocol describes the process for determining FDA Level 3 (OncoKB Level 4) associations. The protocol specifically details the approach for evaluating and interpreting peer-reviewed journals, conference proceedings and clinical trial eligibility criteria with preliminary clinical data and mature preclinical evidence.

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
  - D. **Drug:** must be a targeted therapy (refer to [Chapter 1: Protocol 4: Drug curation](#))
- Note that **GREEN** and **RED** text refer to terminal endpoints in which the the gene-variant-tumor type-drug association qualifies or does not qualify, respectively, as a FDA and OncoKB leveled association
1. Identify a **clinical trial** or **clinical study** to be evaluated for inclusion into OncoKB.
  2. Assess the trial data/study results and complete [Chapter 2: Table 1.4.2: Parameters to consider as clinical evidence in biomarker-based clinical studies](#). This table is for internal use only, as it helps the curator extract, organize, and later assess the information presented in the data source. Does INPUT gene, variant, tumor type and drug match those referenced in the trial/study of interest?
    - a. **YES:** Proceed to Step 3
    - b. **NO:** This gene-variant-tumor type-drug association does not qualify as a potential FDA Level 3 (OncoKB Level 4) association
  3. Note the different data sources that are used to assign the various FDA and OncoKB Levels of Evidence using [Chapter 2: Table 1.1.1: Data sources for VPCS- and tumor type-specific clinical implications](#). Does the evidence presented in the data source describe a potential **FDA Level 2 (OncoKB Level 1, 2, or R1) or FDA Level 3 (OncoKB Level 2, 3A or R2) association?**
    - a. **YES:** Proceed to Step:
      - i. [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 1 or R1) association OR

- ii. [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or guidelines from other expert panels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 2 or R1) association
    - iii. [Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) to assess the data for a potential FDA Level 3 (OncoKB Level 3A or R2) association
  - b. **NO:** *Proceed to Step 4*
4. Is the **INPUT drug (drug of interest) FDA-approved?**
- a. **YES:** *Proceed to Step 6*
  - b. **NO:** *Proceed to Step 5*
5. Is the drug of interest currently **being tested in a biomarker-based clinical trial** or has been tested in a biomarker-based clinical trial within the last 3 years, but there is insufficient (not yet mature) clinical data to qualify as an OncoKB Level 3A association?
- Refer to [Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)
- a. **YES:** *Proceed to Step 6*
  - b. **NO:** This gene-variant-tumor type-drug association does not qualify as a potential FDA Level 3 (OncoKB Level 4) association
6. Is there **strong experimental evidence** demonstrating biomarker-specific response to the drug of interest or drug of interest family in the tumor type of interest?
- Refer to [Chapter 1: Table 4.1: Preclinical \(experimental\) evidence that may be used to support an assertion of drug sensitivity \(for OncoKB Levels 3A, 4 and R2\)](#)
- Refer to [Chapter 1: Table 2.3.2: Definition of the strength of functional \(experimental\) evidence that supports an assertion](#)
- a. **YES:** *Proceed to Step 7*
  - b. **NO:** The INPUT gene-VPCS-tumor type-drug does not qualify as a potential FDA Level 3 (OncoKB Level 4) association
7. The Lead Scientist reviews the evidence for the proposed FDA Level 3 (OncoKB Level 4) gene-variant-tumor type drug association with the Director of the Center for Molecular Oncology (CMO)
- a. If the Director of the CMO approves the proposed association, the INPUT gene-VPCS-tumor type-drug qualifies as a potential FDA Level 3 (OncoKB Level 4) association

- b. If the Director of the CMO does not approve the proposed association, the INPUT gene-VPCS-tumor type-drug does NOT qualify as a potential FDA Level 3 (OncoKB Level 4) association

## Sub-Protocol 1.6: Rules/processes for assigning a VPCS an OncoKB Level of Evidence 3B

This protocol describes the process for determining FDA Level 3 (OncoKB Level 3B) associations.

- Variants that are assigned an OncoKB Level 1 / 2 / 3A but for which the input tumor type is off-label (for Levels 1 or 2 variants) or for which the input tumor type is not the tumor type from which the clinical data arose (for Level 3A variants) are assigned Level 3B per the rules outlined in this protocol.
- Level 3B evidences are not curated directly into OncoKB, but can be propagated from Level 1, 2, or 3A evidence to all other solid tumors or all other liquid tumors based on the scientific evidence and discussion with the Lead Scientist and CGAC.
- *Note that GREEN and RED text refer to terminal endpoints in which the gene-variant-tumor type-drug association qualifies or does not qualify, respectively, as a FDA and OncoKB leveled association*

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
1. Is the INPUT gene-variant- associated with an OncoKB Level of Evidence 1, 2 or 3A in a tumor type other than the INPUT tumor type (this is referred to as the *reference association*)?
    - a. **YES:** Note the drug associated with the reference association and *Proceed to Step 2*
    - b. **NO:** This gene-variant-tumor type association does not qualify as a FDA Level 3 (OncoKB Level 3B) association
  2. Is there data suggesting the INPUT gene-variant-tumor type would itself qualify as OncoKB Level 1, 2 or 3A (in association with the drug from the *reference association* identified in Step 1)?
    - a. **YES:** *Proceed to:*
      - i. [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 1 or R1) association OR
      - ii. [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or guidelines from other expert panels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 2 or R1) association
      - iii. [Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) to assess the data for a potential FDA Level 3 (OncoKB Level 3A or R2) association



- b. **NO:** *Proceed to Step 3*
- 3. Is the INPUT tumor type a solid tumor type?
  - a. **YES:** *Proceed to Step 4*
  - b. **NO:** *Proceed to Step 5*
- 4. Has the reference association been specifically curated to propagate to Level 3B in other solid tumor types (per **Chapter 2, Table 1.6.1:** )?
  - a. **YES:** This gene-variant-tumor type qualifies as a potential FDA Level 3 (OncoKB Level 3B) association (and the drug from the *reference association* identified in Step 1)
  - b. **NO:** *Proceed to Step 5*
- 5. Is the INPUT tumor type a liquid tumor type?
  - a. **YES:** *Proceed to Step 6*
  - b. **NO:** This gene-variant-tumor type association does not qualify as a FDA Level 3 (OncoKB Level 3B) association
- 6. Has the reference association been specifically curated to propagate to Level 3B in other liquid tumor types (per **Chapter 2, Table 1.6.1:** )?
  - a. **YES:** This gene-variant-tumor type qualifies as a potential FDA Level 3 (OncoKB Level 3B) association (and the drug from the *reference association* identified in Step 1)
  - b. **NO:** This gene-variant-tumor type association does not qualify as a FDA Level 3 (OncoKB Level 3B) association

**Table 1.6.1: Rules for determining if an existing OncoKB Level 1/2/3A association propagates to Level 3B in other solid or liquid tumor types**

Rules for determining if an existing OncoKB Level 1/2/3A association (referred to as the *reference association*) propagates to Level 3B in other solid or liquid tumor types.

Reference tumor type associated with a OncoKB Level 1/2/3A association	Does an existing OncoKB Level 1/2/3A association propagate to Level 3B in other tumor types <sup>1</sup>	
	Solid Tumor Types	Liquid Tumor Types
<i>Solid Tumor</i>	Level 1, 2 and 3A associations in solid tumors propagate to Level 3B in other solid tumors unless there is negative or conflicting evidence, in which case the association would NOT propagate to Level 3B in other solid tumors in accordance with the evidence.	Level 1, 2 and 3A associations in liquid tumors do not propagate to other solid or other liquid tumors unless there is specific scientific evidence to support the association as Level 3B in these tumor types.
<i>Liquid Tumor</i>	Level 1, 2 and 3A associations in solid tumors do not propagate to liquid tumors unless there is specific scientific evidence to support the association as Level 3B in liquid tumors.	

<sup>1</sup>Determination of whether an existing OncoKB Level 1/2/3A association propagates to Level 3B in other solid or liquid tumor types is based on analysis of the scientific literature and discussion with CGAC members at the time of Level 1/2/3A assignment.

## Protocol 2: CGAC approval of OncoKB level of evidence assignment

This protocol describes the process for obtaining CGAC approval for proposed OncoKB Level 1, 2, 3A, 4, R1 and R2 associations.

CGAC members are responsible for entering into consensus regarding the assignment of an OncoKB level of evidence to a biomarker. Requests for consensus from CGAC occur in the form of emails from the Lead Scientist to all CGAC members and are typically prompted by new FDA-approvals, FDA-breakthrough designations, or newly reported results of major clinical trials from clinical oncology conferences or publications.

### INPUT:

- A. **Gene** defined as Oncogene or Tumor Suppressor or Both or Neither +
  - B. **Variant** must be defined as a Variants of Possible Clinical Significance (VPCS) as outlined in [Chapter 1: Protocol 2: Variant curation](#)
  - C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
  - D. **Drug**: must be a targeted therapy (refer to [Chapter 1: Protocol 4: Drug curation](#))
1. Use [Chapter 2: Protocol 1: Curation of tumor type specific variant clinical implications](#) to identify a gene-VPCS-tumor type-drug association of interest that may qualify for an FDA and (OncoKB) Level of Evidence
  2. Use [Chapter 2: Table 2.1: Details and examples of how to compose a consensus email for CGAC approval of a proposed OncoKB leveled association](#) to generate a consensus email to all current CGAC members  
  
--Also refer to [Chapter 2: Figure 2.1: Sample consensus email for a proposed OncoKB Leveled 1 association](#) and [Chapter 2: Figure 2.2: Sample consensus email for a proposed OncoKB Level 3A association](#) for examples of how to compose and format a CGAC consensus email
  3. In the consensus email, specifically, request that the following **three CGAC members** respond with feedback and/or **affirmative verification within 5 business days** from the date the email is sent:
    - a. the Director of the Center for Molecular Oncology, Dr. David Solit
    - b. a Disease Management Team (DMT) Chief in the indication of the proposed level of evidence change
    - c. A miscellaneous member of CGAC
  4. Throughout the review period, respond to and address all feedback from CGAC members
  5. At 5 business days from the time of sending the consensus email, if all feedback is addressed and all three CGAC members from Step 3 above approve the leveled association and corresponding

therapeutic summary, the gene-VPCS-tumor type-drug association is approved for inclusion into OncoKB

6. Enter the following data into the OncoKB curation platform (per [Chapter 6: OncoKB formatting and nomenclature in the curation platform](#)) and proceed to [Chapter 3: Data review and release](#) to have the curated data independently, internally reviewed and prepared for release to the OncoKB public website ([www.oncoKB.org](http://www.oncoKB.org))
  - a. Tumor-type (nested under the specified gene-variant)
  - b. Therapeutic summary
  - c. Therapy
  - d. Level of evidence (nested under standard or investigational therapies for sensitivity or resistance)
  - e. Level of Evidence in other solid tumors
  - f. Level of Evidence in other liquid tumors
  - g. Description of Evidence

**Table 2.1 Details and examples of how to compose a consensus email for CGAC approval of a proposed OncoKB leveled association**

Components in consensus email to CGAC	OncoKB Level 1 consensus email example	OncoKB Level 3A consensus email example
<p><b>Email title:</b> Begins with <i>[OncoKB CONSENSUS]</i> and include the OncoKB Level, gene, alteration and tumor type that corresponds to the proposed association</p>	<p>MET exon 14 skipping mts in NSCLC Drug: Capmatinib</p>	<p>Somatic BRCA1/2 oncogenic mutations in pancreatic cancer Drug: Rucaparib</p>
<p><b>Specification of 3 CGAC members required to respond:</b> Identification of 3 CGAC members who must provide affirmative verification of the proposed leveled association</p> <ul style="list-style-type: none"> <li>● The Director of the Center for Molecular Oncology</li> <li>● A Disease Management Team (DMT) Chief in the indication of the proposed level of evidence change</li> <li>● A miscellaneous member of CGAC</li> </ul>	<p>Requires review and response by Drs Paul Paik, Alex Drilon and David Solit</p>	<p>Requires review and response by Drs Eillen O'Reilly, Zsofia Stadler, and David Solit</p>
<p><b>Deadline for response:</b> Provide a deadline for</p>	<p>Date of email: 5/8/2020</p>	<p>Date of email: 1/17/2020</p>

<p>CGAC members to review and provide feedback and/or verification/rejection of the proposed leveled association</p> <ul style="list-style-type: none"> <li>Typically 5 business days from the time the email is sent</li> </ul>	<p>Response required by: 5/15/2020</p>	<p>Response required by: 1/24/2020</p>												
<p><b>Current or proposed OncoKB level of evidence:</b> For the gene, alteration, tumor-type-drug, state the current OncoKB level of evidence (if applicable) and the associated drug</p>	<p>Not yet leveled</p>	<p>Not yet leveled</p>												
<p><b>Proposed change in the OncoKB level of evidence:</b> If the approval is for a change in the level of evidence for a specified gene-alteration-tumor type, note the change in level</p>	<p>NA</p>	<p>NA</p>												
<p><b>Reference links:</b> Provide links to the specific references</p> <ul style="list-style-type: none"> <li>If Level 1, provide link to FDA-approval announcement</li> <li>If Level 2 or R1, provide a link to the relevant NCCN Guideline</li> <li>For all levels, provide a link to the peer-reviewed literature that details the clinical findings are published</li> </ul>	<ul style="list-style-type: none"> <li><a href="#">FDA-approval Capmatinib</a></li> <li><a href="#">GEOMETRY mono-1 trial</a></li> </ul>	<p><a href="#">JCO-PO demonstrating clinical activity of patients with BRCA mt pancreatic cancer treated with PARP inhibitor rucaparib</a></p>												
<p><b>Clinical Trial information:</b> When describing data from a completed or ongoing clinical trial, report the Trial:</p> <ul style="list-style-type: none"> <li>Name</li> <li>Phase</li> <li>Total number of pts (N)</li> <li>Tumor-type of pt cohort</li> <li>Enrollment criteria of pt population (biomarker-specific)</li> </ul>	<p>Based on the nonrandomized, open-label multi-cohort phase II GEOMETRY mono-1 trial study enrolling 97 patients with metastatic NSCLC with MET exon 14 skipping mutations</p>													
<p><b>Study Endpoints</b></p> <ul style="list-style-type: none"> <li>Tumor Response data</li> <li>Overall response rate (ORR)</li> <li>Progression-free survival (PFS)</li> <li>Overall Survival (OS)</li> <li>Duration of Response (DOR)</li> </ul> <p>*Include 95% CI, Hazard Ratio (HR), and p-values when applicable</p>	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Treatment naive patients N=28</th> <th>Previously treated patients N=69</th> </tr> </thead> <tbody> <tr> <td>ORR (95% CI)</td> <td>68% (48 - 84)</td> <td>41% (29 - 53)</td> </tr> <tr> <td>Median DOR (95% CI)</td> <td>12.6 mos (5.5 - 25.3)</td> <td>9.7 mos (5.5 - 13.0)</td> </tr> <tr> <td>Median PFS (95% CI)</td> <td>9.7 mos (5.5 - 13.9)</td> <td>5.4 mos (4.2 - 7.0)</td> </tr> </tbody> </table>	Parameter	Treatment naive patients N=28	Previously treated patients N=69	ORR (95% CI)	68% (48 - 84)	41% (29 - 53)	Median DOR (95% CI)	12.6 mos (5.5 - 25.3)	9.7 mos (5.5 - 13.0)	Median PFS (95% CI)	9.7 mos (5.5 - 13.9)	5.4 mos (4.2 - 7.0)	<p>b. Level 3A (Investigational) annotation of somatic BRCA1/2 Oncogenic mutations in pancreatic cancer</p> <ul style="list-style-type: none"> <li>Based on this study in <a href="#">JCO-PO demonstrating clinical activity of patients with BRCA mt pancreatic cancer treated with PARP inhibitor rucaparib</a> and FDA-approval of PARP inhibitor olaparic in patients with germline BRCA mt pancreatic cancer (see above)</li> <li>N=18 (16 - germline and 2 - somatic)</li> <li>2/3 patients with somatic BRCA2 mutations had objective responses (1 CR and 1 PR). In the same study 3/16 germline BRCA+ pancreatic cancer patients showed an objective response (all BRCA2+).</li> <li>Therefore for a patient with somatic BRCA mt pancreatic cancer the following summary will be included in OncoKB and subsequently into the enhanced MSK-IMPACT reports: BRCA2, a tumor suppressor involved in the DNA damage response, is mutated in various cancer types. The BRCA2 L166F mutation is likely oncogenic. The PARP inhibitor rucaparib is FDA-approved for BRCA-mutant pancreatic cancer in the germline setting only. There is promising clinical activity of the PARP inhibitor olaparic in patients with BRCA-mutant positive pancreatic cancer in the somatic setting.</li> </ul>
Parameter	Treatment naive patients N=28	Previously treated patients N=69												
ORR (95% CI)	68% (48 - 84)	41% (29 - 53)												
Median DOR (95% CI)	12.6 mos (5.5 - 25.3)	9.7 mos (5.5 - 13.0)												
Median PFS (95% CI)	9.7 mos (5.5 - 13.9)	5.4 mos (4.2 - 7.0)												
<p><b>Clinical summary overview</b></p>	<p>Therefore, for a patient with non-small cell lung cancer</p>	<p>Therefore for a patient with somatic BRCA mt pancreatic</p>												

	<p>harboring a MET exon 14 skipping mutation, the following summary will be included in OncoKB and subsequently into the enhanced MSK-IMPACT reports. (Note: MET X1010_splice is used as an example below)</p>	<p>cancer the following summary will be included in OncoKB and subsequently into the enhanced MSK-IMPACT reports:</p>
<p><b>Clinical summary</b></p> <p>Consists of gene summary (sentence 1), mutation summary (sentence 2) and therapeutic summary (sentence 3)<sup>1</sup></p>	<p>MET, a receptor tyrosine kinase, is recurrently altered by mutation, amplification and/or overexpression in various cancer types. The MET X1010_splice mutation is known to be oncogenic. Capmatinib is FDA-approved for the treatment of patients with metastatic non-small cell lung cancer harboring MET exon 14 skipping mutations such as MET X1010_splice.</p>	<p>BRCA2, a tumor suppressor involved in the DNA damage response, is mutated in various cancer types. The BRCA2 L1564* mutation is likely oncogenic. The PARP inhibitor olaparib is FDA-approved for BRCA-mutant pancreatic cancer in the germline setting only. There is promising clinical activity of the PARP inhibitor rucaparib in patients with BRCA2-mutant positive pancreatic cancer in the somatic setting.</p>

<sup>1</sup> Refer to [Chapter 6: Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform](#) for a description of the gene summary and [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#) for a description of the therapeutic summary. The mutation summary is automatically generated based on the variant's curated oncogenic effect.

**Figure 2.1: Sample consensus email for a proposed OncoKB Levelled 1 association [OncoKB Consensus] Level 1 annotation of MET Exon 14 skipping mutations in NSCLC**

Dear Colleagues,

We propose the following OncoKB change:

**Requires review and response by Drs Paul Paik, Alex Drilon and David Solit. Please respond within 5 business days, by Friday, May 15.**

*\*If you have a conflict of interest that specifically relates to the proposed level change below, please inform us at the time of your response.*

- **Level 1 (FDA-recognized) annotation of MET exon 14 skipping mutations in non-small cell lung cancer**

- Based on FDA approval of [Capmatinib](#) for adults with metastatic NSCLC with a MET exon 14 skipping mutation
- Based on the nonrandomized, open-label multi-cohort phase II [GEOMETRY mono-1](#) trial study enrolling 97 patients with metastatic NSCLC with MET exon 14 skipping mutations ([AACR 2020 abstract](#))
- *Efficacy Results*

Parameter	Treatment naïve patients N=28	Previously treated patients N=69
ORR (95% CI)	68% (48 - 84)	41% (29 - 53 )
Median DOR (95% CI)	12.6 mos (5.5 - 25.3)	9.7 mos (5.5 - 13.0)
Median PFS (95% CI)	9.7 mos (5.5 - 13.9)	5.4 mos (4.2 - 7.0)

- Therefore, for a patient with non-small cell lung cancer harboring a MET exon 14 skipping mutation, the following summary will be included in OncoKB and subsequently into the enhanced MSK-IMPACT reports. (Note: MET X1010\_splice is used as an example below)
- *MET, a receptor tyrosine kinase, is recurrently altered by mutation, amplification and/or overexpression in various cancer types. The MET X1010\_splice mutation is known to be oncogenic. Capmatinib is FDA-approved for the treatment of patients with metastatic non-small cell lung cancer harboring MET exon 14 skipping mutations such as MET X1010\_splice.*

If you have any comments or suggestions regarding this proposed changes, please respond to this email within **5 business days**, by Friday May, 15th.

Thank you,

Figure 2.2: Sample consensus email for a proposed OncoKB Level 3A association

**[OncoKB Consensus]: Level 3A annotation of BRCA1/2 oncogenic mutations in pancreatic cancer**

Dear Colleagues,

We propose the following OncoKB change:

**Requires review and response by Drs. Eileen O'Reilly, Zsafia Stadler and David Solit. Please respond within 5 business days, by Friday, January 24**

**a. Level 1 (FDA-recognized) annotation of germline BRCA1/2 Oncogenic mutations in pancreatic cancer**

- o Based on [FDA-approval of olaparib](#) for the maintenance treatment of adult patients with gBRCA mt metastatic pancreatic adenocarcinoma whose disease has not progressed on first-line platinum chemotherapy

o N=154

Parameter	Olaparib	Placebo
ORR	23%	12%
Median PFS (95% CI)	7.4 mos (4.1, 11)	3.8 (3.5, 4.9)
Hazard Ratio (95% CI) p-value	0.53 (0.35, 0.81); p=0.0035	
Median OS (95% CI)	18.9 (14.9,26.2)	18.1 (12.6, 26.1)
Hazard Ratio (95% CI) p-value	0.91 (0.56,1.46); p=0.683	

**b. Level 3A (Investigational) annotation of somatic BRCA1/2 Oncogenic mutations in pancreatic cancer**

- o Based on this study in [JCO-PO demonstrating clinical activity of patients with BRCA mt pancreatic cancer treated with PARP inhibitor rucaparib](#) and FDA-approval of PARP inhibitor olaparib in patients with germline BRCA mt pancreatic cancer (see above)
- o N=19 (16 – germline and 3 – somatic)
- o 2/3 patients with somatic BRCA2 mutations had objective responses (1 CR and 1 PR). In the same study 3/16 germline BRCA+ pancreatic cancer patients showed an objective response (all BRCA2+).
- o Therefore for a patient with somatic BRCA mt pancreatic cancer the following summary will be included in OncoKB and subsequently into the enhanced MSK-IMPACT reports:

*BRCA2, a tumor suppressor involved in the DNA damage response, is mutated in various cancer types. The BRCA2 L1564\* mutation is likely oncogenic. The PARP inhibitor olaparib is FDA-approved for BRCA-mutant pancreatic cancer in the germline setting only. There is promising clinical activity of the PARP inhibitor rucaparib in patients with BRCA2-mutant positive pancreatic cancer in the somatic setting.*

If you have any comments or suggestions regarding this proposed changes, please respond to this email within **5 business days**, by Friday, January 24.

Thank you,

# Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence

The OncoKB levels of evidence are defined in [Chapter 2: Introduction](#). The FDA levels of evidence are defined in the FDA fact sheet titled “[CDRH’s Approach to Tumor Profiling Next Generation Sequencing Tests](#)”, a downloadable document from the FDA website. A copy of this document is provided in [Chapter 2: Figure 3.1: The FDA levels of evidence](#).

Mapping between the OncoKB Levels of Evidence and the FDA Level of Evidence is described in [Chapter 2: Table 3.1: Mapping the OncoKB levels of evidence to the FDA levels of evidence](#) and schematically shown in [Chapter 2: Figure 3.2: Mapping between the OncoKB Therapeutic Levels of Evidence V2 and the FDA Levels of Evidence](#) which is also available on the OncoKB website. Note that OncoKB is not associated with a Companion Diagnostic test. Therefore, by definition, no variant in OncoKB can be mapped to FDA Level 1.

**Table 3.1. Mapping the OncoKB levels of evidence to the FDA levels of evidence**

OncoKB Level of Evidence	Corresponding FDA Level of Evidence
1	2
2 AND the VPCS is NOT an Emerging Biomarker <sup>1</sup>	
R1	
2 AND the VPCS is an Emerging Biomarker <sup>1</sup>	3
3A	
3B	
4	
R2	

<sup>1</sup> Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.



**Figure 3.1 The FDA levels of evidence.**

FDA currently has three levels of recognition of the clinical significance of tumor biomarkers for NGS tests for which the agency has approved somatic variant detection in patients diagnosed with solid neoplasms as described in the FDA fact sheet titled “CDRH’s Approach to Tumor Profiling Next Generation Sequencing Tests”. A copy of this FDA fact sheet is shown here.

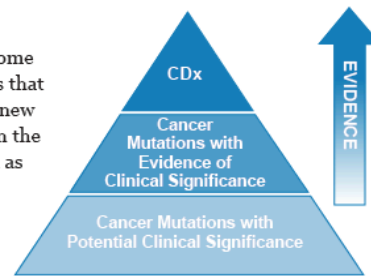
# FDA FACT SHEET

## CDRH’S APPROACH TO TUMOR PROFILING NEXT GENERATION SEQUENCING TESTS

The Food and Drug Administration (FDA) has recently announced the marketing authorization of three tumor profiling next generation sequencing (NGS) tests, Thermo Fisher Scientific’s OncoPrint Dx Target Test,<sup>1</sup> MSK-IMPACT<sup>2</sup> and Foundation Medicine’s FoundationOne CDx<sup>3</sup> which are important advancements in the real-world application of precision oncology. The approach taken to the regulation of these tumor profiling NGS tests includes several key features described below.

### Three-Tiered Approach for Reporting Biomarkers in Tumor Profiling NGS Tests

FDA is committed to and works individually with test developers to use the least burdensome approach for its review of tests. Multiplexed tumor profiling tests assess many biomarkers that may have a range of clinical evidence associated with them that is constantly changing as new science emerges. Below, we discuss the three levels of biomarkers addressed collectively in the OncoPrint Dx Target Test, MSK-IMPACT, and FoundationOne CDx authorizations, as well as the analytical and clinical evidence used to support claims for those biomarkers.



#### Level 1: Companion Diagnostics

Companion diagnostics (CDx) are test that provide information that is essential for the safe and effective use of a corresponding therapeutic product<sup>4</sup>, such as a drug. Tumor profiling NGS tests may include CDx claims that are prescriptive for a specific therapeutic product, such as the Table 1 claims listed in the intended use for the OncoPrint Dx Target Test and FoundationOne CDx. Such claims are supported by analytical validity of the test for each specific biomarker and a clinical study establishing either the link between the result of that test and patient outcomes or clinical concordance to a previously approved CDx.

#### New Level 2: Cancer Mutations with Evidence of Clinical Significance

Tests for biomarkers described as cancer mutations with evidence of clinical significance enable health care professionals to use information about their patients’ tumors in accordance with the clinical evidence, such as clinical evidence presented in professional guidelines, as appropriate. Such claims are supported by a demonstration of analytical validity (either on the mutation itself or via a representative approach, when appropriate) and clinical validity (typically based on publicly available clinical evidence, such as professional guidelines and/or peer-reviewed publications).

#### Level 3: Cancer Mutations with Potential Clinical Significance

Mutations not considered biomarkers in Level 1 or Level 2 can be described as cancer mutations with potential clinical significance. These mutations may be informational or used to direct patients towards clinical trials for which they may be eligible. Such claims are supported by analytical validation, principally through a representative approach, when appropriate, and clinical or mechanistic rationale for inclusion in the panel. Such rationales would include peer-reviewed publications or in vitro pre-clinical models.

#### A Fluid Approach to Reporting within Levels 2 and 3

Following FDA review and authorization of a tumor profiling NGS test, the test developers will be able to report additional variants of the same type post-market within the existing analytically validated genes in the panel, for claims consistent with the clinical criteria established in the original submission, without an additional FDA submission. As evidence of clinical significance becomes recognized by the clinical community, and provided that the analytical validity of the test was reviewed and established in the initial or a subsequent submission, mutations can be moved from Level 3 to Level 2 without an additional FDA submission.

<sup>1</sup> Additional information on the premarket approval for the OncoPrint Dx Target Test is available at [https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma\\_cfm?id=P180045](https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma_cfm?id=P180045)

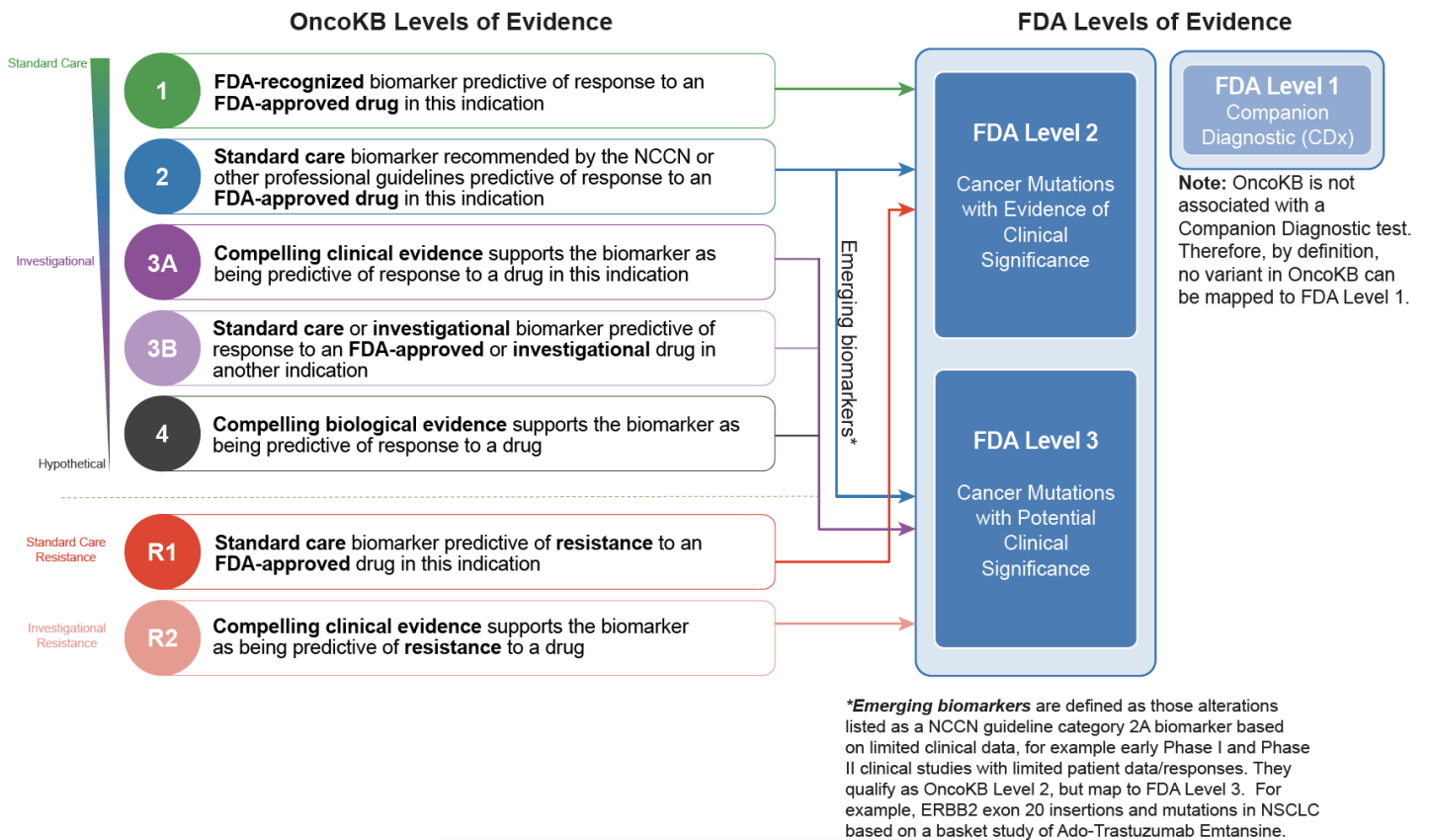
<sup>2</sup> Additional information on the marketing authorization of the MSK-IMPACT is available at <https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm585347.htm>

<sup>3</sup> Additional information on the premarket approval for the FoundationOne CDx is available at <https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm587273.htm>

<sup>4</sup> Additional information regarding companion diagnostics is available in FDA’s guidance entitled “In Vitro Companion Diagnostic Devices,” available at <https://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM262327.pdf>

**Figure 3.2: Mapping between the OncoKB Therapeutic Levels of Evidence V2 and the FDA Levels of Evidence.**

Left panel, OncoKB levels of evidence system (V1) was originally published in JCO-PO in 2017. Since its publication, to be consistent with guidelines published by ASCO/AMP/CAP and ESMO this system was refined to its current version (V2) shown in this figure. Right panel, FDA Levels of Evidence. Since OncoKB is not associated with a companion diagnostic test, by definition no variant in OncoKB can map to FDA Level 1. OncoKB Level 1, R1 and Level 2 (non-Emerging Biomarkers) variants map to FDA Level 2. OncoKB Level 3A, 3B, 4, R2, and Level 2 (Emerging Biomarkers) variants map to FDA Level 3. Emerging biomarkers are defined as those alterations listed as a NCCN guideline category 2A biomarker based on limited clinical data, e.g., early Phase I or Phase II clinical studies with limited patient data or responses.



# Supplemental Material

**Table S1: FDA Level 2 (OncoKB Level 1) Variants of Possible Clinical Significance (VPCS) and the information in FDA drug labels that was utilized to define them**

Specific examples of OncoKB Level 1 (FDA Level 2) associations and the language in the FDA drug label that was used to support each level assignment (per [Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels](#)).

Drug	Tumor type	Gene	Section 1: Indications and Usage	CDx Test	Section 14: Clinical Studies	FDA Level 2 (OncoKB Level 1) VPCS based on the FDA drug label and rules outlined in <a href="#">Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels</a>
			Alteration			
Encorafenib + Binimetinib	Melanoma	BRAF	V600E, V600K	V600E, V600K	NA	V600E, V600K
Erdafitinib	Urothelial Carcinoma	FGFR3	Susceptible FGFR2/3 alterations... as detected by an FDA-approved test	FGFR3: R248C, S249C, G370C, Y373C, FGFR3-TACC3	NA	FGFR3: R248C, S249C, G370C, Y373C, FGFR3-TACC3
Alpelisib + Fulvestrant	Breast Cancer	PIK3CA	PIK3CA-mutated, advanced or metastatic breast cancer as detected by an FDA-approved test	C420R, E542K, E545A/D/G/K, Q546E/R, H1047L/R/Y	NA	C420R, E542K, E545A/D/G/K, Q546E/R, H1047L/R/Y
Olaparib	Prostate Cancer	HRR genes*	...deleterious or suspected deleterious germline or somatic homologous recombination repair (HRR) gene-mutated metastatic castration-resistant prostate cancer (mCRPC). Select	HRR gene alterations <sup>1</sup>	Germline or somatic HRR gene-mutated <sup>2</sup> : BRCA1, BRCA2, ATM, BARD1, BRIP1, CDK12, CHEK1, CHEK2, FANCL, PALB2,	Deleterious mutations <sup>2</sup> in all HRR genes listed in the CDx test

			patients for therapy based on an FDA-approved companion diagnostic.		RAD51B, RAD51C, RAD51D, RAD54L	
Vemurafenib	Erdheim Chester Disease	BRAF	V600	NA	NA	V600
Lorlatinib	NSCLC	ALK	ALK-positive	NA	ALK-rearrangement determined by FISH or IHC	(ALK) Fusions
Tazemetostat	ES	SMARCB1	NA	NA	Patients were required to have INI1 (SMARCB1) loss, detected using local tests	(SMARCB1) Deletion
Selumetinib	NF1	NF1	NA	NA	Pts...with neurofibromatosis type 1 (NF1) <sup>3</sup> who have symptomatic, inoperable plexiform neurofibromas (PN)	Deleterious mts in NF1 <sup>2</sup>

<sup>1</sup> Based on the most recent FDA drug label for Olaparib (12/07/2020), olaparib is indicated for the treatment of adult patients with deleterious or suspected deleterious germline or somatic homologous recombination repair (HRR) gene-mutated metastatic castration-resistant prostate cancer (mCRPC) who have progressed following prior treatment with enzalutamide or abiraterone based on an FDA-approved companion diagnostic for Lynparza. FoundationOne CDx is an FDA-approved test for the detection of Homologous Recombination Repair (HRR) gene (BRCA1, BRCA2, ATM, BARD1, BRIP1, CDK12, CHEK1, CHEK2, FANCL, PALB2, RAD51B, RAD51C, RAD51D and RAD54L) alterations in prostate cancer ([https://www.accessdata.fda.gov/cdrh\\_docs/pdf17/P170019S015C.pdf](https://www.accessdata.fda.gov/cdrh_docs/pdf17/P170019S015C.pdf)).

<sup>2</sup> Deleterious or suspected deleterious mutations in a tumor suppressor gene include OncoKB annotated oncogenic and likely oncogenic variants as defined in **Rule B.4** of [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#) and [Chapter 1: Table 2.5.1: Types of VPS that upon curation are considered VPCS based on the gene classification](#)

<sup>3</sup> NF1 alterations are pathognomonic to neurofibromatosis type 1 (NF1).

**Table S2: Examples of using existing FDA drug labels and NCCN Guidelines to assign somatic variants an FDA and OncoKB Level of Evidence when the defined biomarker is in the germline setting**

Specific examples of FDA and OncoKB leveled associations that are recommended in FDA drug labels (and/or NCCN Guidelines) for germline mutations only.

Level of Evidence		FDA and OncoKB Leveled Association				FDA-approved in the germline or somatic setting?	Are somatic mts recommended at NCCN Cat. 2A or higher for the gene-variant-tumor type of interest?	Is there peer-reviewed data demonstrating pt response in the somatic setting? N#	Reference
FDA	OncoKB	Gene	Alteration	Tumor Type	Drug(s)				
2	3A	BRCA1/2	Deleterious mutations	Breast Cancer	Olaparib Talazoparib	Germline	No	Yes N >8 pts	<a href="#">Tung (and Robson) et al. Abstract# TBCRC048, ASCO 2020</a>
3	3A	BRCA1/2	Deleterious mutations	Pancreatic Cancer	Olaparib	Germline	No	Yes N = 2 pts	<a href="#">PMID: 30051098</a>

**Table S3: Examples of FDA Level 2 or 3<sup>1</sup> (OncoKB Level 2) associations**

Examples of current FDA Level 2 or 3<sup>1</sup> (OncoKB Level 2) associations.

FDA LofE	OncoKB LofE	Gene	Alteration	Tumor Type /NCCN Guideline and version	Drug(s) <sup>3</sup>	NCCN Disease Specific Protocol pg # and section	Emerging Biomarker?	Reference and Notes
2	2	BRAF	V600E	CRC V 2.2021  Jan. 21, 2021	Panitumumab (P) + Encorafenib (E)  Cat. 2A	COL-11  Primary Treatment  COL-D 2 of 13  Systemic Therapy for Advanced or Metastatic Disease	No	<a href="#">PMID: 25673558</a>  NCCN: P + E recommended for BRAF V600E positive tumors
2	2	MET	Exon 14 skipping mutations	NSCLC V 2.2021  Dec. 15, 2020	Crizotinib	NSCLC-J 1 of 2  Targeted Therapy or Immunotherapy for Advanced or Metastatic Disease	No	<a href="#">PMID: 31932802</a>  NCCN: First-line therapy/subsequent therapy for NSCLC with MET exon 14 skipping mts
3 <sup>1</sup>	2	ERBB2	Oncogenic Mutations <sup>2</sup>	NSCLC V 2.2021  Dec. 15, 2020	Ado-Trastuzumab Emtansine	NSCLC-H 5 of 5  Emerging biomarkers to identify novel therapies for pts with metastatic NSCLC	Yes	<a href="#">PMID: 29989854</a>  Phase II Basket Study  8/18 pts with ERBB2 mt NSCLC had a PR  Exon 20 insertions, Exon 17 V659E Exon 8 S310F
3 <sup>1</sup>	2	EGFR	A763_Y764insFQEA	NSCLC V 2.2021  Dec. 15, 2020	Erlotinib (E)	NSCLC-H 2 of 5  Principles of Molecular and Biomarker Analysis	Yes	NCCN: A763_Y764insFQEA is associated with sensitivity to EGFR TKI.  <a href="#">PMID: 28089594</a>  8/11 NSCLC pts with this alteration had a PR to E

<sup>1</sup> Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3. For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

<sup>2</sup> Oncogenic mutations include all OncoKB defined oncogenic and likely oncogenic variants (excluding “Amplification”) per [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)

<sup>3</sup> Drugs are FDA-approved (in any indication) and recommended at NCCN Category 2A or higher

**Table S4: Examples of trial-defined clinical benefit or pathological response that may be used to assess clinical benefit in a defined patient population**

Examples of trial-defined clinical benefit or pathological response that may be used to assess clinical benefit in a defined patient population

Reference	Study Type	Trial Phase	Drug	Patient population			Trial-defined clinical benefit
				Gene	Alteration	Tumor Type	
Hyman, D. et al., Nature, 2018  <a href="#">PMID: 29420467</a>	Basket Study (SUMMIT)	II	Neratinib	ERBB2	Oncogenic Mutations	NSCLC	SD or PR > 24 weeks
Jordan, E. et al., Cancer Discovery 2017  <a href="#">PMID: 28336552</a>	Prospective molecular characterization of lung adenocarcinomas for efficient patient matching	NA	EGFR TKIs	EGFR	Various EGFR alterations	NSCLC	Reduction in tumor size on imaging and documented symptom improvement or stable disease on two consecutive imaging scans $\geq 30$ days apart with symptom improvement
Mateo, J, et al., Lancet Oncology, 2019  <a href="#">PMID: 31806540</a>	Randomized (TOPARP-B)	II	Olaparib	Included pts with mts in BRCA2, ATM, CDK12	Deleterious Mutations	Prostate Cancer	A decrease in PSA of 50% or more

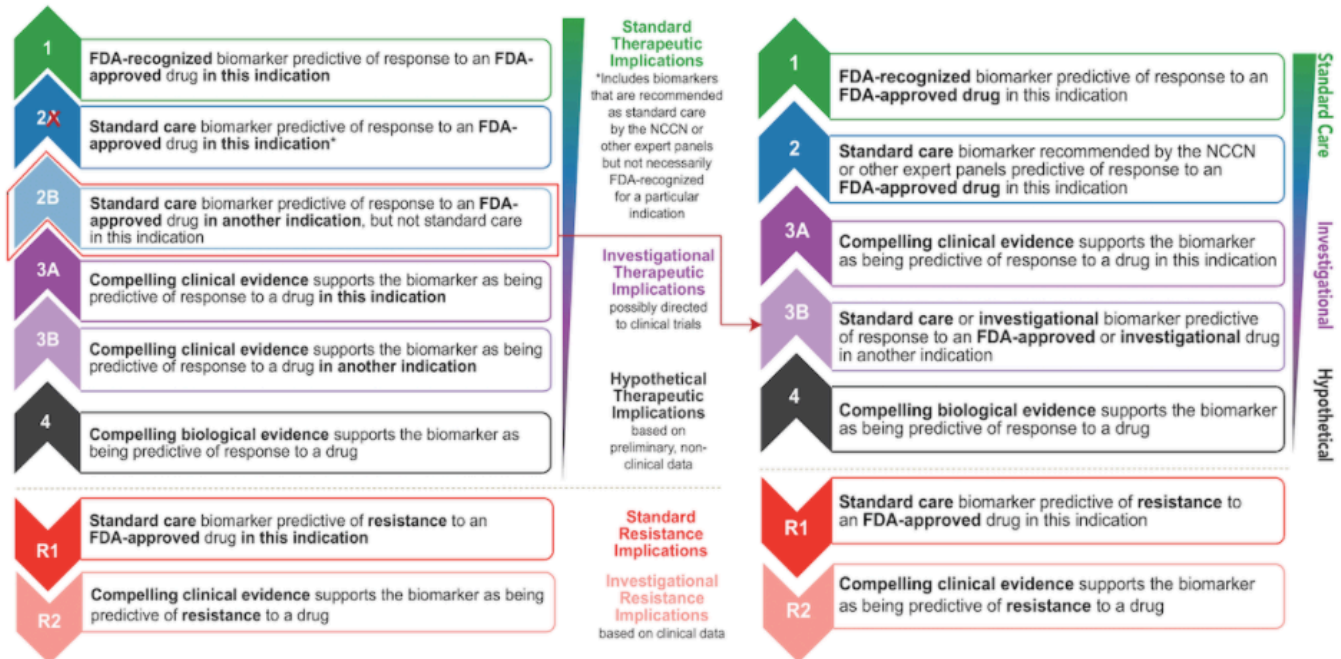


# Figure S1: Mapping between OncoKB Levels of Evidence V1 and OncoKB Levels of Evidence V2

December 20, 2019 Data version: v2.0

Introducing Simplified OncoKB Levels of Evidence:

- 🔗 **New Level 2**, defined as “Standard care biomarker recommended by the NCCN or other expert panels predictive of response to an FDA-approved drug in this indication” (formerly Level 2A).
- 🔗 **Unified Level 3B**, defined as “Standard care or investigational biomarker predictive of response to an FDA-approved or investigational drug in another indication” (combination of previous Levels 2B and 3B).

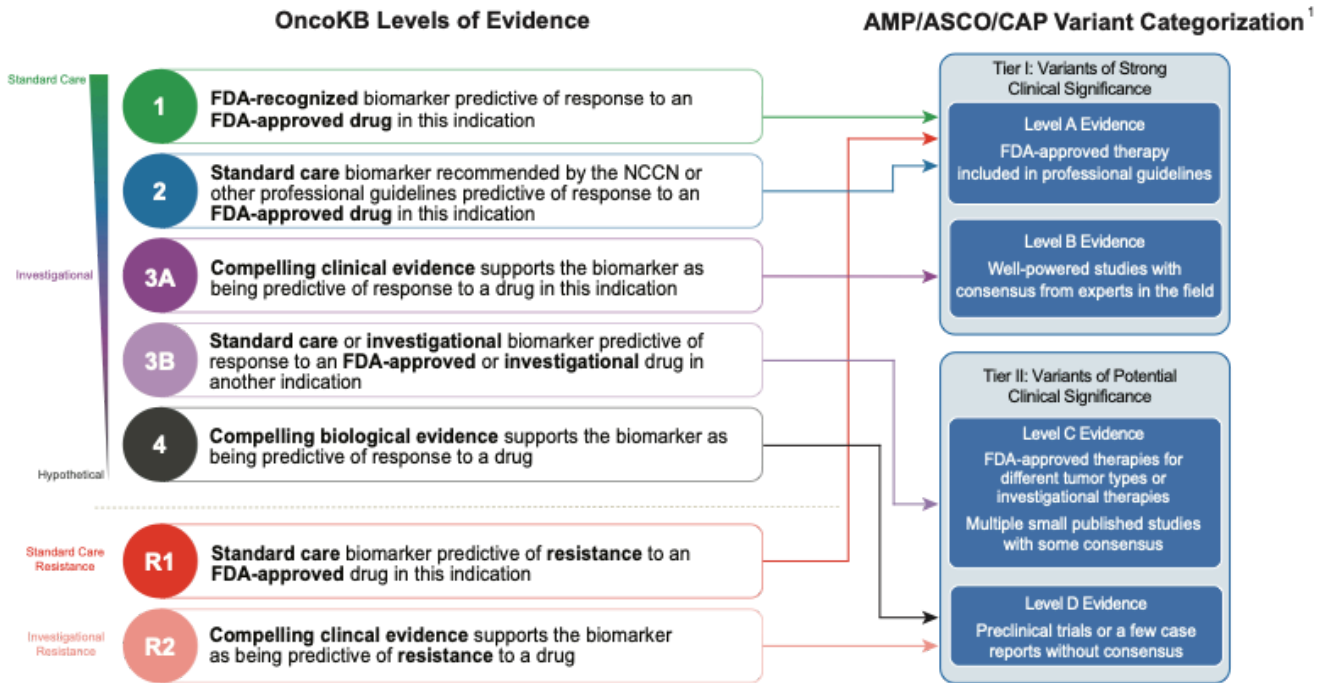


We have implemented these changes for 2 reasons:

- 1) To be consistent with the [Joint Consensus Recommendation by AMP, ASCO and CAP](#) and the [ESMO Scale for Clinical Actionability of molecular Targets \(ESCAT\)](#)
- 2) To reflect the clinical data that demonstrates patients with investigational predictive biomarkers for a specific tumor type based on compelling clinical evidence (currently Level 3A) are more likely to experience clinical benefit compared to patients with predictive biomarkers that are considered standard care in a different cancer type (previously Level 2B, now combined into Level 3B).

**Figure S2: Mapping between the OncoKB Levels of Evidence V2 and the AMP-ASCO-CAP Consensus Recommendation Variant Categorizations**

Mapping between the OncoKB Levels of Evidence and the AMP/ASCO/CAP Consensus Recommendation



<sup>1</sup> Li, MM et al., J Mol Diagn 2017

# Chapter 3: Data review and release

## Introduction

Data curated in the OncoKB curation platform is not publicly available [on cBioPortal for Cancer Genomics ([www.cbioportal.org](http://www.cbioportal.org)) or the OncoKB public website ([www.OncoKB.org](http://www.OncoKB.org))] until it is internally reviewed by a member of the OncoKB staff. Internal, independent review of curated data is performed in the OncoKB curation platform *Review Mode* following [Chapter 3: Protocol 1: Data review](#). All curated data *MUST* be internally reviewed by an OncoKB staff member who did not themselves curate the data. Note that prior to internal review, all proposed OncoKB/FDA leveled associations must be reviewed and approved by CGAC following the process outlined in [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#).

OncoKB curated data reviewed and accepted in *Review Mode* will automatically be released internally at MSK (for utilization in MSK IMPACT reports) and to the cBioPortal for Cancer Genomics ([www.cbioportal.org](http://www.cbioportal.org)). However, the data validation and release process outlined in [Chapter 3: Protocol 2: Data release](#) is required to release OncoKB data to the OncoKB public website ([www.oncokb.org](http://www.oncokb.org)).

Refer to [Chapter 3: Figure 1: Overview of the OncoKB curation and review process](#) for a summary of the OncoKB data curation and review process, including review of proposed OncoKB/FDA leveled associations by CGAC and internal, independent review of all curated data by OncoKB staff members (both which occur prior to releasing data internally at MSK and publicly to the cBioportal for Cancer Genomics). A final review and validation of data is performed prior to releasing data to the OncoKB public website ([www.oncokb.org](http://www.oncokb.org)).

# Protocol 1: Data review

This protocol describes the process for internal, independent review of data additions/deletions/edits in the OncoKB curation platform by a member of the OncoKB staff using the *Review Mode* feature (Step 6 in [Chapter 3: Figure 1: Overview of OncoKB curation and review process](#)). Note that prior to internal review, all proposed OncoKB/FDA leveled associations must be reviewed and approved by CGAC following the process outlined in [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#) (Step 4 in [Chapter 3: Figure 1: Overview of OncoKB curation and review process](#)).

- Refer to [Chapter 3: Figure 1: Overview of the OncoKB curation and review process](#) for a summary of the OncoKB data curation and review process

1. **Is there data that needs to be reviewed** in the OncoKB curation platform? A visualization of how the OncoKB curation platform Homepage informs users that information needs to be reviewed in specified Gene Pages is detailed in [Chapter 6: Protocol: 1: OncoKB curation platform Homepage](#).

--[Chapter 3: Table 1.1: OncoKB staff member curation and review responsibilities](#) details the OncoKB staff members who are responsible for the curation and review of the various OncoKB database elements

a. **YES:** *Proceed to Step 2*

b. **NO:** *Exit protocol*

2. Enter the Gene Page in which there is data that requires review. Once in the Gene Page, **enter Review Mode**. A visualization of how to enter *Review Mode* is detailed in [Chapter 6: Sub-protocol: 6.2: Review Mode](#).

a. *Proceed to Step 3*

3. **Review all changes** highlighted in *Review Mode*, and **Accept, Reject or Edit each proposed change**. A reviewer may not accept his/her own changes in *Review Mode* and must ask another member of the SCMT or the Lead Scientist to review this data (per [Chapter 3: Table 1.1: OncoKB staff member curation and review responsibilities](#)).

--[Chapter 3: Table 1.2: OncoKB curation platform Review Mode](#) highlights: 1) the different curated database elements that require internal review, 2) the protocols that must be referenced when reviewing specific database elements that have been added/deleted/edited in the OncoKB curation platform, and 3) the possible actions that the reviewer may take upon review in *Review Mode*.

--[Chapter 3: Table 1.3: Data additions, deletions and edits highlighted in Review Mode in the OncoKB curation platform](#) details the specific data points (text) that are highlighted in *Review Mode* to alert the reviewer to additions, deletions and/or edits made in the curation platform that require active review

--A visualization of data highlighted in *Review Mode* and the buttons to Accept or Reject data changes are detailed in [Chapter 6: Sub-protocol: 6.2: Review Mode](#)

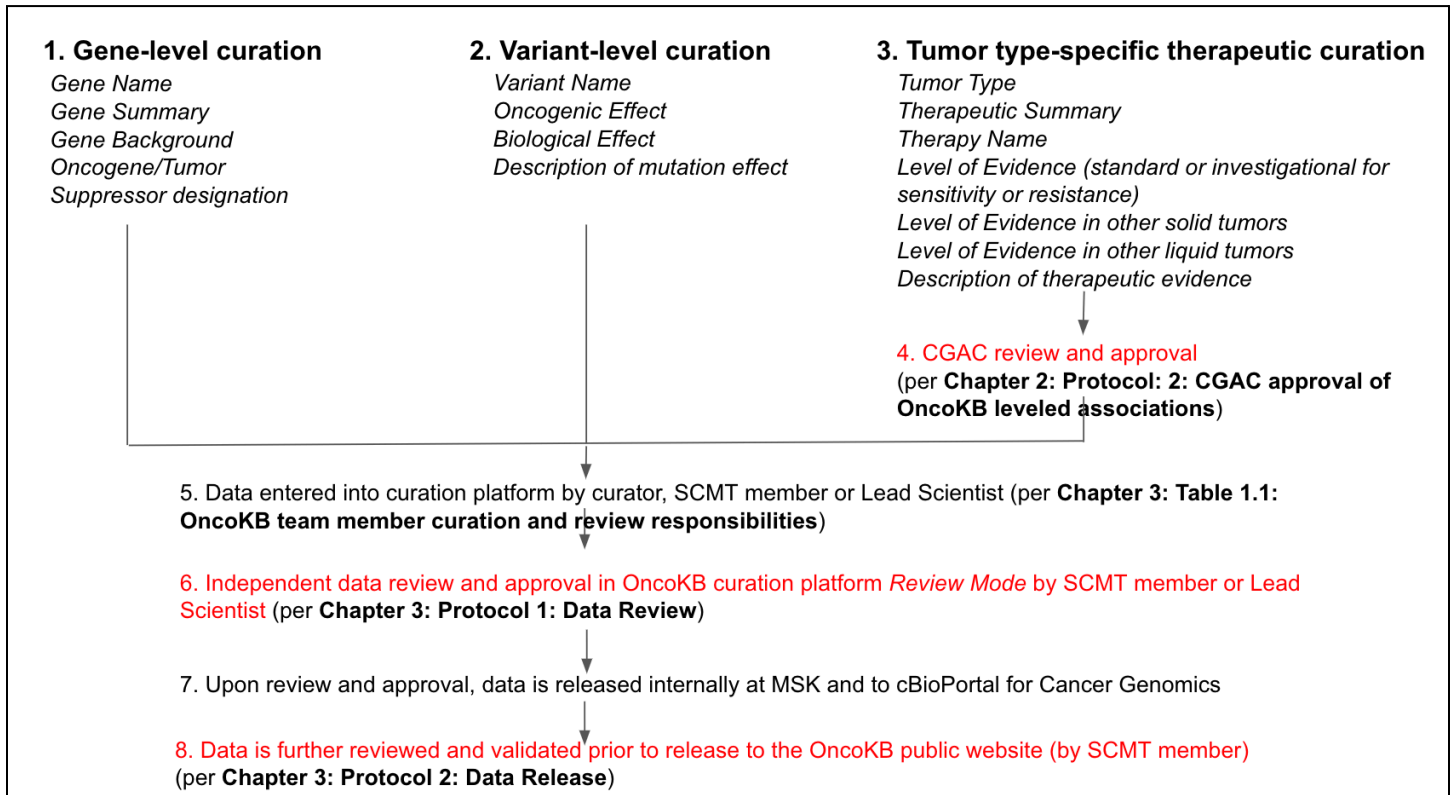
a. Proceed to Step 4

- Exit *Review Mode*. If data was edited during the course of the review process in *Review Mode*, alert another member of the SCMT or the Lead Scientist that there is additional data that requires review.

--A visualization of how to exit *Review Mode* is detailed in [Chapter 6: Sub-protocol: 6.2: Review Mode](#)

### Figure 1: Overview of OncoKB curation and review process

Overview of the OncoKB curation and review process. OncoKB data can be curated on the 1) gene-level, 2) variant-level, or 3) tumor-type level. Tumor-type specific therapeutic curation requires review and approval by CGAC (Step 4). All curated data requires internal review and approval in the OncoKB curation platform *Review Mode* (Step 6) (per [Chapter 3: Protocol 1: Data Review](#)). Following internal review, data is released internally at MSK and to cBioPortal for Cancer Genomics. Data is reviewed and validated following [Chapter 3: Protocol 2: Data release](#) before it is released to the OncoKB public website (Step 8).



**Table 1.1: OncoKB staff member curation and review responsibilities**

Description of the OncoKB staff members who are responsible for the data assessment and curation (STEP 1) and independent internal review (STEP 2) of the various OncoKB database elements.

OncoKB database elements <sup>1</sup>	STEP 1: Data assessment and curation <i>Performed by</i>	STEP 2: Independent internal review <i>Performed by</i>
<ul style="list-style-type: none"> <li>● Designation of gene as Oncogene/Tumor Suppressor</li> <li>● Gene Summary</li> <li>● Gene Background</li> <li>● Mutation Name</li> <li>● Biological Effect</li> <li>● Oncogenic Effect</li> <li>● Mutation Effect Description</li> <li>● Tumor Type</li> <li>● Therapy Name<sup>2</sup></li> <li>● Description of Evidence (therapeutic)<sup>2</sup></li> </ul>	Curator	SCMT member
	SCMT member	SCMT member (who did not perform the data curation) or Lead Scientist
	Lead Scientist	SCMT member
<ul style="list-style-type: none"> <li>● Highest OncoKB Level of Evidence</li> <li>● (Standard or investigational implications for sensitivity or resistance)</li> <li>● Therapeutic Summary<sup>2</sup></li> <li>● Level of Evidence in other Solid Tumors<sup>2</sup></li> <li>● Level of Evidence in other Liquid Tumors<sup>2</sup></li> </ul>	SCMT member	SCMT member (who did not perform the data) curation or Lead Scientist
	Lead Scientist	SCMT member

<sup>1</sup> A description of the curation process (including formatting and nomenclature) for each database element is described in detail in [Chapter 6: OncoKB curation, formatting and nomenclature in the curation platform](#)

<sup>2</sup> Therapies, their associated levels of evidence, and the therapeutic summaries are sent for review to all members of CGAC and must receive positive affirmation from 3 pre-specified CGAC members (per [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#)) prior to independent review by an OncoKB team member in *Review Mode*.

**Table 1.2: OncoKB curation platform *Review Mode***

All data entered into the OncoKB curation platform requires review via *Review Mode* in the OncoKB curation platform prior to its public release [on cBioPortal for Cancer Genomics ([www.cbioportal.org](http://www.cbioportal.org)) or the OncoKB public website ([www.OncoKB.org](http://www.OncoKB.org))] and internal release within MSK (MSK-IMPACT sequencing reports). The following are details on how to review data additions, deletions or edits in OncoKB curation platform *Review Mode*, including: 1) the different curated database elements that require internal review, 2) the protocols that must be referenced when reviewing specific database elements that have been added/deleted/edited in the OncoKB curation platform, and 3) the possible actions that the reviewer may take upon review.

Database elements	Specific data points to review	Protocol to reference when reviewing the data	Possible actions to be taken by reviewer <i>(in addition to either accepting or rejecting the change)</i>
<b>Oncogene/Tumor Suppressor Designation</b>	Oncogene/Tumor Suppressor Designation	<a href="#">Chapter 1: Table 1.3: Assertion of the function of a cancer gene</a>	Reject and suggest the other option
<b>Gene Summary</b>	Review accuracy of statement  Check grammar	<a href="#">Chapter 6: Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform</a>	Edit the text for content and/or grammar and alert a SCMT member to review
<b>Gene Background</b>	Review accuracy of summary  Check references are appropriate  Check grammar	<a href="#">Chapter 6: Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform</a>	Edit the text for content and/or grammar and alert a SCMT member to review
<b>Mutation Name</b>	Confirm the mutation is of the proper isoform and is consistent with the mutation detailed in the description of mutation effect	<a href="#">Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting</a>	Edit the mutation nomenclature before accepting
<b>Biological Effect</b>	Confirm the chosen biological effect is consistent with the criteria outlined in <a href="#">Chapter 1: Protocol 2: Variant curation</a> .  Ensure the correct boxes are checked	<a href="#">Chapter 1: Protocol 2: Variant curation</a>  And <a href="#">Chapter 6: Protocol 3: Variant curation</a>	Suggest a new biological effect and alert a SCMT member to review
<b>Oncogenic Effect</b>	Confirm the chosen oncogenic effect is consistent with the criteria outlined in <a href="#">Chapter 1:</a>	<a href="#">Chapter 1: Protocol 2: Variant curation</a>  And	Suggest a new oncogenic effect and alert a SCMT member to review

	<p><a href="#">Protocol 2: Variant curation</a></p> <p>Ensure the correct boxes are checked</p>	<p><a href="#">Chapter 6: Protocol 3: Variant curation</a></p>	
<b>Mutation Effect Description</b>	<p>Review accuracy of summary</p> <p>Check references are appropriate</p> <p>Check grammar</p>	<p><a href="#">Chapter 6: Table 3.2: Generation and formatting of mutation effect description</a></p>	<p>Edit the text for content and/or grammar and alert a SCMT member to review</p>
<b>Tumor Type</b>	<p>Review accuracy of tumor type</p> <p>Confirm that no other tumor types are relevant to the clinical data nested below</p>	<p><a href="#">Chapter 1: Protocol 3: Tumor type assignment</a></p> <p><b>And</b></p> <p><a href="#">Chapter 6: Protocol 4: Tumor type curation</a></p>	<p>Edit or add an additional tumor type and alert a SCMT member to review</p>
<b>Therapeutic Summary</b>	<p>Review accuracy of summary</p> <p>Check grammar</p>	<p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></p>	<p>Edit therapeutic summary and alert a SCMT member to review</p>
<b>Therapy Name</b>	<p>Confirm accuracy of therapy name and that data has appropriate approval by CGAC to be leveled in OncoKB</p>	<p><a href="#">Chapter 6: Sub-Protocol 5.1: Therapy Selection</a></p> <p><b>AND</b></p> <p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></p> <p><b>AND</b></p> <p><a href="#">Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment</a></p>	<p>Edit the therapy name and alert a SCMT member to review</p>
<b>Highest Level of Evidence (Standard or investigational)</b>	<p>Confirm that the corresponding therapy and level have been approved</p>	<p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of</a></p>	<p>Edit the level and alert a SCMT member to review</p>



<p><b>implications for sensitivity or resistance)</b></p>	<p>by CGAC for inclusion in OncoKB</p>	<p><a href="#">therapy-level data inputs in the OncoKB curation platform</a></p> <p>AND</p> <p><a href="#">Chapter 6: Figure 5.1.3: Selection of a level of evidence.</a></p> <p>AND</p> <p><a href="#">Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment</a></p>	
<p><b>Level of Evidence in other Solid Tumors</b></p>	<p>Confirm that the chosen propagation for the Leveled association follows the rules outlined in <a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a> and has been approved by the Lead Scientist</p>	<p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></p>	<p>Edit the level propagation by choosing a new entry from the drop-down list and alert a SCMT member to review</p>
<p><b>Level of Evidence in other Liquid Tumors</b></p>	<p>Confirm that the chosen propagation for the Leveled association follows the rules outlined in <a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a> and has been approved by the Lead Scientist</p>	<p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></p>	
<p><b>Description of Evidence (therapeutic)</b></p>	<p>Review accuracy of summary</p> <p>Check references are appropriate</p> <p>Check grammar</p>	<p><a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></p> <p>AND</p> <p><a href="#">Chapter 6: Figure 5.1.4: Therapeutic curation</a></p>	<p>Edit the text for content and/or grammar and alert a SCMT member to review</p>



**Table 1.3: Data additions, deletions and edits highlighted in *Review Mode* in the OncoKB curation platform**

*Review Mode* details all changes made in a specified Gene Page since the time of the last review. Specific additions/deletions/edits are highlighted to designate the specific text or entries that have been added, deleted or removed since the time of the last review. *Review Mode* also notes the name of the user who made the data changes and the date/time of the data entry/removal.

Database elements	Additions/deletions/edits that are highlighted in <i>Review Mode</i>
<b>Oncogene/Tumor Suppressor Designation</b>	The user may check a box for 1. Oncogene and/or 2. Tumor Suppressor (or leave both boxes unchecked) Any change in checkbox demarcation (addition or removal of a check) will be compared to previous version to accept/reject
<b>Gene Summary</b>	<ol style="list-style-type: none"> <li>1. Addition of free text: Will be highlighted as-is to accept/reject</li> <li>2. Deletion or change to free text: Will be compared to previous version to accept/reject</li> </ol>
<b>Gene Background</b>	<ol style="list-style-type: none"> <li>1. Addition of free text: Will be highlighted as-is to accept/reject</li> <li>2. Deletion or change to free text: Will be compared to previous version to accept/reject</li> </ol>
<b>Mutation Name</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of mutation: Will be highlighted as-is to accept/reject</li> <li>2. Change to mutation name: Will be compared to previous version to accept/reject</li> </ol>
<b>Biological Effect</b>	Any change in checkbox demarcation (addition or removal of a check) will be compared to previous version to accept/reject
<b>Oncogenic Effect</b>	Any change in checkbox demarcation (addition or removal of a check) will be compared to previous version to accept/reject
<b>Mutation Effect Description</b>	<ol style="list-style-type: none"> <li>1. Addition of free text: Will be highlighted as-is to accept/reject</li> <li>2. Deletion or change to free text: Will be compared to previous version to accept/reject</li> </ol>
<b>Tumor Type</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of tumor type: Will be highlighted as-is to accept/reject</li> <li>2. Change to tumor type: Will be compared to previous version to accept/reject</li> </ol>
<b>Therapeutic Summary</b>	<ol style="list-style-type: none"> <li>1. Addition of free text: Will be highlighted as-is to accept/reject</li> <li>2. Deletion or change to free text: Will be compared to previous version to accept/reject</li> </ol>
<b>Therapy Name</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of therapy: Will be highlighted as-is to accept/reject</li> <li>2. Change to therapy: Will be compared to previous version to accept/reject</li> </ol>
<b>Highest Level of Evidence (Standard or investigational implications for sensitivity or resistance)</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of level: Will be highlighted as-is to accept/reject</li> <li>2. Change to level: Will be compared to previous version to accept/reject</li> </ol>

<b>Level of Evidence in other solid tumors</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of level: Will be highlighted as-is to accept/reject</li> <li>2. Change to level: Will be compared to previous version to accept/reject</li> </ol>
<b>Level of Evidence in other liquid tumors</b>	<ol style="list-style-type: none"> <li>1. Addition/Deletion of level: Will be highlighted as-is to accept/reject</li> <li>2. Change to level: Will be compared to previous version to accept/reject</li> </ol>
<b>Description of Evidence</b>	<ol style="list-style-type: none"> <li>1. Addition of free text: Will be highlighted as-is to accept/reject</li> <li>2. Deletion or change to free text: Will be compared to previous version to accept/reject</li> </ol>

**Note:** The history of reviewed data changes is logged in the Review History tool in the OncoKB curation platform (refer to [Chapter 6: Protocol 6: Review history](#)). This tool tracks all reviewed and accepted changes to data in OncoKB after 07/2017 (with exception of changes to VUS, which are not tracked).

## Protocol 2: Data release

This protocol describes the process for releasing data from the OncoKB curation platform to the public website ([www.oncoKB.org](http://www.oncoKB.org)). Data reviewed and accepted in *Review Mode* in the OncoKB curation platform will automatically be released internally at MSK (for utilization in MSK IMPACT reports) and to the cBioPortal for Cancer Genomics ([www.cbioportal.org](http://www.cbioportal.org)). However, the data validation and release process outlined below is required to release OncoKB data to the OncoKB public website.

Note that following an FDA approval announcement in which the OncoKB staff identifies a new Level 1 and/or Level R1 biomarker(s) requiring CGAC approval, the data will be publicly released within 10 business days following CGAC approval.

1. Is there **curated data that requires internal, independent review** in the OncoKB curation platform (via *Review Mode*)?

-- A visualization of how the OncoKB curation platform Homepage informs users that information needs to be reviewed in specified Gene Pages is detailed in [Chapter 6: Protocol: 1: OncoKB curation platform Homepage](#)

- a. **YES:** Proceed to [Chapter 3: Protocol 1: Data review](#)
- b. **NO:** Proceed to Step 2

2. In the *Tools Page* on the OncoKB curation platform, click the '**Data Validation**' button to run the software that will validate and/or check for errors in the curated OncoKB data. Did the data validation tool return any errors (ie. Is there any data that requires editing)?

--An visualization of the Data Validation feature in the OncoKB curation platform is detailed in [Chapter 6: Figure 6.1.2: Data Validation- Test](#) and [Chapter 6: Figure 6.1.3: Data Validation- Info](#).

--An overview of the data validation process performed by the Data Validation tool on the OncoKB curation website and reviewed by a member of the OncoKB staff is detailed in [Chapter 3: Table 2.1: Data validation procedure](#)

- a. **YES:** Address the error and proceed to [Chapter 3: Protocol 1: Data review](#)
- b. **NO:** Proceed to Step 3

3. Generate an **OncoKB News candidate/draft** and send it to the Lead scientist for review. Does the Lead Scientist approve the News candidate?

--An overview of how to generate the OncoKB News candidate is detailed in [Chapter 3: Table 2.2: OncoKB news release candidate](#)

--An overview of how to generate the therapeutic implication tables which are displayed on the [OncoKB News page](#) following a data release is detailed in [Chapter 3: Subprotocol 2.1: Therapeutic Implication Tables for an OncoKB data release](#)

--An overview of how to generate the the OncoKB email news release candidate that is sent to registered members of the OncoKB Google Group following a data release is detailed in [Chapter 3: Subprotocol 2.2: Email News Release Candidate](#)

- a. **YES:** *Proceed* to Step 4
  - b. **NO:** Address feedback from Lead Scientist until News is accepted/finalized
4. Coordinate with the OncoKB Lead Software Engineer for a **data freeze** and creation of a [www.onckb.org](http://www.onckb.org) beta release candidate. *Proceed to Step 5.*
  5. **Critically review the OncoKB beta release candidate** generated by the Lead Software Engineer. Does any data require editing in the Onckb curation platform?

--An overview of critical checks to perform when evaluating the OncoKB beta release candidate are outlined in [Chapter 3: Table 2.3: Review of the OncoKB beta release candidate](#)

- a. **YES:** Edit the data in the curation platform and *Proceed to* [Chapter 3: Protocol 1: Data review](#)
  - b. **NO:** *Proceed* to Step 6
6. Coordinate with the OncoKB Lead Software Engineer to **update the OncoKB website with the latest data.**
  7. **Generate an email update** from the "[contact@oncokb.org](mailto:contact@oncokb.org)" gmail address detailing the highlights of the OncoKB website release and send to users on the OncoKB low-volume email list (using the google group: [oncokb-news@googlegroups.com](mailto:oncokb-news@googlegroups.com))

## Table 2.1: Data validation procedures

Data validation is required to check all internally, independently reviewed OncoKB curated data for errors before release to the OncoKB public website ([www.oncoKB.org](http://www.oncoKB.org)). An automated data validation tool is built into the *Tools Page* on the OncoKB curation platform. By clicking the ‘Data Validation’ button, the tool queries all curated data (that has been reviewed per [Chapter 3: Protocol 1: Data review](#)) and returns database elements that do not pass the data validation test questions outlined in Column I below. These elements are separated into two sections, or “tabs”, in the data validation tool. An overview of the Data Validation feature in the OncoKB curation platform is detailed in [Chapter 6 \(Figure 6.1.2: Data validation - Test and Figure 6.1.3: Data validation - Info\)](#):

	<b>I. Data<sup>1</sup> validation test question</b> <i>Performed by automated software on the OncoKB curation platform</i>	<b>II. Information reviewed to answer validation test question</b>	<b>III. How to resolve data that is not valid<sup>3</sup></b>
<b>“Test” Tab</b>	For each OncoKB gene, is the Gene Summary or Gene Background empty or include no or unidentifiable references?	<ul style="list-style-type: none"> <li>• Data in Gene Summary</li> <li>• Data in Gene Background</li> <li>• References in Gene Background</li> </ul>	Enter missing data into the OncoKB curation platform, and proceed to <a href="#">Chapter 3: Protocol 1: Data review</a> to have the newly curated data independently reviewed
	For each OncoKB therapeutic association, is required data missing (e.g. therapy name, OncoKB Level of Evidence, references)?	<ul style="list-style-type: none"> <li>• Therapy name</li> <li>• Level of evidence</li> <li>• References in therapy description</li> </ul>	
	For each OncoKB variant, is data missing from the <i>Mutation Effect</i> field (biological effect, oncogenic effect, references) <sup>2</sup>	<ul style="list-style-type: none"> <li>• Specified mutation effect</li> <li>• Specified oncogenic effect</li> <li>• References in alteration description</li> </ul>	
	Are all references properly formatted per <a href="#">Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting</a> ?	PMIDs or Abstracts across all fields	Correct format to align with <a href="#">Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting</a> in curation platform and proceed to <a href="#">Chapter 3: Protocol 1: Data review</a> to have the newly curated data independently reviewed
	Do all alterations adhere to nomenclature rules per <a href="#">Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting</a> ?	Alteration names	
<b>“Info” Tab</b>	Shows a comparison of actionable genes (those associated with an OncoKB Level of Evidence) between the current published version of the OncoKB website and latest reviewed, curated data in the OncoKB curation platform	Confirm all changes are correct according to the OncoKB SOP v2 and CGAC approvals	Follow <a href="#">Chapter 6: Protocol 5: Therapy curation</a> to properly input the therapeutics and proceed to <a href="#">Chapter 3: Protocol 1: Data review</a> to have the newly curated data independently reviewed

<sup>1</sup> Data validation is required to check all internally, independently reviewed OncoKB curated data (refer to [Chapter 3: Protocol 1: Data review](#))

<sup>2</sup> Alterations in “Other Biomarkers” are exempt from the requirement for mutation effect, oncogenic effect and references

<sup>3</sup> Data validation is performed by an SCMT member or the Lead Scientist

## Table 2.2: OncoKB release news candidate

To maintain OncoKB content transparency for end-users, any changes to OncoKB in a given data release are specifically documented on the OncoKB News page ([oncokb.org/news](http://oncokb.org/news)). Each News item and the corresponding data release is dated and version controlled. Access to previous versions of OncoKB are provided via github.

Items to highlight in News	Data to include for each item	Example
<b>General OncoKB news or milestones</b>	<ul style="list-style-type: none"> <li>Free text summary of news item</li> <li>1-2 sentences</li> <li>Links to webpages or media supporting the news item (if applicable)</li> </ul>	<i>"We are excited to announce that our first OncoKB webinar was a success! You can find a video recording here."</i>
<b>Change in website features</b>	<ul style="list-style-type: none"> <li>Free text summary of news item</li> <li>1-2 sentences</li> <li>Media (e.g. JPEG, GIF) supporting item (if applicable)</li> </ul>	<i>"We have introduced an FAQ page where you can find answers to several frequently asked questions."</i>
<b>Addition of therapeutic implications</b>	<p>Level of evidence, gene, mutation, tumor type, drug, and evidence to support the addition (PMID, Abstract)</p> <p>*For level 1, must include the trial on which the FDA approval was based as well as a link to the FDA press release</p> <p>*For level 2, must cite the NCCN guideline used.</p>	<p><i>1 - BRAF - V600E - Colorectal Cancer - Encorafenib + Cetuximab</i></p> <p><i>PMID: <a href="#">31566309</a>, FDA-approval of Encorafenib + Cetuximab</i></p>
<b>Changes to current therapeutic implications</b>	<p>Gene, mutation, tumor type, drug, previous level of evidence, current level of evidence, evidence to support the change (PMID, Abstract)</p> <p>*For level 1, must include the trial on which the FDA approval was based as well as a link to the FDA press release</p> <p>*For level 2, must cite the NCCN guideline used.</p>	<p><i>RET - Fusions - Non-Small Cell Lung Cancer - Selpercatinib</i></p> <p><i>Previous level: 3A</i> <i>Current level: 1</i></p> <p><i>Abstract: <a href="#">Drilon et al. Abstract# PL02.08, IASLC WCLC 2019; FDA-approval of Selpercatinib</a></i></p>
<b>Addition of new genes</b>	<ul style="list-style-type: none"> <li>Names of genes</li> <li>Links to OncoKB gene pages</li> </ul>	<i>Addition of 1 new gene: <a href="#">FANCL</a></i>



### Table 2.3: Review of the OncoKB beta release candidate

The OncoKB Lead software engineer generates a beta version of the [www.oncokb.org](http://www.oncokb.org) release candidate for visualization and review of included changes from the OncoKB database. This review is performed by the SCMT members and the Lead Scientist. Sections of the beta version of the OncoKB release candidate that are critically reviewed are outlined below.

OncoKB.org tab that requires review	Items on each tab to review	Steps to resolve issues identified during review
Homepage	Accuracy of Gene, Alteration, Tumor Type and Durg numbers	If issues are found during the evaluation of the OncoKB beta release candidate:  1. Update the data accordingly in the OncoKB curation platform  2. Notify another member of the OncoKB staff that the data requires review per <a href="#">Chapter 3: Protocol 1: Data Review</a>  3. When all issues have been addressed and reviewed, return to <a href="#">Chapter 3: Protocol 2: Data release</a>
News Page	Content Formatting Reference link accuracy	
Actionable Genes Page	Are new associations included? Are new associations accurate?	
Gene Page		

# Subprotocol 2.1: Therapeutic Implication Tables for an OncoKB data release

This protocol describes the process for creating the therapeutic implication tables which are displayed on the [OncoKB News page](#) following a data release. Updated therapeutic implications require the use of specific tables in the OncoKB release news candidate to highlight changes for biomarkers and therapeutics and the evidence associated with the change. Templates for all therapeutic implications tables are included at the end of this protocol.

1. Assess if the updated therapeutic implication will assign a tumor type-specific level of evidence to a biomarker that was previously unleveled
  - a. **YES:** Proceed to [Table 2.1.1: New alteration\(s\) with a tumor type-specific level of evidence](#)
  - b. **NO:** Proceed to Step 2
2. Assess if the updated therapeutic implication will assign a tumor type-specific sensitivity level of evidence to a biomarker that was previously leveled only for resistance
  - a. **YES: The therapeutic implication is sensitivity-associated for a biomarker with a tumor type-specific resistance level of evidence,** proceed to [Table 2.1.2: Addition of sensitivity-associated therapy\(s\) for an alteration\(s\) with a tumor type-specific resistance level of evidence](#)
  - b. **NO:** Proceed to Step 3
3. Assess if the updated therapeutic implication will assign a tumor type-specific resistance level of evidence to a biomarker that was previously leveled only for sensitivity
  - a. **YES: The therapeutic implication is resistance-associated for a biomarker with a tumor-type specific sensitivity level of evidence,** proceed to [Table 2.1.3: Addition of resistance-associated therapy\(s\) for an alteration\(s\) with a tumor type-specific sensitivity level of evidence](#)
  - b. **NO:** Proceed to Step 4
4. Assess if the updated therapeutic implication will change (via demotion) the tumor type-specific level of evidence for a biomarker
  - a. **YES: The therapeutic implication will demote the tumor type-specific level of evidence for a biomarker,** proceed to [Table 2.1.4: Demotion of tumor type-specific level of evidence for an alteration](#)
  - b. **NO:** Proceed to Step 5

5. Assess if the updated therapeutic implication will change (via promotion) the tumor type-specific level of evidence for a biomarker
  - a. **YES: The therapeutic implication will promote the tumor type-specific level of evidence for a biomarker**, proceed to [Table 2.1.5: Promotion of tumor type-specific level of evidence for an alteration](#)
  - b. **NO: Proceed to Step 6**
6. Assess if the updated therapeutic implication is a removal of therapy(s) that does not change the tumor type-specific level of evidence for a biomarker
  - a. **YES: The therapeutic implication is a removal of therapy(s)**, proceed to [Table 2.1.6: Removal of therapy\(s\) associated with a tumor type-specific leveled alteration\(s\) \(without changing the alteration's highest level of evidence\)](#)
  - b. **NO: Proceed to Step 7**
7. Assess if the updated therapeutic implication is an addition of therapy(s) that does not change the tumor type-specific level of evidence for a biomarker
  - a. **YES: The therapeutic implication is an addition of therapy(s)**, proceed to [Table 2.1.7: Addition of therapy\(s\) associated with a tumor type-specific leveled alteration\(s\) \(without changing the alteration's highest level of evidence\)](#)
  - b. **NO: Proceed to Step 8**
8. Assess if the updated therapeutic implication changes the level of evidence for a specific biomarker-tumor type-drug association currently in OncoKB, without changing the biomarker's highest level of evidence
  - a. **YES: The therapeutic implication is a change in the level of evidence for a specific biomarker-tumor type-drug association (without changing the biomarker's highest level of evidence)**, proceed to [Table 2.1.8: Changed drug specific tumor-type level of evidence for an alteration-tumor type-drug association currently in OncoKB \(without changing the alteration's highest level of evidence\)](#)
  - b. **NO: Proceed to Step 9**
9. Assess if the updated therapeutic implication is an annotation update of a current biomarker and/or tumor type that does not change the tumor type-specific level of evidence for the biomarker
  - a. **YES: The therapeutic implication is a change in the biomarker and/or tumor type without changing the biomarker's level of evidence**, proceed to [Table 2.1.9: Updated alteration and tumor-type for a current tumor type-specific leveled alteration\(s\) \(without changing the alteration's highest level of evidence\)](#)
  - b. **NO: Proceed to Step 10**

10. Create a new therapeutic implication table that will be reviewed by the OncoKB Lead Scientist and added as a table template for the new, specific use case in subsequent release news candidate

**Table 2.1.1: New alteration(s) with a tumor type-specific level of evidence**

This table assigns a tumor type-specific level of evidence to an alteration that was previously unlevelled in OncoKB

Level	Gene	Mutation	Cancer Type	Drug(s)	Evidence
<i>Level of evidence number</i>	<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Drug(s) being added</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

**Table 2.1.2: Addition of sensitivity-associated therapy(s) for an alteration(s) with a tumor type-specific resistance level of evidence**

This table assigns a tumor type-specific sensitivity level of evidence to an alteration currently in OncoKB and leveled only for resistance

Gene	Mutation	Cancer Type	Drug(s) currently in OncoKB™	Drug(s) added to OncoKB™	Current Levels		Evidence
					Sensitivity	Resistance	
<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Resistance associated drug(s) currently in OncoKB (Level #)</i>	<i>Sensitivity associated drug(s) being added (Level #)</i>	<i>Level of evidence for sensitivity</i>	<i>Level of evidence for resistance</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

**Table 2.1.3: Addition of resistance-associated therapy(s) for an alteration(s) with a tumor type-specific sensitivity level of evidence**

This table assigns a tumor type-specific resistance level of evidence to an alteration currently in OncoKB and leveled only for sensitivity

Gene	Mutation	Cancer Type	Drug(s) currently in OncoKB™	Drug(s) added to OncoKB™	Current Levels		Evidence
					Sensitivity	Resistance	
<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Sensitivity associated drug(s) currently in OncoKB (Level #)</i>	<i>Resistance associated drug(s) being added (Level #)</i>	<i>Level of evidence for sensitivity</i>	<i>Level of evidence for resistance</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

**Table 2.1.4: Demotion of tumor type-specific level of evidence for an alteration**

This table documents a demotion in the tumor type-specific level of evidence for an alteration that is currently in OncoKB

Gene	Mutation	Cancer Type	Drug(s)	Previous Level	Current Level	Evidence
<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Drug(s) being removed or drug(s) being demoted [If other drug(s) are currently in the system that will not be removed, split as: Drug(s) currently in OncoKB™: Drug(s) [including removed drug(s)] (Level #) Separate</i>	<i>Previous level of evidence number</i>	<i>New level of evidence number</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

*drugs by  
sensitivity or  
resistance*

*Drug(s)  
removed  
from  
OncoKB™:  
Removed  
drug(s)  
(Level #) OR  
Drug(s)  
demoted in  
OncoKB™:  
Demoted  
drug(s)  
(Level #)]*

**Table 2.1.5: Promotion of tumor type-specific level of evidence for an alteration**

This table documents a promotion in the tumor type-specific level of evidence for an alteration that is currently in OncoKB

<b>Gene</b>	<b>Mutation</b>	<b>Cancer Type</b>	<b>Drug(s)</b>	<b>Previous Level</b>	<b>Current Level</b>	<b>Evidence</b>
<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Drug(s) being added or drug(s) being promoted [If other drug(s) are currently in the system that will not be removed, split as: Drug(s) currently in OncoKB™: Drug(s) [including promoted drug(s)] (Level #) Separate drugs by</i>	<i>Previous level of evidence number</i>	<i>New level of evidence number</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

---

sensitivity or  
resistance

Drug(s)  
added to  
OncoKB™:  
New drug(s)  
(Level #) OR  
Drug(s)  
promoted in  
OncoKB™:  
Promoted  
drug(s)  
(Level #)]

---

**Table 2.1.6: Removal of therapy(s) associated with a tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**

This table documents the removal of a therapy for a tumor type-specific leveled alteration currently in OncoKB, without changing the alteration's highest level of evidence

Gene	Mutation	Cancer Type	Current Level of Evidence	Drug(s) currently in OncoKB™	Drug(s) removed from OncoKB™	Evidence
<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Current level of evidence number</i>	<i>Drug(s) currently in OncoKB (Level #)</i>	<i>Drug(s) being removed (Level #)</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

---

**Table 2.1.7: Addition of therapy(s) associated with a tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**

This table documents the addition of a therapy for a tumor type-specific leveled alteration currently in OncoKB, without changing the alteration's highest level of evidence

Gene	Mutation	Cancer Type	Current Level of Evidence	Drug(s) currently in OncoKB™	Drug(s) added to OncoKB™	Evidence
------	----------	-------------	---------------------------	------------------------------	--------------------------	----------

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<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Current level of evidence number</i>	<i>Drug(s) currently in OncoKB (Level #)</i>	<i>Drug(s) being added (Level #)</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>
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**Table 2.1.8: Changed drug-specific tumor type level of evidence for an alteration-tumor type-drug association currently in OncoKB (without changing the alteration's highest level of evidence)**

This table documents a change in the level of evidence for a specific alteration-tumor type-drug association currently in OncoKB, when the alteration's highest level of evidence does not change

<b>Level</b>	<b>Gene</b>	<b>Mutation</b>	<b>Cancer Type</b>	<b>Drug(s) currently in OncoKB™</b>	<b>Drug(s) changed in OncoKB™</b>	<b>Evidence</b>
<i>Level of evidence number</i>	<i>Gene name</i>	<i>Mutation name</i>	<i>Cancer type name</i>	<i>Drug(s) currently in OncoKB (Level #)</i>	<i>Drug(s) being promoted or demoted (New Level #)</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>

**Table 2.1.9: Updated alteration or tumor type for a current tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**

This table documents an update to a current alteration and/or tumor type currently associated with a tumor type-specific leveled alteration in OncoKB, when the alteration's highest level of evidence does not change

<b>Level</b>	<b>Gene</b>	<b>Previous Annotation</b>		<b>Current Annotation</b>		<b>Drug(s)</b>	<b>Evidence</b>
		<b>Mutation</b>	<b>Cancer Type</b>	<b>Mutation</b>	<b>Cancer Type</b>		

<i>Current level of evidence number</i>	<i>Gene name</i>	<i>Currently used mutation</i>	<i>Currently used cancer type</i>	<i>New mutation change</i>	<i>New cancer type</i>	<i>Drug(s) currently in OncoKB</i>	<i>Hyperlink to evidence from FDA update page, NCCN guideline update or clinical trials</i>
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## Subprotocol 2.2: Email News Release Candidate

This protocol describes the process of creating the OncoKB email news release candidate that is sent to registered members of the OncoKB Google Group following a data release. The OncoKB email news release candidate highlights items from the recent release, including new or changed levels of evidence, SOP or FAQ updates, and new website features, among other changes. Updated therapeutic implications are outlined in sentence format rather than the therapeutic implication tables that are displayed on the OncoKB NEWS page. The template for the email news release candidate is shown below.

### Figure 2.2.1: Email News Release Candidate Template

A template of the OncoKB NEWS release emails sent to registered members of the OncoKB Google Group following an OncoKB data release.

<b>To</b>	oncokb@google-group
<b>Cc</b>	
<b>Bcc</b>	
<b>Subject</b>	OncoKB New Data Release - Month Day, Year



Data Release v\_  
Month Day, Year

### What's New

News and messages from OncoKB team regarding OncoKB SOP updates, OncoKB FAQ updates, OncoKB Year In Review Releases and/or OncoKB Website Updates

## Updated Therapeutic Implications:

- **New alteration(s) with a tumor type-specific level of evidence**
  - **ICON Level #:** Drug(s) added as a treatment/treatment with predictive resistance [for resistance] for **Gene Name Variant in cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
- **Addition of sensitivity-associated therapy(s) for an alteration(s) with a tumor type-specific resistance level of evidence**
  - **ICON Level #**(For sensitivity): Drug(s) added as a treatment for **Gene Name Variant in cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
    - Drug(s) associated with resistance currently in OncoKB™: Drug(s) (Level #)
- **Addition of resistance-associated therapy(s) for an alteration(s) with a tumor type-specific sensitivity level of evidence**
  - **ICON Level #**(For resistance): Drug(s) added as a treatment with predictive resistance for **Gene Name Variant in cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
    - Drug(s) associated with sensitivity currently in OncoKB™: Drug(s) (Level #)
- **Promotion of tumor type-specific level of evidence for an alteration**
  - **ICON Level #:** **Gene Name Variant in cancer type** promoted from **Level #** to **Level #** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#)) in association with **drug(s)** (PMIDs, Abstracts)
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)
- **Demotion of tumor type-specific level of evidence for an alteration**
  - **ICON Level #:** **Gene Name Variant in cancer type** demoted from **Level #** to **Level #** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#)) in association with **drug(s)** (PMIDs, Abstracts)
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)
- **Removal of therapy(s) associated with a tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**
  - **ICON Level #:** Drug(s) removed as a treatment/treatment with predictive resistance [for resistance] for **Gene Name Variant in cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)

- **Addition of therapy(s) associated with a tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**
  - **ICON Level #:** **Drug(s)** added as a treatment/treatment with predictive resistance [for resistance] for **Gene Name Variant** in **cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)
- **Changed drug specific tumor-type level of evidence for an alteration-tumor type-drug association currently in OncoKB (without changing the alteration's highest level of evidence)**
  - **ICON Level #** (*This is the highest level of evidence for the biomarker*): **Drug(s)** promoted/demoted from **Level #** to **Level #** for **Gene Name Variant** in **cancer type** based on ([evidence provided in FDA announcements, NCCN guideline updates or clinical trials](#))
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)
- **Updated alteration and tumor-type for a current tumor type-specific leveled alteration(s) (without changing the alteration's highest level of evidence)**
  - **ICON Level #** (*This is the highest level of evidence for the biomarker*): **Gene Name Variant** in **cancer type** has been updated to **Gene Name New Variant** in **new cancer type** (only highlight the changed annotations) based on ([evidence provided in FDA announcements, NCCN guideline or clinical trials](#))
    - Drug(s) currently in OncoKB™: Drug(s) (Level #)

### Gene Curation:

- **Addition of # new genes:**  
[Gene1](#) [Gene2](#) [Gene3](#)

## We're Here to Help









As always, don't hesitate to reach out if you have comments, questions or suggestions. We love to hear from you. You can reach us at [contact@oncokb.org](mailto:contact@oncokb.org)





## Table 2.2.1: Level of Evidence Icons and Colors for OncoKB Email News Release Candidate

This table includes the level of evidence icon and colors used in the email news release template above.

Level of Evidence Icons and Colors
 <u>Level 1</u>
 <u>Level 2</u>
 <u>Level 3</u>
 <u>Level 3A</u>
 <u>Level 3B</u>
 <u>Level 4</u>
 <u>Level R1</u>
 <u>Level R2</u>
<u>Unleveled</u>

# Chapter 4: Conflicting data and conflicting assertions

## Introduction

This protocol describes how to evaluate and resolve conflicting data in peer-reviewed publications. The identification of conflicting data occurs throughout the OncoKB curation process, including when:

1. Designating a gene as an oncogene or tumor suppressor gene
2. Assigning an oncogenic or biological effect to a variant of possible significance (VPS)
3. Assigning a gene-variant-tumor type-drug association an OncoKB and FDA Level of Evidence

[Chapter 4: Table 1.1: Evaluating and resolving conflicting data in publications](#) details the process by which conflicting information in different publications are evaluated and resolved with respect to points 1 and 2 above.

## Protocol 1: Resolving conflicting data

### Table 1.1 Evaluating and resolving conflicting data in publications

The process for evaluating and resolving conflicting preclinical and/or clinical data when curating OncoKB database elements. For each OncoKB process where conflicting information may be encountered (column I), a description of the potential conflicting information (column II) and the process for evaluating and resolving the conflicting data (column IV) is described.

I. OncoKB process where conflicting information may be encountered	II. Description of potential conflicting information	III. Reference protocol for resolving conflicting information	IV. How conflicting information is evaluated and resolved <sup>2</sup>	
			<i>experimental</i>	<i>clinical</i>
<b>Designating a gene as an Oncogene or Tumor Suppressor or Both or Neither</b>	1. A gene may meet criteria that qualifies it as both an oncogene or tumor suppressor  2. Evidence may be weak and/or conflicting to support a gene as being either an oncogene or tumor suppressor	<a href="#">Chapter 1: Table 1.3: Assertion of the function of a cancer gene</a>	1. Gene can be classified as both an oncogene and tumor suppressor gene if the data fulfills both criteria from the reference protocol  2. Gene can be classified as neither an oncogene and tumor suppressor	NA

<b>Assigning a variant a biological or oncogenic effect</b>	1. Data is weak and/or conflicting as to the biological and/or oncogenic effect of a variant	<a href="#">Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS</a> <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>	1. The biological and/or oncogenic effect of a variant can be classified as inconclusive	
<b>Assigning a VPCS an OncoKB and FDA Level of Evidence</b>	<b>Level 1</b>	NA <sup>1</sup>		
	<b>Level 2</b>	NA <sup>1</sup>		
	<b>Level R1</b>	NA <sup>1</sup>		
	<b>Level 3A and R2</b>	There may be conflicting pre-clinical and/or clinical data as to whether the biomarker is predictive of response or resistance (R2) to a drug	<a href="#">Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a>	For conflicting pre-clinical data, the strength of evidence is carefully evaluated and compared using <a href="#">Chapter 1: Table 2.3.2: Definition of the strength of functional (experimental) evidence that supports an assertion</a> <ul style="list-style-type: none"> <li>● If there is Strong and Weak conflicting evidence → the Strong data is prioritized</li> <li>● If the conflicting evidence are both Strong → the data must be discussed internally with a disease-specific DMT member. If a consensus cannot be reached by the disease-specific DMT member, <b>the VPCS is not assigned a level of evidence</b></li> </ul>



	Level 4		<a href="#">Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence</a>	<ul style="list-style-type: none"> <li>• If the conflicting evidences are both Weak → the VPCS would not qualify as a level 3A, 4 or R2</li> </ul>	<ul style="list-style-type: none"> <li>• <b>4:</b> If there are conflicting results between preclinical and clinical evidence (clinical evidence will be limited), the data must be discussed internally with a disease-specific DMT member.</li> <li>• If a consensus cannot be reached, <b>the VPCS is not assigned a level of evidence</b></li> </ul>
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<sup>1</sup> **NA:** Not Applicable; By definition OncoKB Level 1 variants (FDA-recognized biomarkers predictive of response to an FDA-approved drug in a specified indication), Level 2 variants (Standard care biomarkers recommended by the NCCN or other professional guidelines predictive of response to an FDA-approved drug in a specified indication) and Level R1 variants (Standard care biomarkers predictive of resistance to an FDA-approved drug in this indication) are categorized by their inclusion in either the FDA or NCCN guidelines, and therefore conflicting data is not relevant.

<sup>2</sup> Independent review of curated data is performed by an OncoKB staff member following [Chapter 3: Table 1.1: OncoKB staff member curation and review responsibilities](#)

<sup>3</sup> If conflicting assertions among OncoKB staff members arise during data curation and review process, proceed to [Chapter 4: Protocol 2: Resolving conflicting assertions](#)

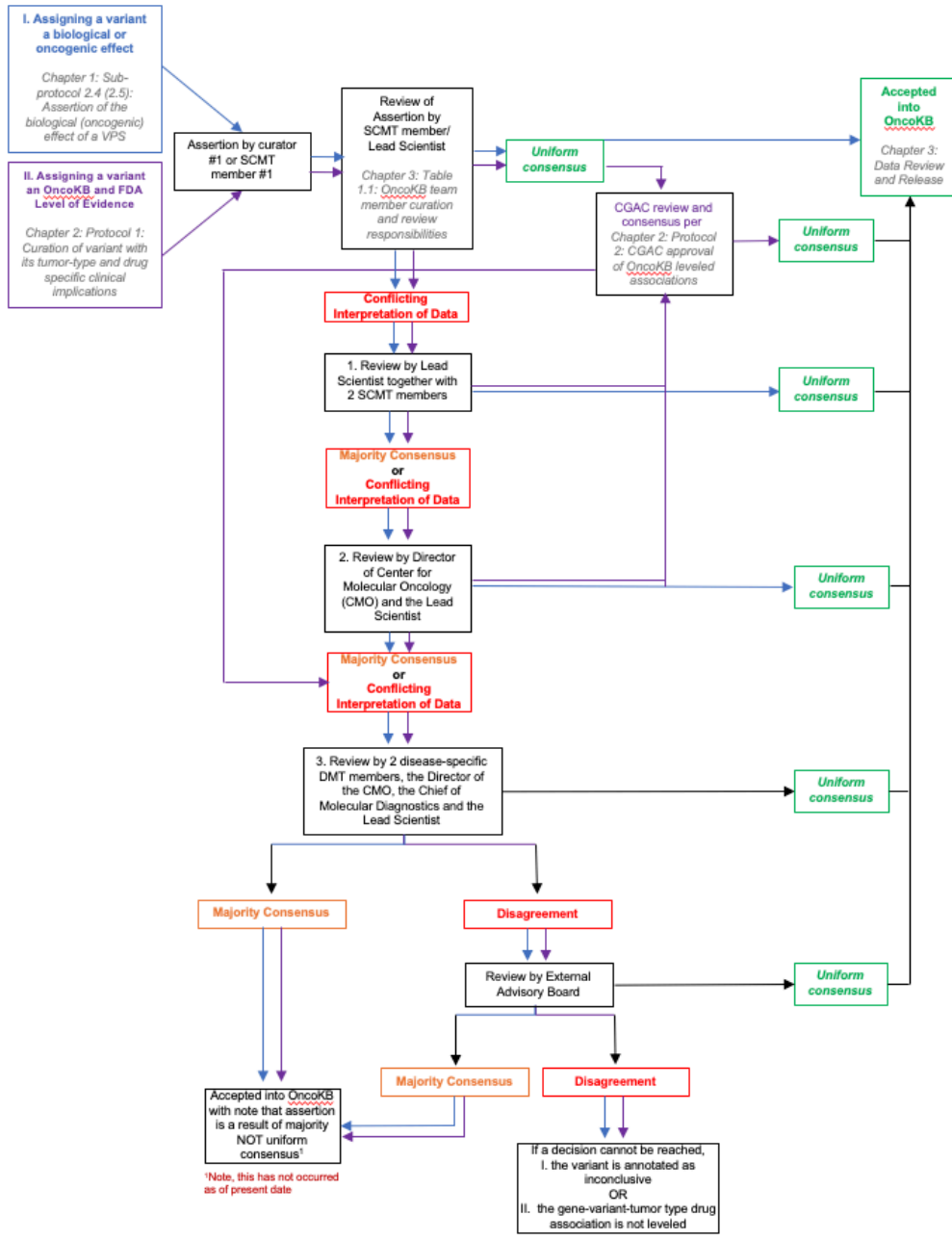
## Protocol 2: Resolving conflicting assertions

This protocol (summarized in [Chapter 4: Figure 2.1: Process for handling conflicting assertions in OncoKB](#)) describes how to resolve conflicting assertions among members of the OncoKB team and/or CGAC. Conflicting assertions can arise during the OncoKB curation with respect to:

1. Assigning a variant a biological and oncogenic effect
2. Assigning a gene-variant-tumor type-drug association with an OncoKB and FDA Level of Evidence

### **Figure 2.1: Process for handling conflicting assertions in OncoKB**

Depiction of how conflicting assertions are assessed and resolved throughout the OncoKB curation process. The process outlined below takes into account the prioritization of scientific evidence and specifies the extent of agreement necessary to resolve such conflicting assertions. Blue arrows show the process for resolving conflicting assertions that arise when assigning a variant a biological and oncogenic effect. Purple arrows show the process for resolving conflicting assertions that arise when assigning a VPCS with an OncoKB and FDA Level of Evidence.



# Chapter 5: Re-analysis and re-evaluation

## Introduction

OncoKB data continuously undergoes re-analysis and re-evaluation in order to keep the database and SOP procedures current with updated FDA approvals, NCCN and other professional guidelines, conference proceedings and peer-reviewed scientific literature.

The SCMT is expected to keep variant interpretations and leveled associations up-to-date by:

1. Addressing all inquiries/and or new evidence submitted by public users and/or members of the MSK community within 72 hours of the inquiry. This may involve assessing new evidence for:
  - a. a previously curated variant or leveled association (evidence may support the previous claim or be discrepant)
  - b. a novel variant or leveled association (not already in OncoKB)
2. Incorporating data from new publications, conference abstracts and proceedings within 12 months of their publication using the process outlined in the [End-to-end curation workflow](#)
3. Reassessing all variants classified as VUS or inconclusive at least every two years

By following all protocols documented in the [End-to-end curation workflow](#), variants are curated in OncoKB with assertions of:

- Biological effect
- Oncogenic effect
- OncoKB Level of Evidence
- FDA Level of Evidence

To maintain accuracy and currency of OncoKB curated variants, OncoKB staff periodically perform the required procedures outlined in this chapter to re-analyze and re-evaluate OncoKB curated variants.

This chapter consists of three protocols which address how OncoKB re-analyzes and re-evaluates variants, OncoKB and FDA-leveled clinical associations, and makes major changes to the OncoKB workflow and SOP. The protocols detailed in this chapter are outlined in the following table.

**Table 1: Overview of Chapter 5: Reanalysis and re-evaluation**

Chapter 5 Sections (Protocols)	Chapter 5 Subsections (Tables)	Description
<a href="#">Protocol 1: Variant re-analysis and re-evaluation</a>	<a href="#">Table 1.1: Overview of procedure for variant re-analysis and re-evaluation</a>	An overview of the procedure for variant re-analysis and re-evaluation including the OncoKB member who performs each task
	<a href="#">Table 1.2: Process for determining the biological effect of a variant following variant re-analysis and re-evaluation</a>	The specific considerations to take into account when deciding to add evidence or change an assertion (biological or oncogenic effect) of a previously curated variant
	<a href="#">Table 1.3: Process for determining the oncogenic effect of a variant following variant re-analysis and re-evaluation</a>	
<a href="#">Protocol 2: Changing existing clinical implications</a>	<a href="#">Table 2.1: Procedure for evaluating data sources that may result in a change in an FDA or OncoKB Level of Evidence</a>	Overview of the data sources and specific considerations that may prompt a change in the FDA and/or OncoKB Level of Evidence for an existing clinical implication in OncoKB. Also noted are the protocols for critically assessing the evidence in each source type, the potential outcome of each protocol assessment and the potential updated FDA and/or OncoKB Level of Evidence for the association in question.
For <a href="#">Chapter 5: Protocols 1 and 2</a> above, consistency of the curation process is maintained by the data review process outlined in <a href="#">Chapter 3: Protocol 1: Data review</a>		
<a href="#">Protocol 3: Implementing a significant change to the OncoKB SOP</a>	<a href="#">Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature</a>	For each OncoKB database element that may require a significant change based on findings from the literature, this table describes the SOP protocols that require reassessment and updating, the data curation elements that require updating, review and release, and the processes carried out by OncoKB staff to ensure all changes are accessible and transparent to the public

# Protocol 1: Variant re-analysis and re-evaluation

OncoKB data continuously undergoes re-analysis and re-evaluation in order to keep the database and SOP procedures current with updated FDA approvals, NCCN and other professional guidelines, conference proceedings and peer-reviewed scientific literature. This protocol provides an overview of the procedure for variant re-analysis and re-evaluation, including the specific considerations to take into account when deciding to add evidence and/or change an assertion (biological or oncogenic effect) of a previously curated variant.

## INPUT:

- A. **Gene** defined as *Oncogene* or *Tumor Suppressor* or *Both* or *Neither* +
  - B. **Variant** must be defined as a *Variants of Possible Clinical Significance (VPCS)* as outlined in [Chapter 1: Protocol 2: Variant curation](#)
1. Identify a **data source** that contains evidence to support variant re-analysis and re-evaluation  
--Refer to [Chapter 1: Sub-Protocol 2.1: Variant sources](#) for an overview of OncoKB data sources for variants curation
    - a. *Proceed to Step 2*
  2. Note the current **OncoKB curated data** for the specified variant (or note whether it is curated in OncoKB as a VUS), including its: 1) *Biological effect*, 2) *Oncogenic effect*, 3) *Mutation effect* and associated *PMIDs*
    - a. *Proceed to Step 3*
  3. Assess the new evidence from the data source identified in Step 1 to **re-evaluate the variant's biological effect, oncogenic effect and description of mutation effect**. Is a change required to the variant's biological effect, oncogenic effect or description of mutation effect?  
-- Refer to [Chapter 5: Table 1.1: Procedure for variant re-analysis, re-evaluation and review](#) for a summary of the variant curation process for re-analysis and re-evaluation
    - a. **YES:** *Proceed to Step 4*
    - b. **NO:** No further action (curation) is necessary. Exit the protocol.
  4. **Enter** the updated data into the OncoKB curation platform  
--Refer to [Chapter 6: Protocol 3: Variant curation](#) for a description of entering variant-level data into the OncoKB curation platform
    - a. *Proceed to Step 4*
  5. Follow the processes outlined in [Chapter 3: Data review and release](#) to have the updated data independently, internally reviewed by a member of the OncoKB staff and released to the various OncoKB outputs [*Internal:* MSK-IMPACT reports, *External:* cBioPortal for Cancer Genomics ([www.cbioportal.org](http://www.cbioportal.org)) and the OncoKB public website<sup>1</sup> ([www.oncokb.org](http://www.oncokb.org))]

<sup>1</sup> When data is released to the OncoKB website (per [Chapter 3: Data review and release](#)), a release note is included that documents the change in the variant's assertion of biological and/or oncogenic effect as well as updated references and/or descriptions.



**Table 1.1: Procedure for variant re-analysis, re-evaluation and review**

Description of the main steps for variant re-analysis and re-evaluation as well as the procedure to review the newly curated/updated data. Also indicated is the OncoKB staff member who may perform each of the procedures. Steps for variant curation (including variants undergoing re-analysis and re-evaluation) is outlined in [Chapter 1: Protocol 2: Variant curation](#).

Step	Procedure for variant re-analysis and re-evaluation	Specific considerations that prompt change	STEP 1: Re-analysis and re-evaluation <sup>1</sup> <i>Performed by</i>	STEP 2: Independent Review <sup>1</sup> <i>Performed by</i>
1	<b>Identification of variant data source(s)</b>	OncoKB data sources that may contain evidence to support adding data or changing the assertion of a previously curated variant are defined in <a href="#">Chapter 1: Sub-Protocol 2.1: Variant sources</a>	<i>OncoKB curator or SCMT member or Lead Scientist or CGAC member</i>  *Data source may also be recommended by an OncoKB user through the feedback mechanism	NA
2	<b>Identifying the variant as a Variant of Possible Significance (VPS) or Variant of Uncertain Significance (VUS)</b>	New evidence may arise that supports a previously curated variant being re-categorized as a VPS or VUS The process for identifying a variant as a VPS or VUS is outlined in <a href="#">Chapter 1: Protocol 2: Variant curation</a> . The process for determining if a variant qualifies as a VPS or VUS is outlined in <a href="#">Chapter 2: Table 2.2.2: Filter to select Variants of Possible Significance (VPS) in OG/TSGs</a>	OncoKB curator  SCMT member	SCMT member  SCMT member or Lead Scientist
3	<b>Variant data curation:</b>			
	<b>Identify functional data and assess its strength</b>	When evaluating new data for variant re-analysis, the following must be taken into consideration: 1. the presence and type of functional evidence and 2. the strength of functional evidence to support assigning a VPS a biological and oncogenic effect  Refer to <a href="#">Chapter 2: Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion</a>	OncoKB curator  SCMT member	SCMT member  SCMT member or Lead Scientist



<b>Assign a biological effect</b>	Considerations for determining whether the biological effect of a VPS should change or remain the same during re-analysis and re-evaluation	OncoKB curator	SCMT member
	Refer to <a href="#">Chapter 5: Table 1.2: Process for determining the biological effect of a variant following variant re-analysis and re-evaluation</a> and <a href="#">Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS</a>	SCMT member	SCMT member or Lead Scientist
<b>Assign an oncogenic effect</b>	Considerations for determining whether the oncogenic effect of a VPS should change or remain the same during re-analysis and re-evaluation	OncoKB curator	SCMT member
	Refer to <a href="#">Chapter 5: Table 1.3: Process for determining the oncogenic effect of a variant following variant re-analysis and re-evaluation</a> and <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>	SCMT member	SCMT member or Lead Scientist
<b>Description of mutation effect (includes references)</b>	If new evidence emerges to support or contradict an existing variant assertion, the data is summarized and referenced following the procedure outlined in <a href="#">Chapter 6: Table 3.2: Generation and formatting of mutation effect description</a>	OncoKB curator	SCMT member
		SCMT member	SCMT member or Lead Scientist

<sup>1</sup> Details about the process for internal, independent review of data additions/deletions/edits in the OncoKB curation platform by a member of the OncoKB staff using the *Review Mode* feature is detailed in [Chapter 3: Protocol 1: Data Review](#).

## Table 1.2: Process for determining the biological effect of a variant following variant re-analysis and re-evaluation

Overview of the process for re-evaluating and re-assigning (if applicable) the biological effect of an existing Variant of Possible Significance (VPS) in OncoKB when new evidence becomes available. The VPS's existing biological effect and the validity and strength of the new information must be considered when determining the VPS's biological effect following re-analysis and re-evaluation. The process for variant re-analysis and re-evaluation is initiated by an OncoKB curator (under the management and direction of a SCMT member) following [Chapter 1: Protocol 2: Variant curation](#) and reviewed by a member of the SCMT following the procedure outlined in [Chapter 3: Protocol 1: Data review](#).

Functional designation (biological effect) of the VPS in OncoKB before re-analysis	Type of new information	Strength of new evidence	Functional designation (biological effect) of the VPS in OncoKB after re-analysis
	Refer to <a href="#">Chapter 1: Sub-protocol 2.4: Assertion of biological effect of a variant</a>	Refer to <a href="#">Chapter 1: Sub-protocol 2.3: Defining the type and strength of evidence to support a variant assertion</a>	
Known (gain/loss/switch of function)	Data suggests neutral function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
Known Neutral	Data suggests gain/loss/switch of function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
Likely (gain/loss/switch of function)	Data suggests neutral function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
	Data suggests gain/loss/switch of function	Strong	Change to known
		Moderate	Do not change
		Weak	Do not change
Likely Neutral	Data suggests gain/loss/switch of function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
	Data suggests neutral function	Strong	Change to known
		Moderate	Do not change
		Weak	Do not change

Inconclusive function due to conflicting evidence	Data suggests gain/loss/switch or neutral function	Strong	Change to “likely gain/loss/switch of function” or “likely neutral” accordingly  <i>*must be discussed with 2 members of the SCMT. If SCMT in disagreement, it remains as inconclusive</i>
		Moderate	Do not change
		Weak	Do not change
Inconclusive function due to only weak evidence	Data suggests gain/loss/switch or neutral function	Strong	Refer to <a href="#">Chapter 1: Sub-protocol 2.4: Assertion of biological effect of a variant</a> to determine biological effect of variant
		Moderate	Refer to <a href="#">Chapter 1: Sub-protocol 2.4: Assertion of biological effect of a variant</a> to determine biological effect of variant
		Weak	Do not change

**Note:** If new evidence supports the current functional designation of the Variant of Possible Significance (VPS) (example: BRAF V600E is designated as gain-of-function and new evidence further supports this claim), the VPS’s biological effect remains the same but the reference and data associated with the new evidence is added to the curation system. References for all new evidence are incorporated into the OncoKB curation system as outlined in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#) and data is added to the mutation effect description as outlined in [Chapter 6: Table 3.2: Generation and formatting of mutation effect description](#).

### Table 1.3: Process for determining the oncogenic effect of a variant following variant re-analysis and re-evaluation

Overview of the process for re-evaluating and re-assigning (if applicable) the oncogenic effect of an existing Variant of Possible Significance (VPS) in OncoKB when new evidence becomes available. The VPS's existing oncogenic effect and the validity and strength of the contradicting information must be considered when determining the VPS's oncogenic effect following re-analysis and re-evaluation. The process for variant re-analysis and re-evaluation is initiated by an OncoKB curator (under the management and direction of a SCMT member) following [Chapter 1: Protocol 2: Variant curation](#) and reviewed by a member of the SCMT following the procedure outlined in [Chapter 3: Protocol 1: Data review](#).

Functional designation (oncogenic effect) of the VPS in OncoKB before re-analysis	Type of new information	Strength of new evidence	Functional designation (oncogenic effect) of the VPS in OncoKB after re-analysis
	Refer to <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a somatic alteration</a>	Refer to <a href="#">Chapter 1: Sub-protocol 2.3: Defining the type and strength of evidence to support a variant assertion</a>	
<b>Known Oncogenic</b>	Data suggests neutral function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
<b>Likely Oncogenic</b>	Data suggests neutral function	Strong	Change to inconclusive
		Moderate	Change to inconclusive
		Weak	Do not change
	Data suggests oncogenic function	Strong	Change to “known oncogenic”
		Moderate	Do not change
		Weak	Do not change
<b>Likely Neutral</b>	Data suggests oncogenic function	Strong	If initial evidence for “likely neutral” designation is strong or moderate, change to inconclusive  If initial evidence for “likely neutral” designation is weak, change to “likely oncogenic”
		Moderate	Change to inconclusive
		Weak	Do not change
<b>Inconclusive function due to conflicting evidence</b>	Data suggests oncogenic or neutral function	Strong	Change to “likely oncogenic” or “likely neutral” accordingly

			<i>*must be discussed with 2 members of the SCMT. If SCMT in disagreement, remain as inconclusive</i>
		Moderate	Do not change
		Weak	Do not change
<b>Inconclusive function due to only weak evidence</b>	Data suggests oncogenic or neutral function	Strong	Refer to <a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a somatic alteration</a> to determine oncogenic effect of variant
		Moderate	
		Weak	Do not change

**Note:** If new evidence supports the current functional designation of the Variant of Possible Significance (VPS) (example: BRAF V600E is designated as oncogenic and new evidence further supports this claim), the VPS's oncogenic effect remains the same but the reference associated with the new evidence is added to the curation system. References for all new evidence are incorporated into the OncoKB curation system as outlined in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#) and data is added to the mutation effect description as outlined in [Chapter 6: Table 3.2: Generation and formatting of mutation effect description](#).

## Protocol 2: Changing existing clinical implications

OncoKB data continuously undergoes re-analysis and re-evaluation in order to keep the database and SOP procedures current with updated FDA approvals, NCCN and other professional guidelines, conference proceedings and peer-reviewed scientific literature. This protocol provides an overview of the procedure for re-analysis and re-evaluation of existing leveled (FDA and OncoKB) associations in OncoKB, including the specific data sources to investigate and considerations to take into account when determining if a change in a level of evidence is warranted.

### INPUT:

- A. **Gene** defined as *Oncogene* or *Tumor Suppressor* or *Both* or *Neither* +
- B. **Variant** must be defined as a *Variants of Possible Clinical Significance (VPCS)* as outlined in [Chapter 1: Protocol 2: Variant curation](#)
- C. **Tumor Type** must correspond to a tumor type in OncoTree as indicated in [Chapter 1: Protocol 3: Tumor type assignment](#)
- D. **Drug**: must be a targeted therapy (refer to [Chapter 1: Protocol 4: Drug curation](#))

1. Identify a **data source** that contains evidence to support changing an existing leveled clinical implication (including FDA and/or OncoKB leveled association)

-- Refer to [Chapter 5: Table 2.1: Procedure for evaluating data sources that may result in a change in an FDA or OncoKB Level of Evidence \(column II\)](#) for an overview of data sources that may prompt a change in the FDA and/or OncoKB Level of Evidence of an existing leveled clinical implication in OncoKB

a. *Proceed to Step 2*

2. Note the **pre-existing OncoKB curated data** for the specified clinical implication, including the: 1) gene, variant, tumor-type and drug of interest, 2) current OncoKB Level of Evidence, 3) current FDA Level of Evidence, and 4) current referenced data sources and source types (e.g. FDA drug label for capmatinib)

a. *Proceed to Step 3*

3. **Critically assess the evidence** in the data source identified in Step 1 by following the process outlined in [Chapter 5: Table 2.1: Procedure for evaluating data sources that may result in a change in an FDA or OncoKB Level of Evidence](#). Should the pre-existing clinical implication be assigned a new FDA and/or OncoKB Level of Evidence?

a. **YES:** *Proceed to:*

- i. [Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 1 or R1) association OR

- ii. [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or guidelines from other expert panels](#) to assess the data for a potential FDA Level 2 (OncoKB Level 2, 3A or R1) association OR
  - iii. [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#) to assess the data for a potential FDA Level 3 (OncoKB Level 3A or R2) association OR
  - iv. [Chapter 2: Sub-Protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence](#) to assess the data for a potential FDA Level 3 (OncoKB Level 4) association
- b. **NO:** No further action (curation) is necessary. Exit the protocol.
4. Follow [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#) to obtain **CGAC review and consensus** for the proposed FDA and/or OncoKB Level of Evidence change

**Table 2.1: Procedure for evaluating data sources that may result in a change in an FDA or OncoKB Level of Evidence**

Overview of the data sources (Column II and III) and specific considerations (column IV) that may prompt a change in the FDA and/or OncoKB Level of Evidence for an existing clinical implication in OncoKB. Also noted are the protocols (column V) for critically assessing the evidence in each source type, the potential outcome of each protocol assessment (Column VI) and the potential updated FDA and/or OncoKB Level of Evidence for the association in question (column VII).

I. Current Level of Evidence for a specified association		II. Data source with updated evidence	III . Frequency each data source is assessed and re-evaluated for updates	IV. Specific considerations that prompt change: <i>Inclusion, removal or updated evidence regarding the specified association in the data source</i>	V. Protocol to reference when considering a change in the Level of Evidence	VI. Outcome of protocol assessment	VII. Potential updated Level of Evidence <sup>1</sup>	
FDA	OncoKB						FDA	OncoKB
2	1	FDA drug label	OncoKB receives automated emails from the FDA announcing all new drug approvals, in real time.	Updated inclusion criteria in which the biomarker specified for inclusion is changed	<a href="#">Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels</a>	All criteria are met - the VPCS associated with the FDA approval is updated according to the newest version of the FDA drug label	2	1

2	2		For relevant drug approvals, data is evaluated and a consensus email is sent to CGAC within 3 business days of the drug approval announcement.	Inclusion of association in FDA drug label	<i>For assigning OncoKB Level 1 or R1 (FDA Level 2)</i>	All criteria are met	2	1
		NCCN Guideline	Updates to NCCN Guidelines are evaluated every 6 months and incorporated into OncoKB. *Feedback from CGAC or OncoKB users may require the OncoKB staff to evaluate a specific NCCN Guidelines prior to the 6 month mark.	Removal	<a href="#">Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a>  <i>For assigning OncoKB Level 3A or R2 (FDA Level 3)</i>	All criteria are met  Criteria is not met  --Proceed to <a href="#">Chapter 2: Sub-protocol 1.5: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature preclinical evidence</a>	3  No level OR 3	3A  No level OR 4
3	3A	Peer-reviewed literature  Conference proceedings	Scientific literature is evaluated on a monthly basis as outlined in <a href="#">Chapter 1: Table 2.1.1: Variant data sources</a>	Updated evidence with additional patients experiencing clinical benefit	<a href="#">Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a>  <i>For assigning OncoKB Level 3A or R2 (FDA Level 3)</i>	All criteria are met  Additional clinical benefit is noted but does not change the assigned FDA and OncoKB Levels of Evidence	3	3A
				Updated evidence with negative data regarding pt response and/or drug toxicity		All criteria are still met  CGAC confirms the specified association still qualifies as a OncoKB Level 3A association	3	3A
						Criteria is not met  CGAC confirms the specified association should no longer qualify as an OncoKB Level 3A association	3 OR No level	4 OR No level



					<a href="#">eligibility criteria with preliminary clinical trial data and mature</a> <i>For assigning OncoKB Level 4 (FDA Level 3)</i>			
		NCCN Guidelines	See above	Inclusion	<a href="#">Chapter 2: Sub-Protocol 1.3: Rules/processes for using existing NCCN guidelines or other published professional guidelines</a> <i>For assigning OncoKB Level 2, 3A<sup>2</sup> or R1 (FDA Level 2 or 3<sup>2</sup>)</i>	All criteria are met and biomarker is not an emerging biomarker <sup>2</sup>	2	2
		FDA drug label	See above	Inclusion	<a href="#">Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels</a> <i>For assigning OncoKB Level 1 or R1 (FDA Level 2)</i>	All criteria are met	2	1
3	4	Peer-reviewed literature Conference proceeding	See above	Updated evidence with additional patients experiencing clinical benefit	<a href="#">Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a> <i>For assigning OncoKB Level 3A or R2 (FDA Level 3)</i>	All criteria are met	3	3A
				Updated evidence with negative data regarding pt	<a href="#">Chapter 2: Sub-Protocol 1.5: Rules/processes</a>	All criteria are met CGAC confirms the specified	3	4

				response and/or drug toxicity	<a href="#">for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with preliminary clinical trial data and mature</a> <i>For assigning OncoKB Level 4 (FDA Level 3)</i>	association still qualifies as an OncoKB Level 4 association		
						Criteria is not met CGAC confirms the specified association should no longer qualify as a leveled association	No level	No level
2	R1	NCCN Guidelines and/or FDA drug label	See above	Removal	<a href="#">Chapter 2: Sub-protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data</a> <i>For assigning OncoKB Level 3A or R2 (FDA Level 3)</i>	All criteria are met for an OncoKB Level R2 variant	3	R2
						Criteria is not met for an OncoKB Level R2 variant	No level	No level
3	R2	NCCN Guidelines and/or FDA drug label	See above	Inclusion	<a href="#">Chapter 2: Sub-protocol 1.2: Rules/processes for using existing FDA drug labels</a> <i>For assigning OncoKB Level 1 or R1 (FDA Level 2)</i>	All criteria are met for an OncoKB Level R1 variant	2	R1

<sup>1</sup> For a newly proposed OncoKB and/or FDA Level of Evidence, follow the steps in [Chapter 2: Curation of variant and tumor type specific clinical implications](#), including CGAC approval of all proposed level changes.

<sup>2</sup> **Emerging biomarkers are defined as those alterations listed as a category 2A biomarker in the NCCN guidelines based on limited clinical data, for example early Phase I and Phase II clinical studies with limited patient data/responses. They qualify as OncoKB Level 2, but map to FDA Level 3.** For example, ERBB2 exon 20 insertions and mutations in NSCLC based on a basket study of Ado-Trastuzumab Emtansine.

# Protocol 3: Implementation processes for significant changes to the OncoKB SOP

This protocol provides an overview of the procedure for implementing a major change to the OncoKB SOP.

- The OncoKB Levels of Evidence were updated in December 2019 to be consistent with the [Joint Consensus Recommendation by AMP, ASCO and CAP](#) and the [ESMO Scale for Clinical Actionability of molecular Targets \(ESCAT\)](#).
  - [Chapter 5: Figure 3.1: Updates to OncoKB \(therapeutic\) Levels of Evidence](#) shows the updates made to the OncoKB Levels of Evidence V1, to create OncoKB Levels of Evidence V2
  - [Chapter 5: Figure 3.2: Overview of implementation, execution, review and release of the updated OncoKB Levels of Evidence](#) provides a detailed overview of the implementation, execution, review and release of the updated OncoKB Levels of Evidence (V2)
  - [Chapter 5: Figure 3.3: Consensus email to CGAC regarding proposed change to the OncoKB Levels of Evidence](#) shows the consensus email sent to CGAC by the Lead Scientist regarding the change in the OncoKB (therapeutic) Levels of Evidence
  - [Chapter 5: Figure 3.4: Transparency and accessibility of old \(V1\) and new \(V2\) OncoKB Therapeutic Levels of Evidence on the OncoKB news page](#) shows how information about the updated OncoKB Levels of Evidence was made transparent and accessible to all OncoKB users. On the date the new Levels of Evidence were released to the public, the OncoKB “News” page was updated to include: 1) an image of both the old (V1) and new (V2) levels of evidence, 2) a detailed description of how the two versions differ and 3) the rationale for the updating the Levels of Evidence.
  
- 1. **Annual Review:** The Lead Scientist annually reviews major findings from the scientific literature that may have significant implications on the OncoKB process with the Director of the Center for Molecular Oncology (CMO)

--The specific data elements that may need to be re-evaluated following a significant SOP change are detailed in [Chapter 5: Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature](#)
  
- 2. **Faculty Review:** If it is agreed upon by the Lead Scientist and the Director of the CMO that there is the need for a major systemic change, a meeting is called with the following faculty members to present the proposed change and discuss how it should be implemented:
  - a. Director of the CMO, Dr. David Solit
  - b. OncoKB Lead Scientist, Dr. Debyani Chakravarty
  - c. Chief, Molecular Diagnostic Service, Dr. Marc Ladanyi
  - d. Head of Knowledge Systems, Dr. Nikolaus Schultz

- e. Associate Director, Marie-Josée and Henry R. Kravis Center for Molecular Oncology, Dr. Michael Berger
3. **CGAC Review:** If all faculty members from Step 2 agree that the change should be implemented and also agree upon a plan for implementing that change, the Lead Scientist proposes the change to all current CGAC members (via email)
    - The email must clearly describe the change, the rationale for the change, and the process for how the change will be implemented (including a step by step guide and timeline for implementing the change)
    - 5 CGAC members must respond to the email and approve the change
    - Any comments or disagreements from the CGAC committee must be discussed and resolved in real time
  4. If the change is approved by CGAC, all relevant **SOPs are updated** to reflect changes in processes and procedures
  5. If a newly updated SOP requires data validation, **the SOP must be validated** by 3 OncoKB curators or individuals outside the OncoKB staff
    - SOPs that require validation are outlined in [Chapter 5: Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature](#)
  6. The OncoKB staff members **execute the approved change and update the data** in the OncoKB curation platform
  7. **Data is reviewed** and accepted in *Review Mode* in the OncoKB curation platform by a member of the OncoKB staff who did not curate/enter the data into the curation platform (per [Chapter 3: Protocol 1: Data review](#))
  8. **Data is released** to [www.oncokb.org](http://www.oncokb.org) using (per [Chapter 3: Protocol 2: Data release](#))
    - The CGAC-approved change must be implemented and released to the OncoKB public website within 1 year of CGAC approval (Note: some changes may require a faster release period as detailed in [Chapter 5: Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature](#))
      - a. Upon data release, the OncoKB news must clearly highlight:
        - i. the change that has taken place
        - ii. the rationale for that change
      - b. If the change necessitates that data be continually updated throughout the year, this must clearly be stated on the News page on the OncoKB website from the time the change is announced until the change is completed
        - i. For transparency, the following statement must be displayed on the OncoKB “News” page: “We are in the process of making a change to [*describe change*] that will affect certain OncoKB assertions. We anticipate this will take [*estimated time*]. If you have

questions or find any discrepancies in our process or data, please contact us at [contact@oncokb.org](mailto:contact@oncokb.org).

**Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature**

This table details how major findings from the literature may necessitate significant changes to various OncoKB database elements. For each OncoKB database element that may require a significant change, the SOP protocols that require re-evaluation and validation, the data curation elements that require updating, review and release, as well as the process to ensure all changes are accessible and transparent to the public are also described.

	I. OncoKB database elements that may require a significant change  <i>Findings that necessitate a change in:</i>	II. OncoKB data inputs that may be affected	III. Protocols that need to be re-evaluated and/or updated	IV. Does the updated protocol need to be validated?  <i>If yes, note the validation exercise</i>	V. Data elements that may need to be re-evaluated following a significant change to the SOP	VI. Data elements released to the OncoKB website	VII. Accessibility, transparency and timeline for release
1	<i>Distinguishing between variants of possible significance (VPS) and variants of uncertain significance (VUS)</i>	<ul style="list-style-type: none"> <li>Classification of all OncoKB variants as a VUS or VPS</li> <li>If variant is re-categorized from VUS →VPS the following data elements need to be re-assessed: <ul style="list-style-type: none"> <li>--Biological effect</li> <li>--Oncogenic Effect</li> <li>--Tumor-type specific clinical implications, including whether the variant is associated</li> </ul> </li> </ul>	<p><a href="#">Chapter 1:</a> <a href="#">Protocol 2:</a> <a href="#">Variant curation</a></p>	<p>Yes</p> <p><i>Validation Exercise:</i> <a href="#">Chapter 7: Supplemental Material: Table S3: Validation exercise (A) and answer key (B) for defining a variant as a VPS or VUS</a></p> <p>AND</p> <p><a href="#">Chapter 7: Supplemental Material: Table S6: Curation protocol proficiency test: 1. Defining a variant as a VPS or VUS and 2. Assigning a VPS an oncogenic</a></p>	<ul style="list-style-type: none"> <li>Re-classify all VUS's as a VPS or VUS using the updated criteria</li> </ul>	<ul style="list-style-type: none"> <li>Updated variant classification as either a VUS or a curated VPS</li> <li>If variant is re-categorized from VUS →VPS the following data elements need to be re-assessed: <ul style="list-style-type: none"> <li>--Biological effect</li> <li>--Oncogenic Effect</li> <li>--Tumor-type specific clinical</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>When the updated assertion of defining a variant as a VPS or VUS is updated on the OncoKB public website (and the appropriate protocol is updated in the OncoKB SOP), the older version of the SOP protocol for defining a variant as a VPS or VUS will still be publicly accessible</li> <li>The rationale and details for implementing the change in defining a variant as a VUS or VPS will be clearly stated on the OncoKB website</li> <li>When a variant's categorization as a VPS or VUS (and any subsequent data for newly categorized VPSs including a biological or oncogenic effect, or OncoKB or FDA Level of Evidence) is updated and released on the public website, the change and the date of the change</li> </ul>

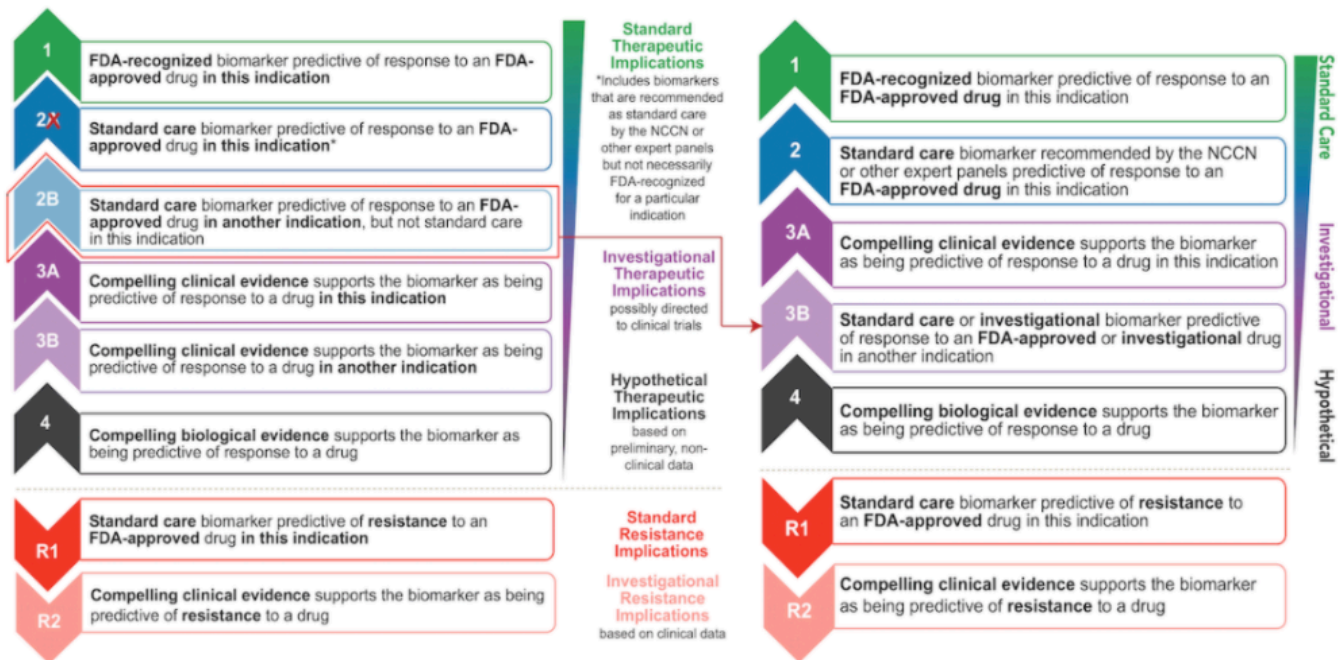
		with an OncoKB Level of Evidence for sensitivity (1, 2, 3A, 4) or resistance (R1 or R2)  --FDA Level of Evidence (if applicable)		<a href="#">and biological effect</a>		implications (if applicable), including whether the variant is associated with an OncoKB LofE for sensitivity (1, 2, 3A, 4) or resistance (R1 or R2)  -- FDA Level of Evidence (if applicable)	will be noted in the website's release notes  • <i>Timeline</i> : data may be continually updated and released to the OncoKB public website throughout the 1 year period following CGAC approval of the change. As data is released, it must be clearly documented on the OncoKB news page
2	<i>Assertion of variant biological effect</i>	<ul style="list-style-type: none"> <li>Biological effect of all variants</li> </ul>	<p><a href="#">Chapter 1: Sub-protocol 1.2.4: Assertion of the biological effect of a VPS</a></p>	<p>Yes</p> <p><i>Validation Exercise:</i></p> <p><a href="#">Chapter 7: Supplemental Material: Table S4 Validation exercise (A) and answer key (B) for Chapter 1, Sub-protocol 2.4: Assertion of the biological effect of a VPS</a></p> <p>AND</p> <p><a href="#">Chapter 7: Supplemental Material: Table S6: Curation protocol proficiency test: 1. Defining a variant as a VPS or VUS and 2. Assigning a VPS an oncogenic and biological effect</a></p>	<ul style="list-style-type: none"> <li>Re-assess and re-assign the biological effect of all OncoKB variants using the updated criteria</li> </ul>	<ul style="list-style-type: none"> <li>Updated biological effect for curated variants (if applicable)</li> </ul>	<ul style="list-style-type: none"> <li>When the updated assertion of a variant's biological (or oncogenic) effect is released on the OncoKB public website (and the appropriate protocols are updated in the OncoKB SOP), the older version of the SOP protocol for assigning a variant a biological (or oncogenic) effect will still be publicly accessible</li> <li>The rationale and details for implementing the change in assigning a variant biological (or oncogenic) effect will be clearly stated on the OncoKB website</li> <li>When a variant's biological (or oncogenic) effect is updated and released on the public website, the change and the date of the change will be noted in the website's release notes</li> <li><i>Timeline</i>: data may be continually updated and released to the OncoKB public website throughout the 1 year period following CGAC approval of the change. As data is released, it must be clearly documented on</li> </ul>
3	<i>Assertion of variant oncogenic</i>	<ul style="list-style-type: none"> <li>Oncogenic effect of all</li> </ul>	<p><a href="#">Chapter 1: Sub-protocol 1.2.5:</a></p>	<p>Yes</p>	<ul style="list-style-type: none"> <li>Re-assess and re-assign</li> </ul>	<ul style="list-style-type: none"> <li>Updated oncogenic effect</li> </ul>	<ul style="list-style-type: none"> <li>When the updated assertion of a variant's biological (or oncogenic) effect is released on the OncoKB public website (and the appropriate protocols are updated in the OncoKB SOP), the older version of the SOP protocol for assigning a variant a biological (or oncogenic) effect will still be publicly accessible</li> <li>The rationale and details for implementing the change in assigning a variant biological (or oncogenic) effect will be clearly stated on the OncoKB website</li> <li>When a variant's biological (or oncogenic) effect is updated and released on the public website, the change and the date of the change will be noted in the website's release notes</li> <li><i>Timeline</i>: data may be continually updated and released to the OncoKB public website throughout the 1 year period following CGAC approval of the change. As data is released, it must be clearly documented on</li> </ul>

	<i>effect</i>	<p>variants</p> <ul style="list-style-type: none"> <li>If a variant is newly categorized as oncogenic or likely oncogenic AND there is an OncoKB leveled association in the specified gene for oncogenic/likely oncogenic variants:</li> <li>Apply the OncoKB Level of Evidence to the variant and</li> <li>Map to the appropriate FDA Level of Evidence (if applicable)</li> </ul>	<p><a href="#">Assertion of the oncogenic effect of a VPS</a></p> <p><a href="#">Chapter 2: Protocol 1: Curation of tumor type specific variant clinical implications (if applicable)</a></p>	<p><i>Validation Exercise:</i></p> <p><a href="#">Chapter 7: Supplemental Material: Table S5: Validation exercise (A) and answer key (B) for Chapter 1, Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a></p> <p>AND</p> <p><a href="#">Chapter 7: Supplemental Material: Table S6: Curation protocol proficiency test: 1. Defining a variant as a VPS or VUS and 2. Assigning a VPS an oncogenic and biological effect</a></p>	<p>the oncogenic effect of all OncoKB variants using the updated criteria</p>	<p>for curated variants (if applicable)</p> <ul style="list-style-type: none"> <li>Updated OncoKB and FDA Level of Evidence for newly assigned oncogenic/likely oncogenic variants (if applicable)</li> </ul>	<p>the OncoKB NEWS page</p>
4	<i>Assigning OncoKB Levels of Evidence (LofE)</i>	<p>OncoKB leveled associations including:</p> <p><i>Sensitivity Levels 1-4</i></p> <p><i>Resistance Levels R1, R2</i></p> <p><i>Associated FDA Levels of Evidence</i></p>	<p><a href="#">Chapter 2: Protocol 1: Curation of tumor type specific variant clinical implications</a></p> <p><a href="#">Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to</a></p>	<p>Yes</p> <p><i>Validation Exercise:</i></p> <p><a href="#">Chapter 7: Supplemental Material: Table S1: Validation exercise (A) and answer key (B) for Chapter 2, Protocol 1: Curation of tumor type specific variant clinical implications and Chapter 2, Protocol 3:</a></p>	<ul style="list-style-type: none"> <li>For all OncoKB leveled assertions, use the updated LofE system to re-evaluate and re-assign an OncoKB and FDA LofE</li> </ul>	<ul style="list-style-type: none"> <li>New LofE system (schematic)</li> <li>Updated level of evidence (using the new leveling system) for all OncoKB leveled associations (if applicable)</li> </ul>	<ul style="list-style-type: none"> <li>The previous version of the OncoKB LofE will still be accessible on the OncoKB website</li> <li>The rationale and details for implementing the change in the LofE will be clearly stated on the website</li> <li><i>Timeline:</i> all data should be released simultaneously to the OncoKB public website within 1 year following CGAC approval of the change</li> </ul>

			<a href="#">FDA Levels of Evidence</a>	<a href="#">Mapping OncoKB Levels of Evidence to FDA Levels of Evidence</a>			
5	<i>Mapping between the OncoKB and FDA Levels of Evidence</i>	FDA leveled assertions	<a href="#">Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence</a>	AND <a href="#">Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence</a>	<ul style="list-style-type: none"> <li>• For all FDA leveled assertions, use the updated mapping system to re-evaluate and re-assign an FDA Level of Evidence</li> </ul>	<ul style="list-style-type: none"> <li>• New mapping criteria between OncoKB and FDA levels of evidence (schematic)</li> <li>• Updated FDA level of evidence (using the new leveling system) for all FDA leveled associations (if applicable)</li> </ul>	<ul style="list-style-type: none"> <li>• When the updated mapping between OncoKB and FDA LofE is released on the OncoKB public website (and the appropriate protocols are updated in the OncoKB SOP), the older version of the mapping will still be publicly accessible</li> <li>• The rationale and details for implementing the change in the mapping between level systems will be clearly stated on the OncoKB website</li> <li>• <i>Timeline</i>: all data should be released to the OncoKB public website simultaneously within 1 year following CGAC approval of the change</li> </ul>

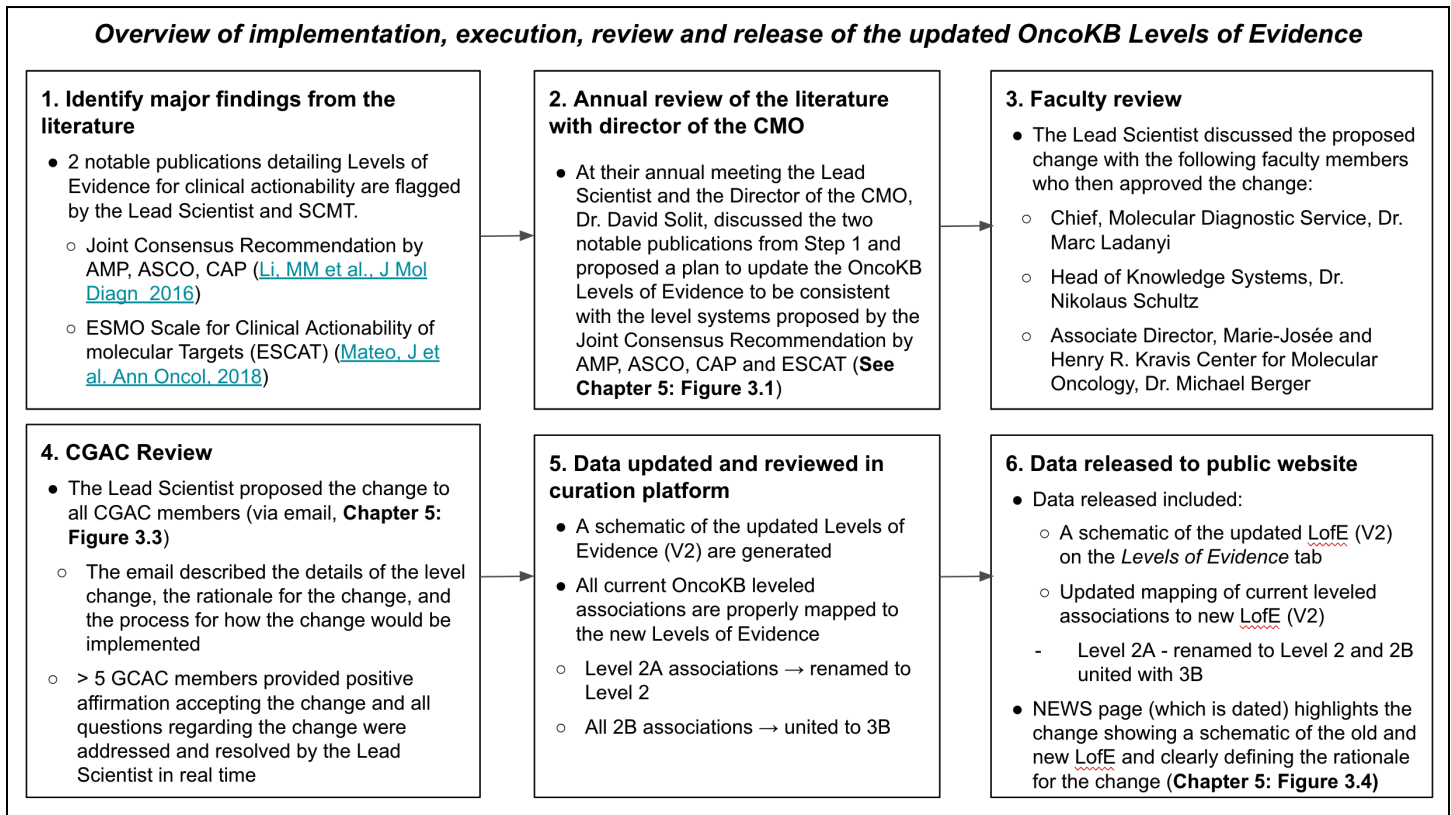


Figure 3.1: Updates to the OncoKB (therapeutic) Levels of Evidence



1. **New Level 2**, defined as “Standard care biomarker recommended by the NCCN or other expert panels predictive of response to an FDA-approved drug in this indication” (formerly Level 2A).
2. **Unified Level 3B**, defined as “Standard care or investigational biomarker predictive of response to an FDA-approved or investigational drug in another indication” (combination of previous Levels 2B and 3B).

**Figure 3.2: Overview of implementation, execution, review and release of the updated OncoKB Levels of Evidence (V2)**



**Figure 3.3: Consensus email to CGAC regarding proposed change to the OncoKB Levels of Evidence**

**[OncoKB Consensus] Proposed Refinement to OncoKB Levels of Evidence**

Dear Colleagues,

We are implementing a refinement to the current OncoKB Levels of Evidence system to be consistent with the [Joint Consensus Recommendation by AMP, ASCO and CAP](#) and the [ESMO Scale for Clinical Actionability of molecular Targets \(ESCAT\)](#).

Please see below our proposed change to the OncoKB Levels of Evidence system (effectively level 2B will be eliminated and investigational Level 3B will now include both 2B and 3B associations):

**Current**

Standard Therapeutic Implications  
Includes biomarkers that are recommended as standard care by the NCCN or other expert panels but not necessarily FDA-recognized for a particular indication

Investigational Therapeutic Implications  
possibly directed to clinical trials

Hypothetical Therapeutic Implications  
based on preliminary, non-clinical data

Standard Resistance Implications

Investigational Resistance Implications  
based on clinical data

**Proposed**

This change is consistent with clinical data that demonstrates patients with investigational predictive biomarkers for a specific tumor type based on **compelling clinical evidence\*** (currently OncoKB Level 3A) are more likely to experience clinical benefit compared to patients with predictive biomarkers that are considered standard care in a different tumor type (currently OncoKB Level 2B).

**\*compelling clinical evidence refers to...**

- 1) retrospective studies showing predictive biomarker positive patients in a specific tumor type experience clinically meaningful benefit with a targeted agent compared with alteration-negative patients (ESCAT);
- 2) prospective clinical trial(s) showing that predictive biomarker positive patients in a specific tumor type results in increased responsiveness when treated with the targeted agent, however, no data is currently available on survival end points (ESCAT)
- 3) Biomarkers that predict response to therapies for a specific type of tumor based on well-powered studies with consensus from experts in the field (AMP, ASCO CAP Joint consensus)

It is therefore anticipated that the newly proposed OncoKB Levels of Evidence system will bring further clarity to clinicians regarding the relative clinical actionability of investigational predictive biomarkers.

**Additionally we propose to shorten the review period for OncoKB consensus emails from 2 weeks to 5 business days. Therefore if you have any comments or suggestions regarding this proposed change, please respond to this email within five business days, by Thursday October 24.**

Thank you,

### Figure 3.4: Transparency and accessibility of old (V1) and new (V2) OncoKB Therapeutic Levels of Evidence on the OncoKB news page

When the updated version of the OncoKB Levels of Evidence (V2) was released to the OncoKB public website in December 2019, the [OncoKB News page](#) was updated to include: 1) an image of both the old (V1) and new (V2) levels of evidence, 2) a detailed description of how the two versions differ and 3) the rationale for the updating the Levels of Evidence.

**December 20, 2019** Data version: v2.0

Introducing Simplified OncoKB Levels of Evidence:

- New Level 2**, defined as "Standard care biomarker recommended by the NCCN or other expert panels predictive of response to an FDA-approved drug in this indication" (formerly Level 2A).
- Unified Level 3B**, defined as "Standard care or investigational biomarker predictive of response to an FDA-approved or investigational drug in another indication" (combination of previous Levels 2B and 3B).

**Standard Therapeutic Implications**  
\*Includes biomarkers that are recommended as standard care by the NCCN or other expert panels but not necessarily FDA-recognized for a particular indication

**Investigational Therapeutic Implications**  
possibly directed to clinical trials

**Hypothetical Therapeutic Implications**  
based on preliminary, non-clinical data

**Standard Resistance Implications**

**Investigational Resistance Implications**  
based on clinical data

**Standard Care**

**Investigational**

**Hypothetical**

We have implemented these changes for 2 reasons:

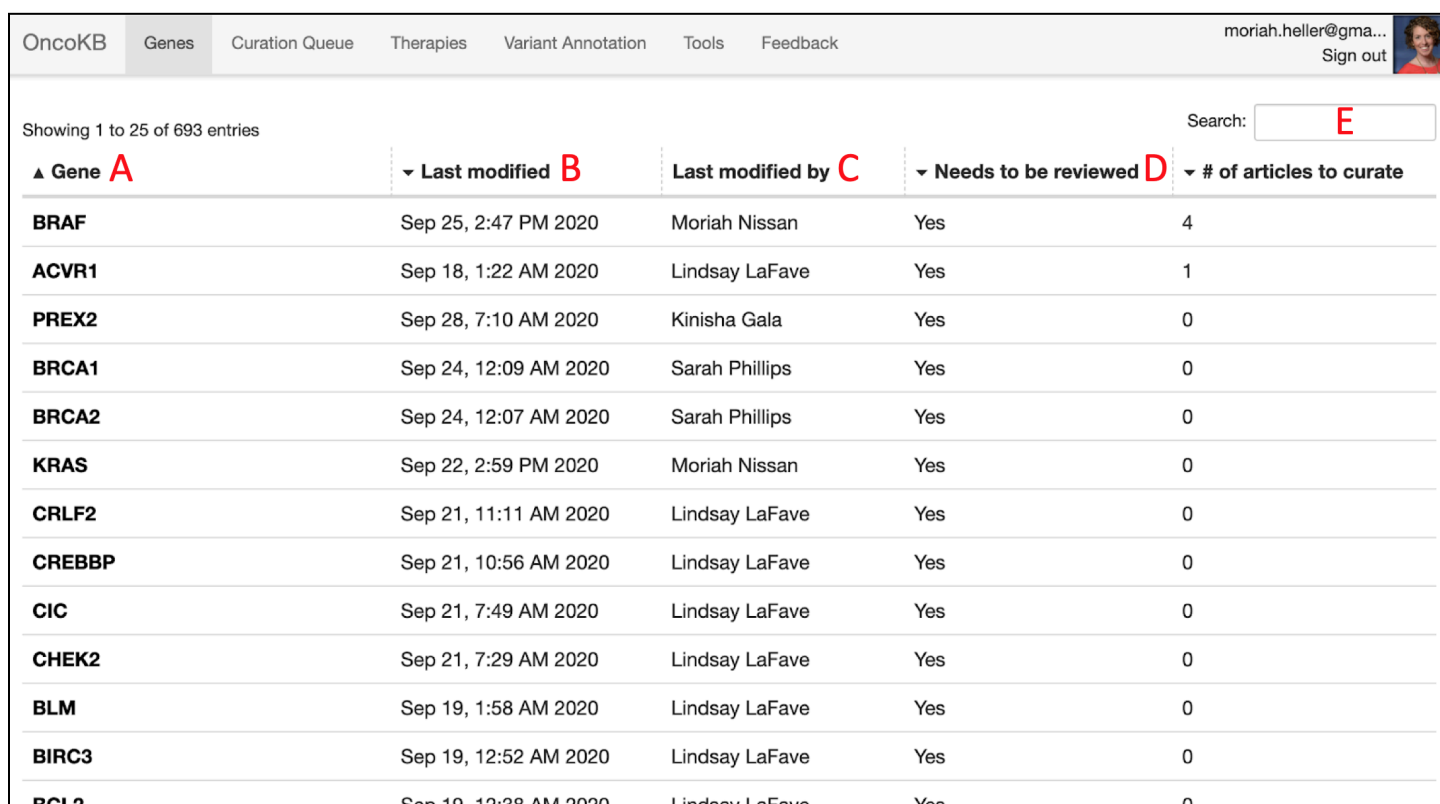
- To be consistent with the [Joint Consensus Recommendation by AMP, ASCO and CAP](#) and the [ESMO Scale for Clinical Actionability of molecular Targets \(ESCAT\)](#)
- To reflect the clinical data that demonstrates patients with investigational predictive biomarkers for a specific tumor type based on compelling clinical evidence (currently Level 3A) are more likely to experience clinical benefit compared to patients with predictive biomarkers that are considered standard care in a different tumor type (previously Level 2B, now combined into Level 3B).

# Chapter 6: OncoKB curation, formatting and nomenclature in the curation platform

## Protocol 1: OncoKB curation platform Homepage

The OncoKB curation platform homepage (<http://oncokb.mskcc.org/curate/#!/genes>) lists all genes in the curation system. The Genes homepage is displayed upon entering the OncoKB curation interface and is the main homepage of the curation interface. This page lists all genes (**Figure 1.1A**) (linking each listed gene to its own Gene Curation Page) in the OncoKB curation system, along with sortable columns containing the following information for each gene:

1. Last modified (**Figure 1.1B**): Timestamp indicating when the Gene Curation Page was last modified
2. Last modified by (**Figure 1.1C**): Name of the last user to edit the page
3. Needs to be reviewed (**Figure 1.1D**): Indicates if there is new content in the Gene Curation Page that needs to be reviewed by the SCMT.
  - Relevant protocols for Data review can be found in [Chapter 3: Protocol 1: Data Review](#)
4. Search Box (**Figure 1.1E**): Allows the user to search for their gene of interest, the last modified user of interest, or the last modified date of interest



OncoKB Genes Curation Queue Therapies Variant Annotation Tools Feedback moriah.heller@gma... Sign out

Showing 1 to 25 of 693 entries Search:

▲ Gene <b>A</b>	▼ Last modified <b>B</b>	Last modified by <b>C</b>	▼ Needs to be reviewed <b>D</b>	▼ # of articles to curate
<b>BRAF</b>	Sep 25, 2:47 PM 2020	Moriah Nissan	Yes	4
<b>ACVR1</b>	Sep 18, 1:22 AM 2020	Lindsay LaFave	Yes	1
<b>PREX2</b>	Sep 28, 7:10 AM 2020	Kinisha Gala	Yes	0
<b>BRCA1</b>	Sep 24, 12:09 AM 2020	Sarah Phillips	Yes	0
<b>BRCA2</b>	Sep 24, 12:07 AM 2020	Sarah Phillips	Yes	0
<b>KRAS</b>	Sep 22, 2:59 PM 2020	Moriah Nissan	Yes	0
<b>CRLF2</b>	Sep 21, 11:11 AM 2020	Lindsay LaFave	Yes	0
<b>CREBBP</b>	Sep 21, 10:56 AM 2020	Lindsay LaFave	Yes	0
<b>CIC</b>	Sep 21, 7:49 AM 2020	Lindsay LaFave	Yes	0
<b>CHEK2</b>	Sep 21, 7:29 AM 2020	Lindsay LaFave	Yes	0
<b>BLM</b>	Sep 19, 1:58 AM 2020	Lindsay LaFave	Yes	0
<b>BIRC3</b>	Sep 19, 12:52 AM 2020	Lindsay LaFave	Yes	0
<b>BCI2</b>	Sep 19, 12:38 AM 2020	Lindsay LaFave	Yes	0

**Figure 1.1: OncoKB Homepage**

(A) Gene list. (B) Timestamp when gene was last modified. (C) User who last modified gene. (D) If the gene has new content that requires review. (E) Search bar for gene or user.

## Protocol 2: Gene curation

- Formatting for gene curation is defined in [Chapter 6: Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform](#)
  - a. A visualization of how to enter a new Gene into the OncoKB platform is detailed in [Chapter 6: Figure 2.1: Gene page](#)
- Designate the gene as an **oncogene**, **tumor suppressor**, **both**, or **neither**
  - a. Protocols to assign gene function can be found in [Chapter 1: Protocol 1: Gene curation](#)
  - b. A visualization of how to enter gene function into the OncoKB curation platform is detailed in [Chapter 6: Figure 2.1: Gene page](#)
- Curate **Gene Summary** for new gene
  - a. The Gene Summary is defined in [Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how to enter the Gene Summary into the OncoKB platform is detailed in [Chapter 6: Figure 2.1: Gene page](#)
- Curate **Gene Background** for new gene
  - a. The Gene Background is defined in [Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how to enter the Gene Background into the OncoKB platform is detailed in [Chapter 6: Figure 2.1: Gene page](#)

### Table 2.1: Examples and formatting of gene-level data inputs in the OncoKB curation platform

The OncoKB curation platform has three gene-level data inputs: 1. Gene Name, 2. Gene Summary, 3. Gene Background, 4. Assertion of gene as an oncogene, tumor suppressor or neither. The table below describes the formatting rules for each gene-level input and provides an example for each.

Gene-level data input	Description and formatting	Example
Gene name	<ul style="list-style-type: none"> <li>• HUGO gene symbol*</li> <li>• Entrez gene aliases</li> <li>• Ensembl transcript ID</li> <li>• RefSeq transcript ID</li> </ul> <p>*Note only the Hugo symbol is manually entered into the OncoKB curation platform. The remaining data points are automatically generated.</p>	<p><i>EGFR</i>  <i>Also known as PIG61, ERBB1, mENA, ERBB, HER1, NISBD2</i>  <i>Isoform: ENST00000275493.7</i>  <i>RefSeq: NM_005228.3</i></p>
Summary	<ul style="list-style-type: none"> <li>• Brief overview of the gene and its role in cancer</li> <li>• 1-2 sentences</li> <li>• No references included</li> </ul>	<p><i>EGFR, a receptor tyrosine kinase, is altered by amplification and/or mutation in lung and brain cancers among others.</i></p>

Background	<ul style="list-style-type: none"> <li>Detailed overview of the biological function of the gene/protein in the normal cell, its role in cancer, and its clinical significance</li> <li>6-10 sentences</li> <li>References included and should primarily come from high impact journals, if possible (see <a href="#">Chapter 1: Table 1.2: Gene data sources</a>)</li> </ul>	<p><i>EGFR (Epidermal Growth Factor Receptor) is a transmembrane receptor that is activated by EGF family extracellular ligands (PMID: 24691965). EGFR is a member of the ErbB family of receptors, including the receptors ERBB2, ERBB3, and ERBB4. Binding of EGFR by its ligands, including EGF ligands and transforming growth factor alpha (TGF<math>\alpha</math>), activates downstream signaling pathways including the canonical MAPK and PI3K/AKT/mTOR signaling cascades (PMID: 22239438). EGFR can homodimerize or heterodimerize with other ErbB family members to initiate signaling (PMID: 25621509). Activation of EGFR-mediated signaling ultimately results in cellular proliferation, migration, and differentiation (PMID: 18045542). While EGFR usually is expressed at low levels in normal adult tissues, hyperactivation of this receptor by somatic mutations and/or amplification of the EGFR gene is found in many cancer types such as lung, brain, colorectal and head and neck cancer (PMID: 10880430, 17318210). In lung cancer, activating mutations in EGFR result in a constitutively activated form of the receptor that is sensitive to EGFR tyrosine kinase inhibition (PMID: 15329413). Tyrosine kinase inhibitors targeting EGFR, including afatinib, erlotinib, and gefitinib, have been approved for first-line treatment of non-small cell lung cancer patients (PMID: 14977817, 24868098, 26039556, 25963089). Second site resistance mutations in EGFR can occur in cancers previously treated with these inhibitors (PMID: 29068003). Osimertinib is a second-line tyrosine kinase inhibitor that has been FDA approved for relapsed patients with non-small cell lung cancer with the EGFR resistance mutations T790M, L858R, and exon 19 deletions (PMID: 27923840). Additionally, copy number amplification of the EGFR gene results in receptor overexpression in several cancer types, including brain and colorectal cancers, and these cancers may also be sensitive to EGFR inhibition (PMID: 11426640).</i></p>
Tumor Suppressor/ Oncogene	<ul style="list-style-type: none"> <li>Genes can be classified as oncogenes, tumor suppressors, both, or neither</li> <li>notated with a checked box</li> <li><a href="#">Chapter 1: Table 1.3: Assertion of the function of a cancer gene</a> should be used to assess OG/TSG</li> </ul>	<p><i>EGFR: Oncogene PTEN: Tumor Suppressor NOTCH1: Both VTCN1: Neither</i></p>



## Sub-Protocol 2.1. Gene Page

The OncoKB Gene Curation Page contains the biological and clinical implications of each gene and its alterations. The Gene Curation Page contains the following sections: Gene name (**Figure 2.1A**), Autopopulated gene information (RefSeq, Isoform, etc) (**Figure 2.1B**), Gene Summary (**Figure 2.1C**), Classification as an Oncogene or Tumor Suppressor Gene (**Figure 2.1D**), Gene Background (**Figure 2.1E**), Variant Curation (**Figure 2.1F**), and VUS Curation (**Figure 2.1G**). Clicking the arrow next to a mutation name reveals the mutation information nested underneath (See [Chapter 6: Figure 3.1.1: Variant Curation](#)). Review mode (covered in [Chapter 6: Sub-Protocol 6.2: Review mode](#)) can be accessed using the “Review” button on the upper right side of the gene page (**Figure 2.1H**). New genes can be added to the system using the “Create Genes” text bar in the tools page (**Figure 2.1I**). Gene curation is covered in [Chapter 1: Protocol 1: Gene Curation](#).

The screenshot displays the OncoKB Gene Curation Page for the gene NTRK2. The page is organized into several sections, each labeled with a letter corresponding to the figure caption:

- A:** Gene name: NTRK2
- B:** Autopopulated gene information: Entrez Gene: 4915, Also known as: TRKB, GP145-TrkB, trk-B, GRCh37 Isoform: ENST00000277120, RefSeq: NM\_006180.3, GRCh38 Isoform: ENST00000277120, RefSeq: NM\_006180.3
- C:** Summary: NTRK2, a receptor tyrosine kinase, is altered by mutation or chromosomal rearrangement in a diverse range of cancers.
- D:** Classification: Tumor Suppressor (unchecked), Oncogene (checked)
- E:** Background: The NTRK2 gene (neurotrophic receptor tyrosine kinase 2) encodes a transmembrane neurotrophic receptor involved in signaling that is important for normal neurologic development (PMID: 8402890, 8145823). NTRK2 consists of an extracellular ligand-binding domain, a transmembrane domain and an intracellular region harboring the tyrosine kinase domain. Normal activation in neural cells occurs upon binding one of its three ligands, the nerve growth factor (NGF), the brain-derived neurotrophic factor (BDNF) or neurotrophin-3 (NT-3), leading to autophosphorylation and activation of downstream signaling pathways controlling and promoting cell proliferation, survival and differentiation via MAPK, PI3K and PLC-γ (PMID: 1649702, 1649703, 10851172). NTRK2 alterations, especially fusions, are found in several human cancers, such as lung cancer, pilocytic astrocytoma, and neuroblastoma (PMID: 25204415, 21242122, 23817572, 8264643, 9049830). Publication IDs: PMID:10851172, PMID:8402890, PMID:8145823, PMID:1649702, PMID:1649703, PMID:25204415, PMID:21242122, PMID:23817572, PMID:8264643, PMID:9049830
- F:** Variants of Unknown Significance (Investigated and data not found): Mutation: R715G, Mutation: R734C, Mutation: M713I, Mutation: Fusions (2x TT, 2x TTS, Levels: 1), Mutation: Oncogenic Mutations (1x TT, 1x TTS), Mutation: ETV6-NTRK2 Fusion
- G:** Variants of Unknown Significance (Investigated and data not found): P169L, QKI-NTRK2 Fusion, NACC2-NTRK2 Fusion, PANS-NTRK2 Fusion, TRIM24-NTRK2 Fusion, SQSTM1-NTRK2 Fusion, AFAP1-NTRK2 Fusion, E84K, E84D, P530S, P530L, V824M, S510L, P287T, A107S, S740N
- H:** Review button
- I:** Create Genes tool

**Figure 2.1: Gene page.** (A) Gene name. (B) Autopopulated gene information. (C) Gene summary. (D) Oncogene/Tumor Suppressor Gene classification. (E) Gene background. (F) Variant Curation. (G) VUS curation. (H) Button to enter Review Mode. (I) “Create Genes” tool in the Tools page.

## Protocol 3: Variant curation

- Formatting for variant curation is defined in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#)
  - a. A visualization of how to enter a new variant into the OncoKB platform in a gene page is detailed in [Chapter 6: Figure 2.1: Gene page](#)
- Curate **Oncogenic Effect** for new variant
  - a. Protocols to determine the Oncogenic effect of a variant can be found in [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#)
  - b. A visualization of how to enter the oncogenic effect into the OncoKB platform is detailed in [Chapter 6: Sub-Protocol 3.1: Mutation header and mutation effect](#)
- Curate **Biological Effect** for new variant
  - a. Protocols to determine the biological effect of a variant can be found in [Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS](#)
  - b. A visualization of how to enter the biological effect is detailed in [Chapter 6: Sub-Protocol 3.1: Mutation header and mutation effect](#)
- Curate **Mutation Effect Description** for new variant
  - a. Protocols to write the mutation effect description can be found in [Chapter 6: Table 3.2: Generation and formatting of mutation effect description](#)
  - b. A visualization of how to enter the mutation effect description is detailed in [Chapter 6: Sub-Protocol 3.1: Mutation header and mutation effect](#)
- If a variant is defined as a **VUS** (as per [Chapter 1: Protocol 2: Variant curation](#)) It must be entered into the VUS section of the gene page on the curation platform
  - a. Protocols to enter VUS can be found in [Chapter 6: Sub-Protocol 3.2: VUS curation](#)
  - b. A visualization of how to enter a VUS into the OncoKB platform is detailed in [Chapter 6: Figure 3.2.1: VUS Curation](#).

### Table 3.1: OncoKB alteration nomenclature, style and formatting

Describes general rules for how to input and format variant-level data in the OncoKB curation platform. Also described is the biological, oncogenic or therapeutic data that may be associated with a variant. Examples of each formatting type in the curation platform are shown in [Chapter 6: Protocol 7: Examples of alteration formatting](#)

	Style and formatting rules for variant-level data in OncoKB curation platform	Nesting of biological/therapeutic information
<b>General variant input rules</b>	Multiple mutations may be grouped together (comma separated) for curation of shared clinical implications and/or tumor type summaries. The oncogenic and mutation effect of each of the mutations should be curated separately.	Must have an associated oncogenic effect, mutation effect, and description of evidence based on the available evidence. References (PMIDs and abstracts) must be included in the description of mutation effect.

			Clinical implications and/or tumor type summaries can also be curated
<b>Alteration codes</b>	<p>a. mis = missense mutation - e.g., 102_292mis [DNA binding domain missense mutations]</p> <p>b. dup = duplication of a specified range - e.g., S501_A502dup</p> <p>c. del = in-frame deletion of a specified range - e.g., P551_E554del</p> <p>d. ins = in-frame insertion - e.g., W557_V559delinsC; e.g.T574insTQLPYD</p> <p>e. delins = in-frame alteration - interpreted by the number of amino acid changes.</p> <p>f. nontrunc = any non-truncating mutation - e.g., R449_E514 nontrunc</p> <p>g. fs = frameshift - e.g., N457Mfs*22</p> <p>h. _splice = splice mutations - e.g., X963_D1010splice or X963_splice</p> <p>i. trunc = truncating mutation - e.g., D286_L292trunc</p> <p>j. 1? = start lost - e.g., M1?</p> <p>k. * = stop gained - e.g., R2019*</p>		
<b>Brackets and parentheses in the mutation header</b>	Square Brackets [ ] - used in the mutation header to rename a curated alteration.	The OncoKB website will display the alteration as the text in the bracket versus variant name (e.g. "Exon 19 insertion" instead of 729_761ins).	
	Parentheses () - used in the mutation header to leave comments.	Any text in () in the mutation header is for administrative purposes only and can only be viewed within the OncoKB curation interface. Does not affect the output of how a mutation is displayed.	
<b>Missense mutations</b>	naming convention for missense mutations is <ref_allele><position><tumor_allele> (e.g., V600E)		Every missense mutation needs to be separately curated with respect to its oncogenic and mutation effect.
	Positional variants, which capture all amino acid substitutions at a given position, can be used for curation of shared clinical implications and/or tumor type summaries (e.g., KRAS G12, BRAF V600).		Do not include curation of oncogenic effect or mutation effect, as this information should be captured under each allele-specific missense mutation for which there is functional data.
<b>Truncating mutations</b>	"Truncating Mutations" can be curated as a specific alteration within a Gene Page. Truncating mutations in a tumor		Must have an associated oncogenic effect, mutation effect,

	<p>suppressor gene include the following mutations: nonsense/frameshift/deletion/splice site mutation</p> <p>All tumor suppressors must have all “Truncating Mutations” curated as likely oncogenic (note exceptions can be made and curated independently at the allele-level).</p>	<p>and description of evidence.</p> <p>Oncogenic and mutation effect should be marked as “Likely Oncogenic “ and “Likely Loss of Function” respectively.</p> <p>Clinical implications and/or tumor type summaries can also be curated under “Truncating Mutations.”</p> <p>The oncogenic effect, mutation effect and clinical implications associated with “Truncating Mutations” can be limited by defining a range for the truncation (e.g., “CCND1 256_286trunc [C Terminal Truncating Mutations]”).</p>
	<p>“Truncating Mutations” include the following based on the Sequence Ontology :</p> <ul style="list-style-type: none"> <li>a. Stop_lost: A sequence variant where at least one base of the terminator codon (stop) is changed, resulting in an elongated transcript</li> <li>b. Start_lost: A codon variant that changes at least one base of the canonical start codon</li> <li>c. Stop_gained: A sequence variant where at least one base of a codon is changed, resulting in a premature stop codon and leading to a shortened transcript</li> <li>d. TFBS_ablation: A feature ablation where the deleted region includes a transcription factor binding site</li> <li>e. Feature_truncation: A sequence variant that causes the reduction of a genomic feature, with regard to the reference sequence</li> <li>f. Frameshift_variant: A sequence variant which causes a disruption of the translational reading frame, i.e., the number of nucleotides inserted or deleted is not a multiple of three</li> <li>g. Transcript_ablation: A feature ablation whereby the deleted region includes a transcript feature</li> <li>h. Splice_donor_variant: A splice variant that changes the 2 base region at the 5' end of an intron</li> <li>i. Splice_region_variant: A sequence variant in which a change has occurred within the region of the splice site, either within 1-3 bases of the exon or 3-8 bases of the intron</li> <li>j. Stop_retained_variant: A sequence variant where at least one base in the terminator codon is</li> </ul>	

	<p>changed, but the terminator remains</p> <p>k. Splice_acceptor_variant: A splice variant that changes the 2 base region at the 3' end of an intron</p> <p>l. Incomplete_terminal_codon_variant: A sequence variant where at least one base of the final codon of an incompletely annotated transcript is changed.</p>	
<b>Fusions</b>	<p>“Fusions” can be curated as a specific gene alteration within a Gene Page, and include any fusion that involves the specified gene</p>	<p>Must have an associated oncogenic effect, mutation effect, and description of evidence.</p>
		<p>Oncogenic and mutation effect should be marked as “Likely Oncogenic “ and “Likely Gain of Function” respectively.</p>
		<p>Clinical implications and/or tumor type summaries can also be curated under “Fusions.”</p>
	<p>Specific fusions, in which both fusion partners are specified, can be curated if there is functional evidence in the literature describing their oncogenic and/or mutation effect. These have the format “GeneA-GeneB Fusion” (e.g. BCR-ABL1 Fusion)</p>	<p>Oncogenic effect, mutation effect, and clinical implications of the specific fusion alteration will be prioritized over those of the “Fusions” alteration.</p>
		<p>Specific fusion names two gene partners, the alteration is only curated in one Gene Page - the gene that is the main driver (or hypothesized to be the main driver) of the fusion oncoprotein</p>
<b>Copy number aberrations</b>	<p>“Amplification” and “Deletion” can be curated as specific gene alterations within a Gene Page if appropriate functional data exists</p>	<p>Must have an associated oncogenic effect, mutation effect, and description of evidence.</p>
		<p>Prognostic implications, clinical implications and/or tumor type summaries can also be curated under “Amplification” and “Deletion.”</p>
<b>In-frame Deletions or Insertions</b>	<p>In-frame deletions or insertions can be curated as a specific gene alteration within a Gene Page</p> <p>All tumor suppressors must have “in-frame Deletions” curated as likely oncogenic (note exceptions can be made and curated independently).</p>	<p>Each curated alteration must have an associated oncogenic effect, mutation effect, and description of evidence.</p>
		<p>Clinical implications and/or tumor type summaries can also be curated under an in-frame deletion</p>
	<p>1. “del” = in-frame deletion (e.g., P551_E554del, P191del)</p>	

	<p>2. “ins” = in-frame insertion (e.g., T574insTQLPYD)</p> <p>3. “delins” = a specified in-frame alteration. Whether the alteration is an in-frame deletion or in-frame insertion is determined by the specified number of amino acid changes</p> <p>*For specific in-frame deletions or insertions the reference allele must always be specified in the variant name (e.g. L12_L18del and NOT 12_18del)</p>	or insertion.	
<b>Mutation Ranges</b>	<p>Mutation ranges, which capture all amino acid substitutions in a specified amino acid range, can be used (e.g., TP53 102_292mis [TP53 DNA binding domain mutations]).</p> <p>Any mutation within the range will be mapped/associated with the biological and oncogenic effect and clinical implications assigned to the range mutation</p> <p>*For range mutations, the reference allele should not be specified</p>	<p>Must have an associated oncogenic effect, mutation effect, and description of evidence based on the available evidence. References (PMIDs and abstracts) must be included in the description of mutation effect.</p> <p>Clinical implications and/or tumor type summaries can also be curated</p>	
<b>Oncogenic Mutations</b>	<p>can be curated as a specific gene alteration within a Gene Page.</p> <p>is used when there is tumor-specific information that applies to ALL functional (oncogenic/likely oncogenic) alterations within a Gene Page.</p>	<p>The tumor-specific information will automatically get linked to all mutations in the Gene Page that have the “Yes” or “Likely” boxes checked next to the Oncogenic label.</p>	<p>If a gene has “Amplification” curated as “Oncogenic” or “Likely Oncogenic”, this alteration will NOT be associated with the tumor-type specific information under “Oncogenic Mutations.”</p>
<b>Excluding a mutation</b>	<ol style="list-style-type: none"> <li>Oncogenic Mutations {excluding V600E}</li> <li>Oncogenic Mutations {excluding V600E, V600K}</li> </ol>	<ol style="list-style-type: none"> <li>Will include all oncogenic and likely oncogenic mutations except V600E</li> <li>Will include all oncogenic and likely oncogenic mutations except V600E and V600K</li> </ol>	
<b>Hard-coded Alteration Names</b>	<p>Alterations that do not follow the above nomenclature are not supported unless they are hard coded.</p>	<ol style="list-style-type: none"> <li>FLT3: internal tandem duplication</li> <li>EGFR: vIII</li> <li>EGFR: Kinase domain duplication</li> <li>EGFR: C-terminal domain</li> </ol>	
<b>Citation Type</b>	<b>Format</b>	<b>Example</b>	
<b>Publication in PubMed</b>	(PMID: #####)	(PMID: 28890946)	

<b>Conference Abstract</b>	(Abstract: Author et al. Abstract# ###, Meeting, Year. URL).	(Abstract: Suehnholz et al. Abstract# 3208, AACR 2020. <a href="https://cancerres.aacrjournals.org/content/80/16_Supplement/3208">https://cancerres.aacrjournals.org/content/80/16_Supplement/3208</a> )
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### Table 3.2: Generation and formatting of mutation effect description

The mutation effect description provides a brief overview of the biological and oncogenic effect of the VPS and includes appropriate references to peer-reviewed literature. The format, which is standardized across all variants, is outlined in the table below.

Sentence number	General information to be included	Specific details on information to be included	Is the sentence required?	Specific examples of information to be included in each section of the mutation effect description (the OncoKB curated mutation NTRK1 G595R is used as an example)
1	Gene, variant, domain	<ul style="list-style-type: none"> <li>Conveys positional information</li> <li>Includes exon for relevant genes (e.g. KIT, EGFR)</li> <li>Does not include references</li> </ul>	Y	The NTRK1 G595R mutation is located in the kinase domain of the NTRK1 protein.
2	Tumor types in which it is found	<ul style="list-style-type: none"> <li>Highlights most prominent tumor type(2)</li> <li>Can include germline syndromes (e.g. Noonan Syndrome) when applicable</li> <li>Includes references<sup>1</sup></li> </ul>	N	This mutation has been found in colorectal cancers, among others (PMID: 26546295, 29466156).
3	Biological and oncogenic effect	<ul style="list-style-type: none"> <li>Describes the data used to assign the biological effect and oncogenic effect</li> <li>Includes mutation affect (e.g. inactivating, neutral) as well as the evidence type (e.g. downstream pathway activation)</li> <li>Includes references</li> </ul>	Y	In vitro studies have demonstrated that this mutation is activating as measured by increased ATP affinity and kinase activity compared to wildtype (PMID: 28578312).
4	Preclinical drug sensitivity and/or resistance	<ul style="list-style-type: none"> <li>Describes the data in preclinical drug or biomarker studies</li> <li>Includes mutation effect (sensitivity or resistance) as well as the evidence type (e.g. growth arrest in presence of drug)</li> <li>Includes references</li> </ul>	N	Structural modeling shows that the G595R mutation induces steric clashes with larotrectinib; however, the TRK inhibitor LOXO-195 is able to accommodate bulky side chains without steric clashes, and shows inhibitory activity against the NTRK1 G595R mutation (PMID: 28578312).
5	Clinical drug sensitivity and/or resistance	<ul style="list-style-type: none"> <li>Describes the patient data in clinical drug or biomarker studies</li> <li>Includes the number of</li> </ul>	N	The NTRK1 G595R mutation has also been identified in patients as a resistance mutation to kinase inhibitors like entrectinib and

		<p><i>patients, the disease type, the trial type (if applicable) and the response</i></p> <ul style="list-style-type: none"> <li>• <i>Includes references</i></li> </ul>		<p><i>larotrectinib (PMID: 26546295, 29466156).</i></p>
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<sup>1</sup>References are formatted uniformly and according to the instruction outlined in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#)



## Sub-Protocol 3.1: Mutation header and mutation effect

All alterations in OncoKB are named (**Figure 3.3.1A**) and entered into the gene page of the curation platform based on the formatting and nomenclature rules outlined in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#), and are classified according to 1) their oncogenic effect (**Figure 3.3.1B**) and 2) their biological effect (**Figure 3.3.1C**), based on the curated evidence, which is described (**Figure 3.3.1D**) as outlined in [Chapter 6: Table 3.2: Generation and formatting of mutation effect description](#). Sources in the description that are formatted according to [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#) are automatically listed below the variant description (**Figure 3.3.1E**) and link out to PubMed or the abstract webpage, whichever is applicable. Tumor type (**Figure 3.3.1F**) and other therapeutic evidence can be further curated underneath the alteration node (See [Chapter 6: Protocol 4: Tumor type curation](#) and [Chapter 6: Protocol 5: Therapy curation](#)). The tumor type and therapeutic information nested under a mutation is summarized on the right side of the mutation node (**Figure 3.3.1G**). Alteration order on the gene page can be changed by clicking on the arrows on the right side of the alteration node (**Figure 3.3.1H**) and subsequently clicking on the desired place for the mutation on the gene page. Clicking the trash icon (**Figure 3.3.1I**), also on the right side of the node, will delete the mutation and all its nested information, which must be reviewed in Review mode ([Chapter 6: Sub-Protocol 6.2: Review mode](#)) before it is changed in any OncoKB outputs (OncoKB public website, cBioPortal, MSK-IMPACT reports, OncoKB API, etc).

**A** Mutation: G595R **G** 1x TT, 1x TTS, Levels: R2 **H I**

**B** **C** **D** **E** **F**

**▼ Mutation Effect**

Oncogenic:  Yes  Likely  Likely Neutral  Inconclusive

Mutation effect:  Gain-of-function  Likely Gain-of-function  Loss-of-function  Likely Loss-of-function  Switch-of-function  
 Likely Switch-of-function  Neutral  Likely Neutral  Inconclusive

**Description of Evidence:**  
The NTRK1 G595R mutation is located in the kinase domain of the NTRK1 protein. This mutation has been found in colorectal cancers, among others (PMID: 26546295, 29466156). In vitro studies have demonstrated that this mutation is activating as measured by increased ATP affinity and kinase activity compared to wildtype (PMID: 28578312). The NTRK1 G595R mutation has also been identified in patients as a resistance mutation to kinase inhibitors like entrectinib and larotrectinib (PMID: 26546295, 29466156). Structural modeling shows that the G595R mutation induces steric clashes with larotrectinib. However, the TRK inhibitor LOXO-195 is able to accommodate bulky side chains without steric clashes, and shows inhibitory activity against the NTRK1 G595R mutation (PMID: 28578312).  
Publication IDs: [PMID:26546295](#) [PMID:29466156](#) [PMID:28578312](#)

**Additional Information (Optional):**

**> Tumor type: All Solid Tumors** 1x TTS, 1x Level R2

**Add tumor type(s)**

Cancer Type:  Subtype:

### **Figure 3.1.1: Variant Curation.**

(**A**) Alteration name. (**B**) Oncogenic Effect. (**C**) Mutation Effect. (**D**) Description of evidence. (**E**) Publication IDs. (**F**) Tumor Type. (**G**) Tumor Type and Therapeutic information summary. (**H**) Button to change alteration order on the gene page. (**I**) Trash icon to delete an alteration from the gene page.

## Sub-Protocol 3.2: VUS curation

VUS are added to a unique section within the OncoKB Gene Curation Page called “Variants of Unknown Significance (Investigated and data not found)” ( See [Chapter 6: Sub-Protocol 2.1. Gene Page](#)). Once a VUS is added (**Figure 3.2.1H**), it is linked to a timestamp displaying the date the VUS was last edited. If a VUS on the Gene Curation Page is investigated at a future date and still no data is found, the “Refresh” button (**Figure 3.2.1A**) can be clicked to update the timestamp associated with the VUS in question. If the VUS becomes a VPS, it can be curated in the mutation section of the gene page ([Chapter 6: Protocol 3: Variant curation](#)) and deleted from the VUS section (**Figure 3.2.1C**). A VUS name can be edited using the edit button (**Figure 3.2.1D**).

VUS are alterations for which limited or no information is publicly available and falls into one of two possible classes (detailed in [Chapter 1: Protocol 2: Variant curation](#)):

1. No data exists.

2. The variant has been identified within a tumor, but not functionally tested (in this case, the comment bubble (**Figure 3.2.1B**) for each variant lists the appropriate publications for SCMT reference).

A VUS on the Gene Curation Page entered:

1. Grey = Curated < 3 months prior to the current date (**Figure 3.2.1G**)
2. Yellow = Curated 3 > 6 months prior to the current date (**Figure 3.2.1F**)
3. Red = Curated > 6 months prior to the current date. (**Figure 3.2.1E**)

**Figure 3.2.1: VUS Curation.**

(A) Refresh button for the VUS timestamp. (B) Comment bubble for notes or PMIDs. (C) Delete button. (D) Edit button for VUS name. (E) Red VUS curated >6 months ago. (F) Yellow VUS curated 3>6 months ago. (G) Grey VUS curated <3 months ago. (H) Text box to add a new VUS.

## Protocol 4: Tumor type curation

- Protocols for selecting tumor type are described in [Chapter 1: Protocol 3: Tumor type assignment](#) and [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
- A visualization of how to enter a new tumor type into the OncoKB platform in a gene page under a variant header is detailed in [Chapter 6: Figure 4.1: Tumor type curation](#).

Tumor types are split into main cancer type (**Figure 4.1A**) and cancer subtype (**Figure 4.1B**), are nested under the Alteration node and can be selected from a drop-down list (as shown in **Figure 4.1B**).

Nested under the Tumor Type node (**Figure 4.1C**) are the elements associated with a Tumor Type, including a Therapeutic summary (**Figure 4.1D**), Diagnostic and Prognostic summary (**Figure 4.1E**; only applicable to liquid tumors), Diagnostic and Prognostic implications (**Figure 4.1F**; applicable only to liquid tumors), and Therapeutic implications (**Figure 4.1G**; as described in [Chapter 6: Protocol 5: Therapy curation](#)).

The Tumor Type “Other Tumor Types” (**Figure 4.1H**) should only be curated to add a therapeutic summary, which propagates for any tumor type not given its own node under that alteration.

The screenshot displays the 'Add tumor type(s)' section of the OncoKB platform. It features two dropdown menus for selecting a tumor type. The first dropdown, labeled 'A', is set to 'Bladder Cancer'. The second dropdown, labeled 'B', is set to 'Bladder Urothelial Carcinoma'. Below these dropdowns is a search bar and a list of tumor types, with 'Bladder Urothelial Carcinoma' highlighted. To the right of the list, there are two rows of information: '2x TT, 2x TTS, Levels: 1' and '2x TT, 2x TTS, Levels: 1, R1'. The interface also shows a list of mutations: 'Mutation: G719', 'Mutation: T790M', and 'Mutation Effect'.

**C** Tumor type: Non-Small Cell Lung Cancer 1x TTS, 1x Level 1; 1x Level R1

**D** Therapeutic Summary (Optional):  
The EGFR tyrosine kinase inhibitor (TKI) osimertinib is FDA-approved for the treatment of patients with metastatic EGFR T790M mutant non-small cell lung cancer (NSCLC) who have progressed on or after other EGFR TKI therapies. Patients with EGFR T790M mutant NSCLC do not respond to the EGFR TKI therapies erlotinib, afatinib and gefitinib.

**E** Diagnostic Summary (Optional):  
Prognostic Summary (Optional):

**F** > Diagnostic implications: No Entry  
> Prognostic implications: No Entry

**G** > Standard implications for sensitivity to therapy:  
> Standard implications for resistance to therapy:  
> Investigational implications for sensitivity to therapy: No Entry  
> Investigational implications for resistance to therapy: No Entry

**H** > Tumor type: Other Tumor Types 1x TTS

**Figure 4.1: Tumor type Curation.**

(A) Main Cancer type. (B) Cancer subtype. (C) Tumor Type node. (D) Therapeutic summary. (E) Diagnostic and Prognostic summaries (Liquid only). (F) Diagnostic and Prognostic implications (Liquid only). (G) Therapeutic implications. (H) Tumor type “Other Tumor Types” (For Therapeutic summary only).

A tumor type can be modified once it is already in the curation system (Figure 4.2A).

Tumor types can also be excluded by using the “EXCLUSION” feature (Figure 4.2B). For example, a therapeutic implication may apply to “All Solid Tumors” excluding Colorectal Cancer, and this feature allows the user to curate this use case by choosing “Colorectal Cancer” in the “Tumor type Exclusion” drop-down box.

**A.**

**Modify Cancer Types**

Select cancer types for INCLUSION

Cancer Type: All Solid Tumors Subtype: Choose a tumor type

Cancer Type: Choose a main tumor type Subtype: Choose a tumor type

**B.**

Select cancer types for EXCLUSION

---

Cancer Type:  Subtype:

**Colorectal Adenocarcinoma**

**Figure 4.2: Modifying a Tumor Type and Tumor Type Exclusion**

(A) Modifying a tumor type. (B) Excluding a tumor type.

# Protocol 5: Therapy curation

- Formatting for therapy curation is defined in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
- A visualization of how to enter a new therapy into the OncoKB curation platform therapy database is detailed in [Chapter 6: Sub-Protocol 5.2: Curated therapies page](#)
- Protocols to determine whether the biomarker/therapeutic can be given an oncoKB level of evidence can be found in [Chapter 2: Protocol 1: Curation of tumor type specific variant clinical implications](#)
- Protocols to obtain CGAC approval for a biomarker/therapeutic that warrants a Level of Evidence can be found in [Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#)
- Curate a **GCAC-approved therapeutic** for a variant
  - a. A visualization of how to enter an OncoKB leveled therapeutic into the OncoKB platform under its relevant alteration and tumor type is detailed in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#)
- Choose the Relevant **Therapeutic type (standard or investigational)**
  - a. Explanation of standard versus investigational therapeutic type can be found in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how standard and investigational therapeutics are organized in the OncoKB platform under a relevant alteration and tumor type is detailed in [Chapter 6: Figure 5.1.1: Entering therapies in the gene page](#).
- Input the **therapeutic** into the gene page under the appropriate gene, alteration, tumor type, and therapeutic type
  - a. Nomenclature and formatting for inputting therapeutic names can be found in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how to input therapeutics is detailed in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#)
- Select the **GCAG-approved level of evidence**, as well as the level of evidence to **propagate to other tumor types**
  - a. Explanation of level propagation to other tumor types can be found in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how to select level and tumor type in the curation platform can be found in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#)
- Write and enter the **therapeutic description of evidence**

- a. Formatting for the description of evidence can be found in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
  - b. A visualization of how to enter the description into the curation platform can be found in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#)
- Write and enter a **tumor type therapeutic summary**
    - a. Formatting for the tumor type therapeutic summary can be found in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#)
    - b. A visualization of how to enter the summary into the curation platform can be found in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#)

### Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform

The OncoKB curation platform has multiple tumor-type and therapy level inputs under a mutation header on a gene page that are required to curate a therapeutic with a level of evidence. The format for all the input nodes are below. Visualization of these features in the curation platform is outlined in [Chapter 6: Sub-Protocol 5.1: Therapy selection](#).

Therapy-level data input	Description and formatting	Example
Tumor Type	<ul style="list-style-type: none"> <li>• Dropdown menu for main tumor type and subtype, both populated by Oncotree</li> <li>• Main type and subtype must be in agreement according to the tumor type in Oncotree</li> <li>• One or multiple tumor types can be listed in the same tumor type heading</li> </ul> <p>*Non-small cell lung cancer must be entered as a main type even though it also exists as a subtype  **Inclusive headings may be used, such as “All Solid Tumors”  *** “Other Tumor Types” is used only for Therapeutic Summary purposes</p>	<p><i>Cancer Type: Bladder Cancer  Subtype: Urothelial Carcinoma</i></p> <p>-OR-</p> <p><i>Cancer Type: Non-Small Cell Lung Cancer  Subtype: None</i></p>
Therapeutic (Tumor Type) summary	<ul style="list-style-type: none"> <li>• Description summarizing the therapeutics used for the indicated variant-tumor type association</li> <li>• Mentions evidence level (e.g. FDA-approved, investigational, preclinical)</li> <li>• 1-2 sentences</li> <li>• No references included</li> <li>• May include OncoKB curation programming language as defined in <a href="#">Chapter 6: Protocol 8: Table 8.1: OncoKB Curation Programming Language</a></li> </ul> <p>* A therapeutic summary nested under the tumor type</p>	<p><b><i>For tumor type “Melanoma”:</i></b> “The RAF-targeted inhibitors encorafenib, dabrafenib and vemurafenib alone or in combination with the MEK-targeted inhibitors binimetinib, trametinib and cobimetinib, respectively, are FDA-approved for the treatment of patients with BRAF V600E/K mutant melanoma.”</p> <p>-OR-</p> <p><b><i>For tumor type “Other Tumor Types”:</i></b></p>



	<p>“Other Tumor Types” will be included for that variant in any tumor type other than those explicitly listed under the variant and given their own therapeutic summary</p>	<p><i>“While the RAF-targeted inhibitor dabrafenib in combination with the MEK1/2-targeted inhibitor trametinib is FDA-approved for the treatment of patients with BRAF V600E mutant melanoma, non-small cell lung cancer and anaplastic thyroid cancer, the clinical utility of dabrafenib in combination with trametinib in patients with [[variant]] has yet to be defined.”</i></p>
Therapeutic Type	<ul style="list-style-type: none"> <li>• Nested under the Tumor Type, it is a heading under which a therapeutic must be curated</li> <li>• Describes the category of evidence level implications for variant-tumor type-therapeutic association as either standard (levels 1 or 2) or investigational (levels 3A or 4)</li> <li>• Describes the type of variant-tumor type-therapeutic association as either sensitivity (levels 1-4) or resistance (levels R1 and R2)</li> </ul>	<p><i>Standard implications for sensitivity to therapy</i></p> <p><i>Standard implications for resistance to therapy</i></p> <p><i>Investigational implications for sensitivity to therapy</i></p> <p><i>Investigational implications for resistance to therapy</i></p>
Therapy	<ul style="list-style-type: none"> <li>• Free-text that auto-populates a drop-down list of therapies curated in the OncoKB Curated Therapies page of the curation platform (see <a href="#">Chapter 6: Sub-Protocol 5.2: Curated therapies page</a>)</li> <li>• Selected therapy will be linked to all other aliases via NCI Thesaurus Code</li> <li>• Multiple therapies can be listed in the same line (e.g “Therapy 1”) to denote a combination regimen, which will display with a “+” sign</li> <li>• Multiple therapies of the same class being given the same level of evidence for the variant-tumor type-therapeutic association can be listed in separate lines (e.g “Therapy 1”, “Therapy 2”) in order to curate the level of evidence for the whole group as separate regimens, which will display with a “,”</li> </ul>	<p><i>“Vemurafenib”</i></p> <p><i>“Encorafenib + Binimetinib”</i></p> <p><i>“Binimetinib, Cobimetinib, Trametinib”</i></p>
Level of Evidence	<ul style="list-style-type: none"> <li>• Denotes the level of evidence that was CGAC approved for the variant-tumor type-therapeutic association</li> <li>• Select level from dropdown list</li> </ul>	<p><i>1- FDA-recognized biomarker predictive of response to an FDA-approved drug in this indication</i></p>
Level propagation in solid and liquid tumors	<ul style="list-style-type: none"> <li>• Denotes the level, if any, to which the therapeutic should be propagated in tumor types other than those specified in the CGAC-approved association</li> <li>• Selected from a dropdown list</li> <li>• Associations in solid tumors will by default propagate to 3B in other solid tumor types. One can change this to propagate as level 4 or no level.</li> <li>• Associations in solid tumors will by default not propagate to liquid tumors. One can change this to propagate as level 3B or level 4.</li> </ul>	<p><i>Level of evidence in other solid tumor types: Level 3B</i></p> <p><i>Level of evidence in other liquid tumor types: No level</i></p>

	<p>Variants associated with resistance to a therapeutic in a given tumor type (Level R1 or R2) do not propagate to other tumor types</p>	
Description	<ul style="list-style-type: none"> <li>• Describes the major data and publications supporting the variant-tumor type-therapeutic association</li> <li>• Free text</li> <li>• 3-4 sentences</li> <li>• Includes references</li> </ul> <p>*For level 1 associations, the data/citation used in the description should be the major trial on which the FDA-approval was based</p>	<p><i>Pemigatinib, a small molecule inhibitor of the FGFR kinases, is FDA-approved for the treatment of adults with previously treated, advanced cholangiocarcinoma with an FGFR2 fusion or other FGFR2 rearrangement. FDA-approval was based on the results of the Phase II FIGHT-202 trial of pemigatinib in 107 patients with cholangiocarcinoma harboring an FRFG2 fusion or FGFR2 rearrangement in which the overall response rate was 35.5% (38/107; 95% CI: 26.5 - 45.4), the disease control rate was 82% (88/107; 95% CI: 74-89), the median progression-free survival was 6.9 months (95%CI: 6.2-9.6) and the median overall survival was 21.1 months (95% CI: 14.8-NE) (PMID: 32203698). Of patients who responded, three patients had complete response (2.8%), 35 patients had partial response (32.7%) and 50 patients had stable disease (46.67%) (PMID: 32203698).</i></p>

## Sub-Protocol 5.1: Therapy selection

Therapies are entered under the appropriate Therapeutic Type (**Figure 5.1.1A**), detailed in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#). Therapies are entered as free text and then selected from automatic dropdowns (**Figure 5.1.1B**) which match to OncoKB curated therapeutics using NCI Thesaurus Codes. A list of all therapies curated in OncoKB can be found in the “Therapies” page outlined in [Chapter 6: Sub-Protocol 5.2: Curated therapies page](#).

The screenshot displays the OncoKB curation interface for a gene page. At the top, the tumor type is set to "Non-Small Cell Lung Cancer" with associated evidence levels: "1x TTS, 1x Level 1; 1x Level R1".

**Panel A:** Shows the "Standard implications for sensitivity to therapy" section. A dropdown menu is open, displaying "Therapy: Osimertinib".

**Panel B:** Shows the "Add Therapies" section. A search bar contains the letter "G". A dropdown menu is open, listing several therapeutics:

- Gilteritinib**: Also known as 6-Ethyl-3-((3-methoxy-4-(4-(4-methylpiperazin-1-yl)piperidin-1-yl)phenyl)amino)benzoic acid
- GSK2636771**: Also known as GSK2636771
- Gefitinib**: Also known as GEFITINIB, Iressa, N-(3-chloro-4-fluorophenyl)-7-methoxy-6-[3-(4-morpholinyl)pyridin-2-yl]pyridin-4-amine
- GDC-0077**: Also known as RO 7113755, GDC 0077, GDC-0077, RG 6114, GDC0077, RG-6114, RO-6114
- Vismodegib**: Also known as GDC-0449, 2-chloro-N-[4-chloro-3-(pyridin-2-yl)phenyl]-4-(methylsulfonyl)benzamide
- Carboplatin-Taxol Regimen**: Also known as carboplatin-Taxol regimen, CaT regimen, PC Regimen, Carbo-Tax regimen

At the bottom, the tumor type is set to "Other Tumor Types" with "1x TTS" evidence level.

**Figure 5.1.1: Entering therapies in the gene page.**

(A) Therapeutic type, under which therapies are entered into the gene page. (B) Automatic dropdown that populates when letters in a therapeutic are entered into the text bar. Therapeutics can be entered on the same therapy line (A) to indicate a combination regimen (displayed with a “+”: X + Y) or on separate lines (B) to denote drugs of the same class being associated with the same level of evidence (displayed with a “,”: X, Y) as outlined in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#) and as displayed in C.

**Add Therapies** C

The result will be shown as **Gefitinib + Crizotinib, Erlotinib**

**A** Therapy 1:

**B** Therapy 2:

Therapy 3:

To add a new drug not found in the drop-down list, [click here](#)

**Figure 5.1.2: Entering therapies to denote combination regimens and therapies clustered from the same class.**

(A) Therapies in a combination regimen (X+Y). (B) Therapies clustered (X, Y).

Nested under the appropriate Therapeutic Type (**Figure 5.1.3A**) is a dropdown (**Figure 5.1.3B**) listing the levels of evidence that fall under that category: standard (levels 1, 2 or R1) or investigational (levels 3A, 4 or R2), and sensitivity (levels 1-4) or resistance (levels R1 and R2). Therapeutic Type can be selected as outlined in [Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform](#). The CGAC-approved level of evidence for a given therapy can be selected from the dropdown.

**A**  Standard implications for sensitivity to therapy:

Therapy: Osimertinib

**B** Highest level of evidence:

2 - Standard care biomarker recommended by the NCCN or other expert panels predictive of response to an FDA-approved drug in this indication

**FDA approved indications:**

FDA granted accelerated approval to osimertinib once daily tablets for the treatment of patients with metastatic EGFR T790M mutation-positive non-small cell lung cancer (NSCLC), as detected by an FDA-approved test, who have progressed on or after EGFR tyrosine kinase inhibitor (TKI) therapy.

**Description of Evidence:**

Osimertinib is a third generation EGFR tyrosine kinase inhibitor (TKI) that inhibits T790M-mutant EGFR and is FDA-approved for the treatment of patients with metastatic EGFR T790M mutation-positive non-small cell lung cancer (NSCLC) who have progressed on prior EGFR TKI therapy. FDA-approval was based on the results of the Phase I AURA study of osimertinib in 127 patients with T790M mutation-positive NSCLC (PMID: 25923549) and the Phase II AURA2 study of osimertinib in 210 patients with T790M mutation-positive NSCLC (PMID: 27751847). In the Phase I dose-escalation and dose-expansion studies, the response rate was 61% (95% CI 52-70) among patients with T790M mutations, with a median progression-free survival (PFS) of 9.6 months (95% CI 8.3-na)

**Figure 5.1.3: Selection of a level of evidence.**

(A) Therapeutic Type under which drugs are curated. (B) Dropdown with the relevant level of evidence choices for the given therapeutic type.

Within the Therapy node are dropdowns for the highest level of evidence (Figure 5.1.4A), the level to propagate in other solid (Figure 5.1.4B) or other liquid tumor types (Figure 5.1.4C), and free text sections for the description of evidence (Figure 5.1.4D), all as described in Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform. Areas for “FDA-approved indication” and “Additional information” are both for internal use only and do not appear in any OncoKB outputs (e.g MSK-IMPACT reports, cBioPortal or OncoKB.org).

Standard implications for sensitivity to therapy:

Therapy: Osimertinib

**Highest level of evidence:**

A 1 - FDA-recognized biomarker predictive of response to an FDA-approved drug in this indication

**Level of Evidence in other solid tumor types:**

B Level 3B

**Level of Evidence in other liquid tumor types:**

C No level

**FDA approved indications:**

FDA granted accelerated approval to osimertinib once daily tablets for the treatment of patients with metastatic EGFR T790M mutation-positive non-small cell lung cancer (NSCLC), as detected by an FDA-approved test, who have progressed on or after EGFR tyrosine kinase inhibitor (TKI) therapy.

**Description of Evidence:**

D Osimertinib is a third generation EGFR tyrosine kinase inhibitor (TKI) that inhibits T790M-mutant EGFR and is FDA-approved for the treatment of patients with metastatic EGFR T790M mutation-positive non-small cell lung cancer (NSCLC) who have progressed on prior EGFR TKI therapy. FDA-approval was based on the results of the Phase I AURA study of osimertinib in 127 patients with T790M mutation-positive NSCLC (PMID: 25923549) and the Phase II AURA2 study of osimertinib in 210 patients with T790M mutation-positive NSCLC (PMID: 27751847). In the Phase I dose-escalation and dose-expansion studies, the response rate was 61% (95% CI 52-70) among patients with T790M mutations, with a median progression-free survival (PFS) of 9.6 months (95% CI 8.3-na) versus 2.8 months (95% CI 2.1-4.3) in patients without T790M mutations (PMID: 25923549). In the Phase II single-arm study of patients with T790M-positive NSCLC who progressed on previous EGFR TKI therapy, six of 199 patients (3%) achieved a complete response and 134 of 199 patients (67%) achieved a partial response, with a median PFS in the study of 9.9 months (95% CI 8.5-12.3) (PMID: 27751847). Since its FDA-approval, a Phase II trial of osimertinib as a first-line therapy in patients with metastatic EGFR exon 19 deletion or L858R mutation-positive NSCLC showed significantly longer PFS with osimertinib versus erlotinib or gefitinib (18.9 months vs. 10.2 months; HR= 0.46; 95% CI 0.37-0.57; P<it;0.001) suggesting utility of osimertinib as a first-line TKI in patients with EGFR activating mutations (PMID: 29151359). Osimertinib was found to specifically have an effect on patients with NSCLC and central nervous system (CNS) metastases. Of the 419 patients in the phase III AURA trial, 116 patients had CNS lesions. Of those 116 patients, PFS was 11.7 months on osimertinib and 5.6 months on platinum-pemetrexed and the overall response rate was 40% with osimertinib (30/75) and 17% with platinum-pemetrexed (7/41) (PMID: 30059262).

Publication IDs: [PMID:29151359](#) [PMID:25923549](#) [PMID:27751847](#) [PMID:30059262](#)

**Additional Information (Optional):**

**Figure 5.1.4: Therapeutic curation**

(A) Level of evidence. (B) Level of evidence to propagate in other solid tumor types. (C) Level of evidence to propagate in other liquid tumor types. (D) Description of evidence, including references for the selected level of evidence.

## Sub-Protocol 5.2: Curated therapies page

The Therapies page (Figure 5.2.1A) in the Curation platform comprises all the therapies curated in the OncoKB database and propagates to the therapy drop down on the gene page (Chapter 6: Figure 5.1.1: [Entering therapies in the gene page](#)). If a drug is not listed as an option in the gene page dropdown when curating therapeutics (See Chapter 6: Figure 5.1.1: [Entering therapies in the gene page](#)), it must be added to this Curated Therapies page. All drugs already curated in the system can be searched using the search bar (Figure 5.2.1B) on this page. A dropdown at the bottom of the page (Figure 5.2.1C) allows new drugs to be added to the database and allows the preferred drug name to be selected. After a drug is added to this page, it will appear as an option in the gene page therapeutic dropdown (see Chapter 6: Figure 5.1.1: [Entering therapies in the gene page](#)).

The screenshot displays the OncoKB Curated Therapies page. The top navigation bar includes 'OncoKB', 'Genes', 'Curation Queue', 'Therapies', 'Variant Annotation', 'Tools', and 'Feedback'. A user profile for 'moriah.heller@gma...' is visible in the top right corner. The main content area is titled 'Curated Therapies' and features a search bar (B) and a 'Show 10 entries' dropdown. Below the search bar is a table listing various therapies with their NCI Thesaurus Codes and associated genes. At the bottom of the page, there is a form (C) for adding a new drug, which includes a 'Default NCI Drug Name' field (containing 'AZD'), an 'Add Drug' button, and a dropdown menu for selecting the 'Preferred Drug Name'. The dropdown menu is currently open, showing several options with their respective NCI Thesaurus Codes and descriptions.

Therapy	NCI Thesaurus Code	Description	Genes
Abemaciclib	C97660		CDK4 CDKN2A
Ado-Trastuzumab Emtansine	C82492		ERBB2
Afatinib	C66940		EGFR
Alectinib	C101790		ALK
Alpelisib	C94214		PIK3CA
AMG-510	C154287		KRAS
Asciminib	C114494		ABL1
Atezolizumab	C106250		BRAF
Avapritinib	C123827		KIT PDGFRA
AZD4547	C88272		FGFR1 FGFR2 FGFR3

**Figure 5.2.1: Curated Therapies page.**

(A) Location of the curated therapies page on the curation platform toolbar. (B) Search bar to search for a curated therapeutic. (C) Text bar to add a therapy to the curated therapies page, and a dropdown used to select the correct drug.

## Protocol 6: Review history

- Protocols detailing the review process can be found in [Chapter 3: Protocol 1: Data review](#).
- Visualization of review mode in the curation platform can be found in [Chapter 6: Sub-Protocol 6.2: Review mode](#)
- For visualization of entering the review history and using the validation tools, see [Chapter 6: Figure 6: Review history](#) and [Chapter 6: Sub-Protocol 6.1: Query, download and validate reviewed data](#)

Within the Tools page is Review History (**Figure 6A**). All reviewed changes to an indicated gene (**Figure 6B**) (those listed in [Chapter 3: Table 1.3: Data additions, deletions and edits highlighted in Review Mode in the OncoKB curation platform](#)) within a designated date range can be visualized by selecting the dates in the dropdown (**Figure 6C**); alternatively, only changes of a certain type (e.g updates, name change, etc) can be selected using the type checkboxes (**Figure 6D**). Example results retrieved from this query are shown in **Figure 6E**. Review History highlights the difference from the pre-reviewed version as well as the user who initiated the change, the SCMT member who reviewed and accepted the change, and the date the change was reviewed.

OncoKB Genes Curation Queue Therapies Variant Annotation Tools Feedback moriah.heller@gma... Sign out

### Create Genes

Comma-separated gene names

### Review History **A**

**B** Genes:   Include UUID

**C** Date:

**D** Type:  update  name change  add  delete

Showing 1 to 10 of 15 entries Search:

Gene	Reviewed by	Reviewed at	Records <b>E</b>
ABL1	Moriah Nissan	Jan 28, 2:21 PM 2020	<p>BCR-ABL1 Fusion, Chronic Myelogenous Leukemia, INVESTIGATIONAL_THERAPEUTIC_IMPLICATIONS_DRUG_SENSITIVITY, 1e3c2981-4cc6-43e7-be76-b479050ebdca</p> <p>update Moriah Nissan</p> <pre>{   "description": "This assertion is supported by (Abstract: Mauro, M. et al. Abstract# TPS7081, ASCO 2018. http://abstracts.asco.org/214/AbstView_214_220317.html)(PMID: 31826340)."</pre> <pre>{ "description": "This assertion is supported by (Abstract: Mauro, M. et al. Abstract# TPS7081, ASCO 2018. http://abstracts.asco.org/214/AbstView_214_220317.html)(PMID: 31826340)."</pre>
ABL1	Sarah Phillips	Dec 20, 9:45 PM 2019	<p>T315I, Chronic Myelogenous Leukemia, STANDARD_THERAPEUTIC_IMPLICATIONS_FOR_DRUG_RESISTANCE, 142768c5-4918-4244-98dd-6ea97a4d3c2a, df40a264-628f-4070-9078-965c0471bd2c, 0f991d49-4cf2-4975-b52f-d7d037aa7f11, 80a4278a-4622-45e5-9e3f-8ca98657692f</p> <p>update Sarah Phillips</p> <pre>{   "description": "(PMID: 18403620, 17768119, 17339191, 21562040, 19075254)"</pre> <pre>{ "description": "(PMID: 18403620, 17768119, 17339191, 21562040, 19075254)"</pre>

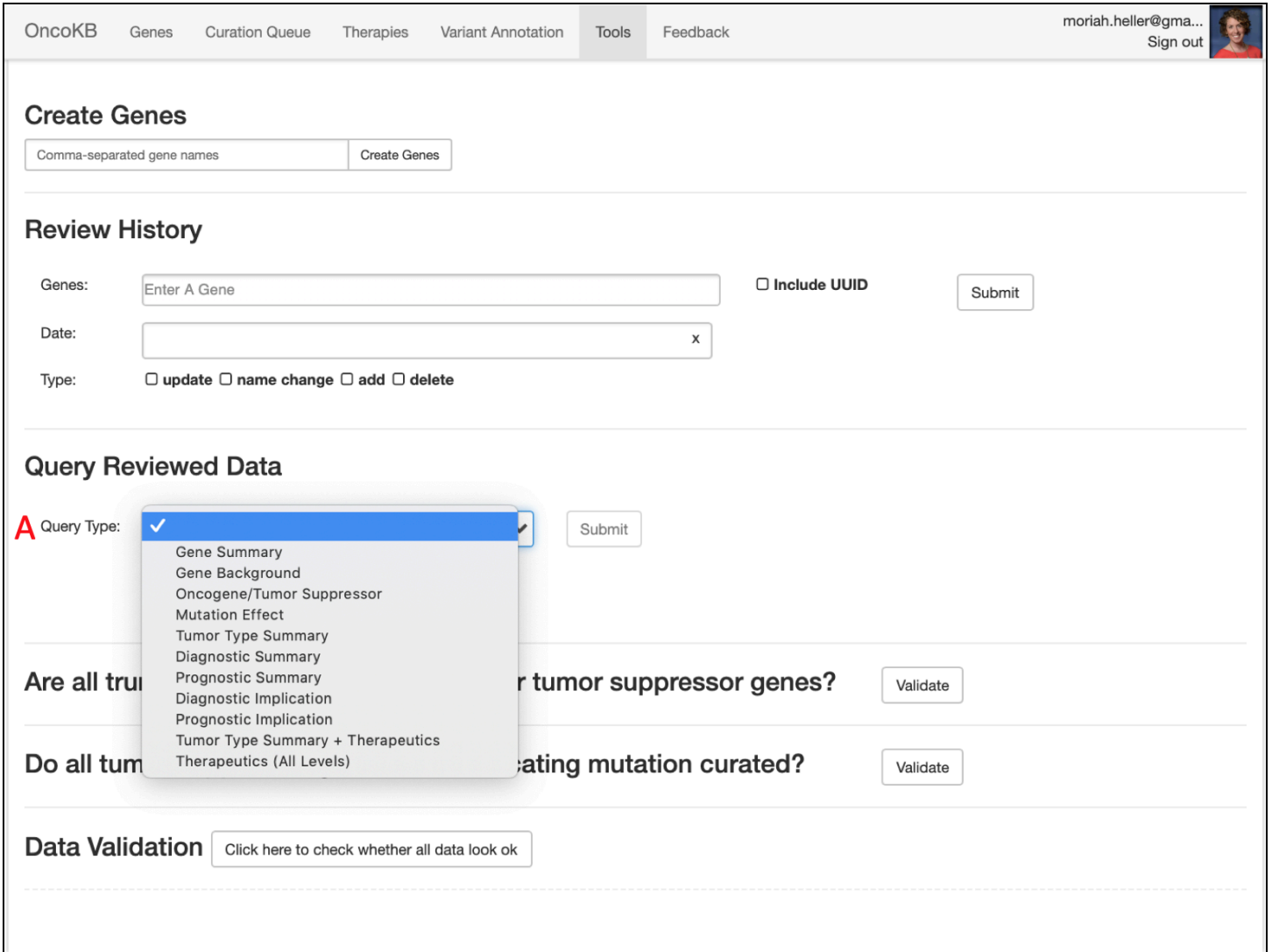
**Figure 6: Review history.**

(A) Location of Review History within the Tools page. (B) Text bar for Gene name. (C) Calendar bar to select date range. (D) Check boxes to limit the reviewed data fetched by the query. (E) Example data fetched in a Review History Query.



## Sub-Protocol 6.1: Query, download and validate reviewed data

Within the Tools page is the option to query reviewed data, which will retrieve downloadable lists of the most current reviewed data, e.g. all gene summaries, all mutation effects and their descriptions, etc. This option can be used to batch visualize data across genes (e.g. all tumor type summaries across all genes) in a manner that is searchable. Data to download can be accessed via dropdown (**Figure 6.1.1A**).



The screenshot shows the OncoKB interface with the 'Tools' tab selected. The 'Query Reviewed Data' section is highlighted, featuring a dropdown menu for 'Query Type' with the following options: Gene Summary, Gene Background, Oncogene/Tumor Suppressor, Mutation Effect, Tumor Type Summary, Diagnostic Summary, Prognostic Summary, Diagnostic Implication, Prognostic Implication, Tumor Type Summary + Therapeutics, and Therapeutics (All Levels). The 'Gene Summary' option is selected. Other visible elements include the 'Create Genes' section, 'Review History' form, and 'Data Validation' section.

**Figure 6.1.1: Query reviewed data.**

(A) Dropdown list in the Query Reviewed Data section that allows you to select the query type for download.

Data Validation (**Figure 6.1.2A**) can be found in the Tools page. Data validation is mandatory before release and checks the data for major errors, as described in [Chapter 3: Table 2.1: Data validation procedures](#). The Validation contains two tabs: “Test” (**Figure 6.1.2B**), which checks for errors in the data (displayed), and “Info” (**Figure 6.1.2C**), which compares the published actionable genes to the latest candidate actionable genes.

OncoKB
Genes
Curation Queue
Therapies
Variant Annotation
Tools
Feedback

moriah.heller@gma...  
Sign out

## Data Validation A

B
C

Test

Info

✔ Whether gene missing summary or background

✔ Whether treatment missing information

⚠ Whether biological alteration missing information
 

Variant	Issue
CSF1R / Fusions	No oncogenicity is specified
CSF1R / Fusions	No mutation effect is specified
CSF1R / Fusions	Mutation effect does not have any reference (pmids, abstracts)
FLT3 / E604_Y958mut	No oncogenicity is specified
FLT3 / E604_Y958mut	No mutation effect is specified
FLT3 / E604_Y958mut	Mutation effect does not have any reference (pmids, abstracts)
FOXP1 / IGH-FOXP1 Fusion	No oncogenicity is specified
FOXP1 / IGH-FOXP1 Fusion	No mutation effect is specified
FOXP1 / IGH-FOXP1 Fusion	Mutation effect does not have any reference (pmids, abstracts)
MAP2K1 / P162F	Mutation effect does not have any reference (pmids, abstracts)
MECOM / inv	No oncogenicity is specified
MECOM / inv	No mutation effect is specified
MECOM / inv	Mutation effect does not have any reference (pmids, abstracts)
MECOM / t	No oncogenicity is specified
MECOM / t	No mutation effect is specified
MECOM / t	Mutation effect does not have any reference (pmids, abstracts)
Other Biomarkers / Microsatellite Instability-High (MSI-H)	No mutation effect is specified
Other Biomarkers / Microsatellite Instability-High (MSI-H)	Mutation effect does not have any reference (pmids, abstracts)
Other Biomarkers / Tumor Mutational Burden-High (TMB-H)	No oncogenicity is specified
Other Biomarkers / Tumor Mutational Burden-High (TMB-H)	No mutation effect is specified
Other Biomarkers / Tumor Mutational Burden-High (TMB-H)	Mutation effect does not have any reference (pmids, abstracts)

⚠ Whether evidence description has wrong format content
 

Variant	Issue
BRD4 / GENE_BACKGROUND	Following PMID(s) cannot be identified: 29776910

### Figure 6.1.2: Data validation - Test.

(A) the location of Data Validation in the tools page. (B) The “Test” tab lists the errors in the reviewed data, as displayed in the example. (C) Location of the “Info” Tab.

Data Validation contains two tabs: “Test”, which checks for errors in the data, and “Info”, which compares the published actionable genes to the latest candidate actionable genes (displayed), as described in [Chapter 3: Table 2.1: Data validation procedures.](#)

Variant	Issue
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / B-Lymphoblastic Leukemia/Lymphoma / Dasatinib / 17496201, 20131302, 21931113 / 1 abstract(s)	Latest
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / B-Lymphoblastic Leukemia/Lymphoma / Imatinib / 11287973, 12200353, 24441288 / 0 abstract(s)	Latest
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / B-Lymphoblastic Leukemia/Lymphoma / Ponatinib / 24180494 / 0 abstract(s)	Latest
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / Chronic Myelogenous Leukemia / Bosutinib / 24345751, 26040495, 29091516 / 0 abstract(s)	Latest
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / Chronic Myelogenous Leukemia / Dasatinib / 20525995, 27217448 / 0 abstract(s)	Latest
LEVEL_1 / ABL1 / BCR-ABL1 Fusion / Chronic Myelogenous Leukemia / Imatinib / 11287972, 11287973, 12637609, 28095277 / 0 abstract(s)	Latest

### Figure 6.1.3: Data validation - Info.

Example data displayed in the Info tab of Data Validation.

## Sub-Protocol 6.2: Review mode

Review Mode can be accessed through the “Review mode” button on the upper right side of the gene page ([Chapter 6: Sub-Protocol 2.1. Gene Page, Figure 2.1H](#)) and can be used according to [Chapter 3: Protocol 1: Data review](#). Entry into review mode highlights the changes made in the gene page since the last review ([Figure 6.2A](#)), as well as the timestamp of the change and the user who made the change ([Figure 6.2C](#)). Changes can be edited *in situ* on this page, and accepted or rejected using the “check” and “x” buttons on the upper right side of the highlighted change ([Figure 6.2D](#)). Otherwise, all items can be batch accepted using the “accept all changes from...” buttons on the upper right side of the page ([Figure 6.2B](#)). Once changes have been reviewed, Review mode can be exited using the “Review Complete” button ([Figure 6.2E](#)).

The screenshot shows the OncoKB interface for the BRAF gene page in Review mode. At the top, there are navigation tabs: OncoKB, Genes, Curation Queue, Therapies, Variant Annotation, Tools, and Feedback. The user's name, moriah.heller@gma..., and a Sign out button are visible in the top right. The gene name is BRAF, with a note that it is being reviewed by Moriah Nissan. Below the gene name, there are buttons for Review Complete, Exit Review, Citations, and Download PDF. A red banner indicates that the user is currently in "Review" mode and should click the "Review Complete" button to exit. Below this, there are buttons to accept all changes from Lindsay LaFave and Moriah Nissan. The main content area shows a mutation (E501K) with a description of evidence and a difference comparing to the old content. The description of evidence includes a new content section and a difference section. The difference section highlights changes made since the last review. The interface also includes buttons to accept or reject indicated changes (C and D) and a "Review Complete" button (E).

**Figure 6.2: Review mode.**

(A) Changes made since last review. (B) Options to accept all changes made by a certain user. (C) Timestamp and user associated with the most recent change. (D) Buttons to accept or reject indicated changes. (E) “Review Complete” button needed to exit review mode.

# Protocol 7: Examples of alteration formatting

- Examples of alteration formatting described in [Chapter 6: Table 3.1: OncoKB alteration nomenclature, style and formatting](#) are found below.

## Grouping of multiple mutations

Mutations which share Tumor Type and therapeutic implications can be grouped together for curation of such information (e.g. BRAF V600E, V600K). Grouped mutation strings should not be given oncogenic effects, mutation effects or descriptions of evidence. Each mutation in the string should have its own individual string in which it is assigned its own oncogenic effect, mutation effect and description of evidence.

The screenshot shows a grouped mutation entry in OncoKB. The top bar indicates the mutation is "V600E, V600K" with "1x TT, Levels: 1". Below this, the "Mutation Effect" section is collapsed and shows "No Entry". The "Oncogenic" section has radio buttons for "Yes", "Likely", "Likely Neutral", and "Inconclusive", all of which are unselected. The "Mutation effect" section has radio buttons for "Gain-of-function", "Likely Gain-of-function", "Loss-of-function", "Likely Loss-of-function", "Switch-of-function", "Likely Switch-of-function", "Neutral", "Likely Neutral", and "Inconclusive", all of which are unselected. There are empty text boxes for "Description of Evidence:" and "Additional Information (Optional):". The bottom bar shows the tumor type as "Melanoma" with "4x Level 1".

Figure 7.1: Grouping of multiple mutations

## Mutation ranges and use of brackets [ ]

All mutations in a range (e.g. TP53 102\_292mis) can be assigned a blanket oncogenic and mutation effect, which should always be “likely” rather than “known”. Strings can appear publicly with a different name by using brackets around the desired public name (e.g. [DNA binding domain missense mutations])

The screenshot shows a mutation range entry in OncoKB. The top bar indicates the mutation is "V218dup, 102\_292mis [DNA binding domain missense mutation], 102\_292ins [DNA binding domain insertion], 102\_292del [DNA binding domain deletion]". Below this, the "Mutation Effect" section is expanded. The "Oncogenic" section has radio buttons for "Yes", "Likely", "Likely Neutral", and "Inconclusive", with "Likely" selected. The "Mutation effect" section has radio buttons for "Gain-of-function", "Likely Gain-of-function", "Loss-of-function", "Likely Loss-of-function", "Switch-of-function", "Likely Switch-of-function", "Neutral", "Likely Neutral", and "Inconclusive", with "Likely Loss-of-function" selected. The "Description of Evidence:" section contains a text box with the following text: "This mutation, which is located within the TP53 DNA-binding domain (DBD), leads to conformational changes of the p53 protein. These changes result in altered contact of p53 with its target DNA sequences, thereby altering its transcriptional function (PMID: 8023157, 11900253). Given that p53 directs the transcription of proteins that enable apoptosis (PMID: 11900253), its inactivation results in cells harboring damaged DNA and overall genomic instability (PMID: 11900253). Publication IDs: [PMID:8023157](#) [PMID:11900253](#)". The "Additional Information (Optional):" section contains a text box with the following text: "There is preliminary laboratory evidence that missense mutations in the DBD can have an 'activating' oncogenic effect on p53 protein function, contrary to the wildtype protein's normal function as a tumor suppressor, but this is highly dependent upon tissue context (PMID: 24651012). Publication IDs: [PMID:24651012](#)".

Figure 7.2: Mutation ranges and use of brackets [ ]

## Use of parentheses ( )

Parenthesis can be used to leave a note or comment about the mutation string that can only be viewed internally on the curation platform and does not display in any OncoKB outputs (e.g. KIT D820A (Exon 17))



Figure 7.3: Use of parentheses ( )

## Positional variants

All amino acid substitutions at a given position which share Tumor Type and therapeutic implications can be grouped together for curation of such information by using a positional variant (e.g. BRAF V600). Positional variant strings should not be given oncogenic effects, mutation effects or descriptions of evidence.

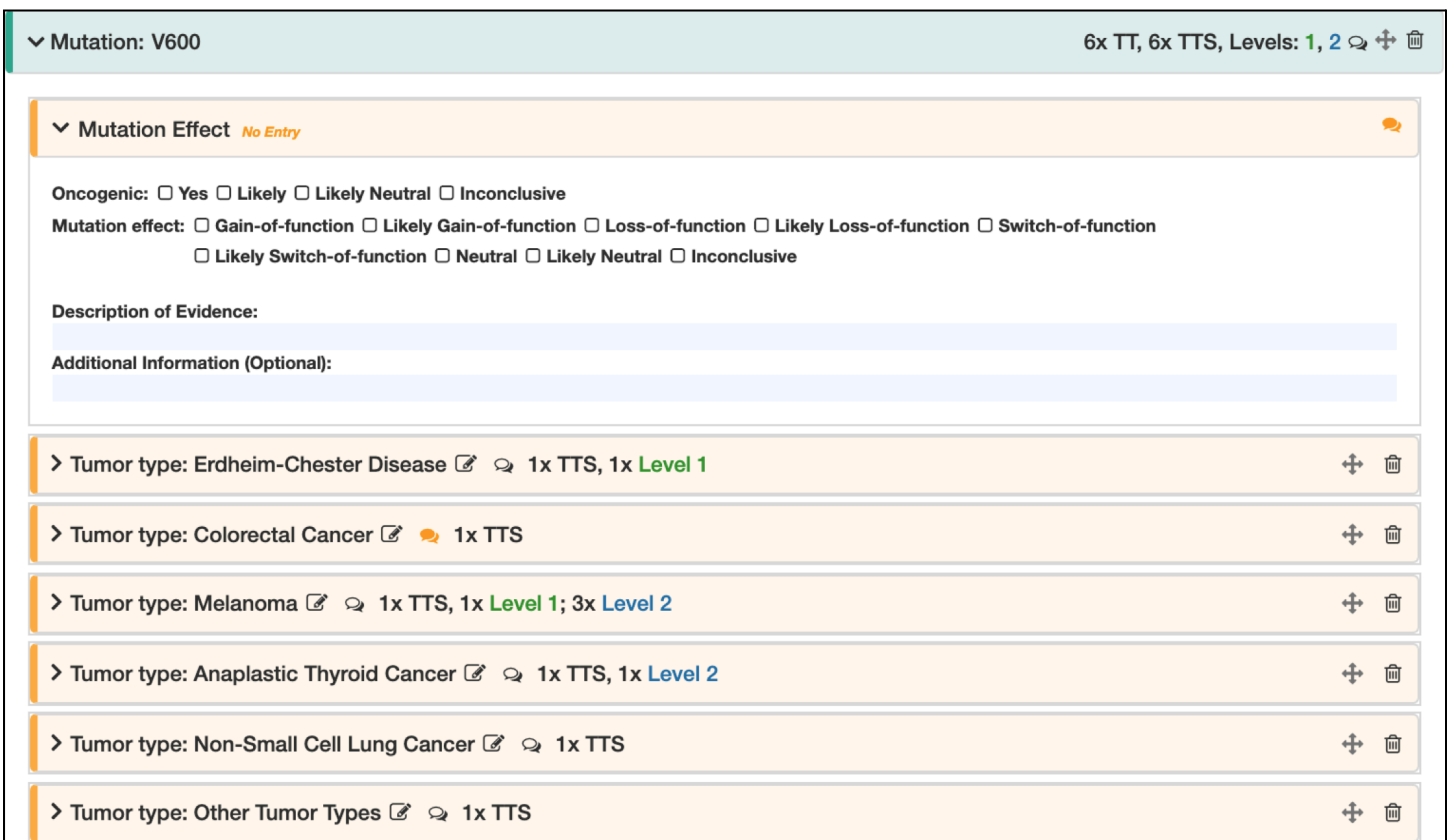


Figure 7.4: Positional variants

## Truncating Mutations

All truncating mutations in a gene can be curated as a single alteration within a Gene Page and must be given a blanket oncogenic and mutation effect, which should always be “likely” rather than “known”. Tumor type and therapeutic data can be curated under this header.

▼ Mutation: Truncating Mutations

▼ Mutation Effect

Oncogenic:  Yes  Likely  Likely Neutral  Inconclusive

Mutation effect:  Gain-of-function  Likely Gain-of-function  Loss-of-function  Likely Loss-of-function  Switch-of-function  
 Likely Switch-of-function  Neutral  Likely Neutral  Inconclusive

**Description of Evidence:**  
Truncating mutations of TP53 occur throughout the gene and lead to the production of several C-terminally truncated protein forms. These alterations are predicted to be inactivating and are associated with poor prognosis (PMID: 11900253, 11753428, 16007150, 21467160, 19336573). Experimental studies have revealed that truncating mutations promote cancer cell proliferation, survival and metastasis, since ectopic expression of these mutations in melanoma cells increased cell motility and tumor formation in vivo. This was due in part to aberrant localization of truncated proteins to the mitochondria, regulating genes involved in cell survival, including CypD (PMID: 27759562).  
Publication IDs: [PMID:11900253](#) [PMID:11753428](#) [PMID:16007150](#) [PMID:21467160](#) [PMID:19336573](#) [PMID:27759562](#)

**Additional Information (Optional):**

Figure 7.5: Truncating mutations

## Fusions

All fusions in a gene can be curated as a single alteration within a Gene Page and must be given a blanket oncogenic and mutation effect, which should always be “likely” rather than “known”. Specific fusions can also be curated with their own oncogenic effects, mutation effects, descriptions of evidence and therapeutic information, which will supersede any such information found under the general Fusions header in terms of OncoKB output. Tumor type and therapeutic data can be curated under the Fusions header.

▼ Mutation: Fusions 3x TT, 3x TTS, Levels: 3A

▼ Mutation Effect

**Oncogenic:**  Yes  Likely  Likely Neutral  Inconclusive

**Mutation effect:**  Gain-of-function  Likely Gain-of-function  Loss-of-function  Likely Loss-of-function  Switch-of-function  
 Likely Switch-of-function  Neutral  Likely Neutral  Inconclusive

**Description of Evidence:**

BRAF fusions generally arise from chromosomal translocations that fuse the N-terminal end of a partner gene with the C-terminal end of BRAF (exons 9-18, containing the kinase domain), such that the fusion protein excludes the BRAF CR1 regulatory domain (PMID:15630448), thereby resulting in a constitutively active BRAF kinase. These class II hyperactivating BRAF fusions have been found in melanoma, prostate cancer, gastric cancer, and multiple other cancers (PMID: 28783719, 26343582, 24345920, 20526349, 25985019, 26324360, 18974108). Biological characterization of diverse BRAF fusion proteins demonstrate that they activate the downstream MAPK pathway independent of RAS (PMID: 24345920, 21424530, 22745804, 21424530, 18974108, 26343582), render BRAF active as a homo- or heterodimer dimer with CRAF (PMID: 26343582), and, while sensitive to MEK inhibition by targeted inhibitors such as trametinib (PMID: 24345920, 28783719, 26343582, 26314551), are insensitive to RAF monomer inhibitors such as vemurafenib and dabrafenib (PMID: 26343582, 28783719). BRAF fusions have been found across multiple studies in post-treatment samples of patients with EGFR-mutant lung cancer who progressed on osimertinib (PMID: 30257958, 30073261).

Publication IDs: [PMID:28783719](#) [PMID:26343582](#) [PMID:20526349](#) [PMID:15630448](#) [PMID:24345920](#) [PMID:25985019](#) [PMID:26324360](#) [PMID:18974108](#) [PMID:21424530](#) [PMID:22745804](#) [PMID:26314551](#) [PMID:30257958](#) [PMID:30073261](#)

**Additional Information (Optional):**

> Tumor type: Ovarian Cancer 1x TTS, 1x Level 3A

> Tumor type: Melanoma 1x TTS, 1x Level 3A

> Tumor type: Other Tumor Types 1x TTS

Add tumor type(s)

Cancer Type:  Subtype:

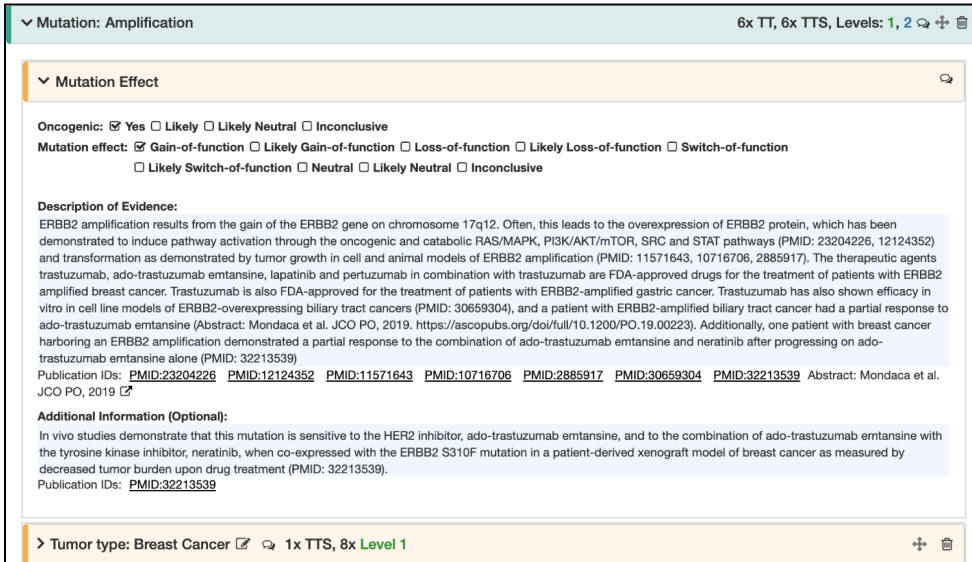
> Mutation: AGAP3-BRAF Fusion

Figure 7.6: Fusions



## Copy number alterations

“Amplification” and “Deletion” can be curated as specific gene alterations within a Gene Page, and include a blanket oncogenic and mutation effect. Tumor type and therapeutic data can be curated under this header.

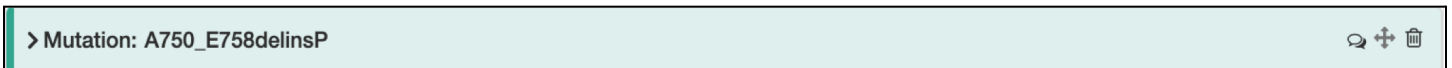


The screenshot shows a mutation entry for ERBB2 amplification. At the top, it indicates "Mutation: Amplification" and "6x TT, 6x TTS, Levels: 1, 2". Below this is a "Mutation Effect" section with several checkboxes: "Oncogenic: Yes" (checked), "Likely", "Likely Neutral", and "Inconclusive". Under "Mutation effect", "Gain-of-function" is checked, with other options like "Loss-of-function" and "Switch-of-function" also present. A "Description of Evidence" section follows, containing a detailed paragraph about ERBB2 amplification and its clinical implications, along with several PMIDs and a reference to a JCO PO abstract. Below the description is an "Additional Information (Optional)" section with text about in vivo studies and a PMID. At the bottom, the "Tumor type" is set to "Breast Cancer" with "1x TTS, 8x Level 1".

Figure 7.7: Copy number alterations

## In-frame deletions or insertions

In-frame deletions and insertions can be curated as individual alterations on the gene page.



The screenshot shows a mutation entry for "A750\_E758delinsP". The entry is displayed in a light blue box with a right-pointing arrow and the text "> Mutation: A750\_E758delinsP". On the right side of the box, there are three small icons: a speech bubble, a plus sign, and a trash can.

Figure 7.8: In-frame deletions or insertions

## Oncogenic Mutations

"Oncogenic Mutations" is used when there is tumor-specific information that applies to ALL functional (oncogenic/likely oncogenic) mutations (excluding "Amplification") within a Gene Page, and is used for curation of tumor type and therapeutic implications. Oncogenic Mutations should not be given "oncogenic effects, mutation effects or descriptions of evidence.

▼ Mutation: Oncogenic Mutations 2x TT, 2x TTS

▼ Mutation Effect *No Entry*

Oncogenic:  Yes  Likely  Likely Neutral  Inconclusive

Mutation effect:  Gain-of-function  Likely Gain-of-function  Loss-of-function  Likely Loss-of-function  Switch-of-function  
 Likely Switch-of-function  Neutral  Likely Neutral  Inconclusive

Description of Evidence:

Additional Information (Optional):

> Tumor type: Non-Small Cell Lung Cancer 1x TTS

> Tumor type: Other Tumor Types 1x TTS

Figure 7.9: Oncogenic Mutations

## Hard-coded Alteration names

Several outlier mutations do not follow the OncoKB formatting guidelines and must be hardcoded in the curation platform (e.g. EGFR Kinase Domain Duplication).

▼ Mutation: Kinase Domain Duplication 1x TT, 1x TTS, Levels: 3A, 4

▼ Mutation Effect

Oncogenic:  Yes  Likely  Likely Neutral  Inconclusive

Mutation effect:  Gain-of-function  Likely Gain-of-function  Loss-of-function  Likely Loss-of-function  Switch-of-function  
 Likely Switch-of-function  Neutral  Likely Neutral  Inconclusive

Description of Evidence:  
EGFR-KDD is an exon 18-25 or 18-26 kinase domain duplication (PMID: 26286086). This alteration has been found in lung cancer and glioma (PMID: 26286086, 9692551, 10698499). In vitro and Ba/F3 cell line experiments demonstrate that the EGFR-KDD is activating and transforming as measured by increased basal receptor phosphorylation and IL-3 independent growth (PMID: 26286086, 10698499, 19915609). A patient with non-small cell lung cancer harboring the EGFR-KDD alteration had a partial response to afatinib that lasted for seven cycles of therapy, and other patients with the EGFR-KDD alteration have had clinical benefit in response to EGFR TKIs (PMID: 26286086, 30255937).  
Publication IDs: [PMID:26286086](#) [PMID:9692551](#) [PMID:10698499](#) [PMID:19915609](#) [PMID:30255937](#)

Additional Information (Optional):

> Tumor type: Non-Small Cell Lung Cancer 1x TTS, 1x Level 3A; 2x Level 4

Figure 7.10: Hard-coded alterations names

## Protocol 8: OncoKB Programming Language

The OncoKB curation platform uses certain coding (referred to as OncoKB Curation Programming Language, or OCPL) that is recognized by the API to include query-specific data in output annotations instead of general terms. The codes contained in the OCPL and what the API will recognize and replace upon query output are outlined in [Chapter 7: Table 8.1: OncoKB Curation Programming Language](#). OCPL was designed for use in Therapeutic summaries but can be used in the following places in the OncoKB curation platform:

- Gene Background
- Gene Summary
- Variant Description
- Therapeutic Summary
- Therapeutic Description
- Diagnostic Summary
- Diagnostic Description
- Prognostic Summary
- Prognostic Description

### Table 8.1: OncoKB Curation Programming Language

This table lists OncoKB Curation Programming Language (OCPL) codes, the output of the code when recognized by the API, and examples of how each code might appear in a query-specific annotation

OCPL Code	Output of Code from API	Example of output in an annotation
[[tumor type]]	Tumor type	Melanoma
[[gene]]	Gene	BRAF
[[mutation]] [[[mutation]]]	Mutation + 'mutation'	V600E mutation
[[mutation]] [[[mutant]]]	Mutation + 'mutant'	V600E mutant
[[variant]]	Gene + Mutation + 'mutant' + Tumor Type	BRAF V600E mutant melanoma

# Protocol 9: Assignment of oncogenic effect and biological effect to allele-specific variants that are not curated in OncoKB

There are two instances when variants not specifically curated within the OncoKB curation platform will receive OncoKB annotation (ie oncogenic effect, biological effect, and therapeutic implications, if applicable) if called through the API.

**1. Alternate-allele:** An alternate allele is a missense mutations that, itself, is not curated in OncoKB, however, a separate allele-specific missense mutation at the same position is curated in OncoKB, ie. associated with a biological and oncogenic effect (this is called the reference allele)

- The alternate allele is assigned a biological effect and oncogenic effect based on that of the reference allele
- Refer to [Chapter 6: Table 9.1: Assigning an Biological Effect to an Alternate Allele When There is Only 1 Curated Reference Allele](#) for assignment of alternative-allele biological effect when only 1 reference allele is curated in OncoKB (or if there are >1 reference alleles that all have the same biological and oncogenic effect)
- If there is >1 reference alleles with different biological effects, the biological effect of the alternate allele is reported by OncoKB as “Unknown”
- Refer to [Chapter 6: Table 9.2a: Assigning an Oncogenic Effect to an Alternate Alleles When There is Only 1 Curated Reference Allele](#) for assignment of alternative-allele oncogenic effect when only 1 reference allele is curated in OncoKB (or if there are >1 reference alleles that all have the same oncogenic effect)
- If there is >1 reference alleles with different oncogenic effects, the oncogenic effect of the alternate allele is reported according to [Chapter 6: Table 9.2b: Assigning an Oncogenic Effect to an Alternate Allele When There are >1 Curated Reference Alleles with Different Oncogenic Effects](#)

**2. Hotspot:** For the purpose of OncoKB and the SOP, a hotspot is defined as a variant that is found recurrently in cancer in a statistically significant manner as defined in [Chang et al. 2017](#)

- The hotspots defined by [Chang et al. 2017](#) are positional, not allele-specific. For example *BRAF* V600 is a hotspot, and therefore all single-residue variants at this position are considered hotspots.
- Each allele-specific hotspot, in the absence of functional data describing its oncogenicity (refer to [Chapter 1: Sub-Protocol 2.3: Defining the type and strength of evidence to support a variant assertion](#)), is annotated as “Likely Oncogenic” per [Chapter 1: Sub-protocol 2.5: Assertion of the Oncogenic Effect of a VPS](#)
  - This rule applies to all allele-specific hotspots, including those not specifically curated in OncoKB
  - Therefore, if an allele-specific hotspot that is not specifically curated in OncoKB is called through the API, it will be annotated as “Likely Oncogenic”

- If there is functional data describing the oncogenic and/or biological effect of an allele-specific hotspot, the hotspot is assigned an oncogenic and/or biological effect per [Chapter 1: Sub-protocol 2.5: Assertion of the Oncogenic Effect of a VPS](#) and [Chapter 1: Sub-protocol 2.4: Assertion of the Biological Effect of a VPS](#)

**Table 9.1: Assigning a Biological Effect to an Alternate Allele When There is Only 1 Curated Reference Allele**

Reference Allele	Alternate-allele
<i>Biological Effect</i>	
Gain-of-Function	Likely Gain-of-Function
Loss-of-Function	Likely Loss-of-Function
Likely Gain-of-Function	Likely Gain-of-Function
Likely Loss-of-Function	Likely Loss-of-Function
Switch-of-Function	Likely Switch-of-Function
Likely Switch-of-Function	Likely Switch-of-Function
Neutral	Unknown
Likely Neutral	Unknown
Inconclusive	Unknown

**Note:** These rules apply when there is only 1 curated reference allele, or if there are > 1 reference alleles that all have the same biological effect. If there are >1 reference alleles with different biological effects, the biological effect of the alternate allele is reported by OncoKB as “Unknown”

**Table 9.2a: Assigning an Oncogenic Effect to an Alternate Alleles When There is Only 1 Curated Reference Allele**

Reference Allele	Alternate-allele	Example	Reference Allele	Alternate-allele
Oncogenic Effect			OncoKB variant summary	
Oncogenic	Likely Oncogenic	<p><b>Reference Allele:</b> PIK3CB A1048V</p> <p><b>Alternate Allele:</b> PIK3CB A1048T</p>	<p><i>The PIK3CB A1048V mutation is known to be oncogenic.</i></p>	<p><i>There is no available functional data about the PIK3CB A1048T mutation (last reviewed on 08/04/2017). However, PIK3CB A1048V is known to be oncogenic, and therefore PIK3CB A1048T is considered likely oncogenic.</i></p>
Likely Oncogenic	Likely Oncogenic	<p><b>Reference Allele:</b> AKT2 R170W</p> <p><b>Alternate Allele:</b> AKT2 R170L</p>	<p><i>The AKT2 R170W mutation is likely oncogenic.</i></p>	<p><i>There is no available functional data about the AKT2 R170L mutation (last reviewed on 04/18/2017). However, AKT2 R170W is likely oncogenic, and therefore AKT2 R170L is considered likely oncogenic.</i></p>

Likely Neutral	Unknown	<b>Reference Allele:</b> BRAF R509H  <b>Alternate Allele:</b> BRAF R509Q	<i>The BRAF R509H mutation is likely neutral.</i>	<i>There is no available functional data about the BRAF R509Q mutation (last reviewed on 04/04/2023). While BRAF R509H is likely neutral, the oncogenic effect of BRAF R509Q is unknown.</i>
Inconclusive	Unknown	<b>Reference Allele:</b> AKT2 D324N  <b>Alternate Allele:</b> AKT2 D324Y	<i>There is conflicting and/or weak data describing the biological significance of the AKT2 D324N mutation.</i>	<i>There is no available functional data about the AKT2 D324Y mutation (last reviewed on 08/04/2017), and therefore its biological significance is unknown.</i>
Resistance	Unknown	<b>Reference Allele:</b> NTRK3 G623R  <b>Alternate Allele:</b> NTRK3 G623E	<i>The NTRK3 G623R mutation has been found in the context of resistance to a targeted therapy(s).</i>	<i>There is no available functional data about the NTRK3 G623E mutation (last reviewed on 08/07/2017). While NTRK3 G623R has been found in the context of resistance to a targeted therapy(s), the oncogenic effect of NTRK3 G623E is unknown.</i>

Note: These rules apply when there is only 1 curated reference allele, or if there are > 1 reference alleles that both have the same biological and oncogenic effect

**Table 9.2b: Assigning an Oncogenic Effect to an Alternate Alleles When There are >1 Curated Reference Alleles with different oncogenic effect**

# signifies a reference allele	Reference Allele	Alternate Allele	Example	Reference Allele	Alternate Allele
	Oncogenic Effect			OncoKB variant summary	
1	Oncogenic	Likely Oncogenic	<b>Reference Alleles:</b> 1) KLF5 E419Q (O) 2) KLF5 E419K (LO)  <b>Alternate Allele:</b> KLF5 E419G	1) The KLF5 E419Q mutation is known to be oncogenic.  2) The KLF5 E419K mutation is likely oncogenic.	There is no available functional data about the KLF5 E419G mutation (last reviewed on 10/15/2019). However, KLF5 E419Q is known to be oncogenic and KLF5 E419K is likely oncogenic; therefore KLF5 E419G is considered likely oncogenic.
2	Likely Oncogenic		<b>Reference Alleles:</b> 1) RET C634R (O) 2) RET C634Y (LO) 3) RET C634W (LO) 4) RET C634S (LO)  <b>Alternate Allele:</b> RET C634F	1) The RET C634R mutation is known to be oncogenic.  2) The RET C634Y mutation is likely oncogenic.  3) The RET C634W mutation is likely oncogenic.  4) The RET C634S mutation is likely oncogenic.	There is no available functional data about the RET C634F mutation (last reviewed on 03/02/2017). However, RET C634R is known to be oncogenic and RET C634S/W/Y are likely oncogenic; therefore RET C634F is considered likely oncogenic.



1	Oncogenic or Likely Oncogenic	Likely Oncogenic	<b>Reference Alleles:</b> 1) ERBB2 A644F(LO) 2) ERBB2 A644V (LN)	1) <i>The ERBB2 A644F mutation is likely oncogenic.</i>  2) <i>The ERBB2 A644V mutation is likely neutral.</i>	<i>There is no available functional data about the ERBB2 A644S mutation (last reviewed on 06/23/2023). However, ERBB2 A644F is likely oncogenic and ERBB2 A644V is likely neutral; therefore ERBB2 A644S is considered likely oncogenic.</i>
2	Likely Neutral				
1	Oncogenic or Likely Oncogenic	Likely Oncogenic	<b>Reference Alleles:</b> 1) PIK3CA G451R (LO) 2) PIK3CA G451V (I)	1) <i>The PIK3CA G451R mutation is likely oncogenic.</i>  2) <i>There is conflicting and/or weak data describing the biological significance of the PIK3CA G451V mutation.</i>	There is no available functional data about the PIK3CA G451K mutation (last reviewed on 08/04/2017). However, PIK3CA G451R is likely oncogenic, and therefore PIK3CA G451K is considered likely oncogenic.
2	Inconclusive				
1	Oncogenic or Likely Oncogenic	Likely Oncogenic	<b>Reference Alleles:</b> 1) BRCA1 M1652K (LO) 2) BRCA1 M1652I (LN) 3) BRCA1 M1652T (I)	1) <i>The BRCA1 M1652K mutation is likely oncogenic.</i>  2) <i>The BRCA1 M1652I mutation is likely neutral.</i>  3) <i>There is conflicting and/or weak data describing the</i>	<i>The BRCA1 M1652L mutation has not specifically been reviewed by the OncoKB team. However, BRCA1 M1652K is likely oncogenic and BRCA1 M1652I is likely neutral; therefore BRCA1 M1652L is considered likely oncogenic.</i>
2	Likely Neutral				

3	Inconclusive			<i>biological significance of the BRCA1 M1652T mutation.</i>	
1	Oncogenic or Likely Oncogenic	Likely Oncogenic	<b>Reference Alleles:</b> 1) EGFR D761N (LO) 2) EGFR D761Y (R)  <b>Alternate Allele:</b> EGFR D761K	1) <i>The EGFR D761N mutation is likely oncogenic.</i>  2) <i>The EGFR D761Y mutation has been found in the context of resistance to a targeted therapy(s).</i>	<i>The EGFR D761K mutation has not specifically been reviewed by the OncoKB team. However, EGFR D761N is likely oncogenic and EGFR D761Y has been found in the context of resistance to a targeted therapy(s); therefore EGFR D761K is considered likely oncogenic.</i>
2	Resistance				
1	Likely Neutral	Unknown	<b>Reference Alleles:</b> 1) SMO E518K (LN) 2) SMO E518A (R)  <b>Alternate Allele:</b> SMO E518V	1) <i>The SMO E518K mutation is likely neutral.</i>  2) <i>The SMO E518A mutation has been found in the context of resistance to a targeted therapy(s).</i>	<i>The SMO E518V mutation has not specifically been reviewed by the OncoKB team. While SMO E518K is likely neutral and SMO E518A has been found in the context of resistance to a targeted therapy(s), the oncogenic effect of SMO E518V is unknown.</i>
2	Resistance				

1	Likely Neutral	Unknown	<b>Reference Alleles:</b> 1) EGFR V774L (LN) 2) EGFR V774M (I)  <b>Alternate Allele:</b> EGFR V774S	1) <i>The EGFR V774L mutation is likely neutral.</i>  2) <i>There is conflicting and/or weak data describing the biological significance of the EGFR V774M mutation.</i>	<i>The EGFR V774S mutation has not specifically been reviewed by the OncoKB team. While EGFR V774L is likely neutral, the oncogenic effect of EGFR V774S is unknown.</i>
2	Inconclusive			1) <i>There is conflicting and/or weak data describing the biological significance of the ERBB2 E719K mutation.</i>  2) <i>The ERBB2 E719G mutation has been found in the context of resistance to a targeted therapy(s).</i>	
1	Inconclusive	Unknown	<b>Reference Alleles:</b> 1) ERBB2 E719K (I) 2) ERBB2 E719G (R)  <b>Alternate Allele:</b> ERBB2 E719A	1) <i>There is conflicting and/or weak data describing the biological significance of the ERBB2 E719K mutation.</i>  2) <i>The ERBB2 E719G mutation has been found in the context of resistance to a targeted therapy(s).</i>	<i>The ERBB2 E719A mutation has not specifically been reviewed by the OncoKB team. While ERBB2 E719G has been found in the context of resistance to a targeted therapy(s), the oncogenic effect of ERBB2 E719A is unknown.</i>
2	Resistance				

Note: Examples are relevant as of 12/12/23, the date this chart was created and are subject to change upon the curation of new data in the system.

# Chapter 7: OncoKB staff qualifications, training and proficiency testing

## Protocol 1: OncoKB staff

This protocol ([Chapter 7: Table 1.1: OncoKB staff members and qualifications](#)) describes the different members of the OncoKB staff and their qualifications.

**Table 1.1: OncoKB staff members and qualifications**

OncoKB staff members and their required minimum qualifications, including educational background, professional training and required skills.

OncoKB staff member	Minimum educational background	Minimum years of professional training	Experience Details	Required skills
<b>Lead Scientist, OncoKB</b>	Ph.D. in biological sciences	5	Molecular biology, cancer biology, genetics, genomics (or equivalent)	<ul style="list-style-type: none"> <li>• Deep knowledge of cancer biology</li> <li>• Strong record of scientific publications and/or presentations at professional meetings</li> <li>• Experience with computational biology</li> <li>• Strong communication skills (written and oral)</li> <li>• Strong record of leadership</li> </ul>
<b>Lead Scientist, Knowledge Systems</b>	Ph.D. in computer science, bioinformatic or equivalent	5	Computer Science, bioinformatics or related field	<ul style="list-style-type: none"> <li>• Deep knowledge of computer science/bioinformatics</li> <li>• Strong record of leading bioinformatics projects in the cancer genomics domain</li> <li>• Deep knowledge of front-end frameworks such as React or AngularJS</li> <li>• Deep knowledge of server-side web frameworks such as Java/Spring/SpringBoot</li> <li>• Deep knowledge of cloud deployment</li> <li>• Strong communication skills (written and oral)</li> <li>• Strong record of leadership</li> </ul>
<b>Scientific Content Management Team (SCMT) member</b>	Ph.D. or M.S. in biological sciences	1-2	Molecular biology, cancer biology, genetics, genomics (or equivalent)	<ul style="list-style-type: none"> <li>• Deep knowledge of cancer biology concepts and terminology</li> <li>• Experience in scientific data mining and interpretation</li> <li>• Strong writing/editing skills</li> <li>• Strong communication skills (written and oral)</li> <li>• Ability to work both independently and in a team</li> <li>• Extreme attention to detail</li> </ul>

<b>Lead Software Engineer</b>	MS in computer science, bioinformatics or related field <b>or</b> 5 years of professional training in one of the above fields	MS or 3 years of professional training	Computer science, bioinformatics or related field	<ul style="list-style-type: none"> <li>• Skilled in web application development</li> <li>• Deep knowledge of HTML5, CSS, Java and Python</li> <li>• Skilled with databases such as MySQL and MongoDB</li> <li>• Highly proficient developing in teams using Git/GitHub or other source code control systems</li> <li>• Experience with Google Firebase</li> <li>• User interface design knowledge</li> <li>• Prior work with open source projects</li> <li>• Prior involvement in bioinformatics or cancer genomics domain</li> </ul>
<b>Software Engineer</b>	BS. in computer science, bioinformatics or related field and 1+ years of software development experience, or a master's degree	MS or 1 year of professional training	Computer science, bioinformatics or related field	<ul style="list-style-type: none"> <li>• Web application development experience</li> <li>• Experience with HTML5, CSS</li> <li>• Experience with Java or Python</li> <li>• Experience with databases, such as MySQL and MongoDB</li> <li>• Experience with shell scripting</li> <li>• Experience developing in teams using Git/GitHub or other source code control systems</li> </ul>
<b>Data and Software Liaison</b>	MS in biomedical engineering, bioinformatics, molecular biology or genomics <b>or</b> 5 years of professional training in one of the above fields	MS or 3 years of professional training	Biomedical engineering, bioinformatics, molecular biology, genetics or genomics	<ul style="list-style-type: none"> <li>• Experience working in the field of cancer biology</li> <li>• Management training/experience</li> <li>• Biomedical data curation experience</li> <li>• Deep knowledge in at least one of the fields of biology, imaging, and genomics</li> <li>• Experience in handling clinical data such as radiology and pathology reports, medical</li> <li>• Experience in handling Next Generation Sequencing (NGS) data</li> <li>• History of contributing to open source and/or team-based projects</li> <li>• Experience with shell scripting in a Linux environment</li> <li>• Strong communication skills (written and oral)</li> <li>• Attention to detail</li> <li>• Ability to work in a team</li> </ul>
<b>Curator</b>	BS in biomedical engineering, bioinformatics, molecular	NA		<ul style="list-style-type: none"> <li>• Biomedical data curation experience</li> <li>• Deep knowledge in at least one of the fields of biology and genomics</li> <li>• Experience in handling clinical data such as radiology, medical and pathology reports</li> </ul>

	biology or genomics			<ul style="list-style-type: none"> <li>• Strong communication skills (written and oral)</li> <li>• Extreme attention to detail</li> <li>• Ability to work in a team</li> </ul>
<b>OncoKB Faculty</b>	MD or PhD	NA	Medicine, Pathology and Bioinformatics coalition	<p>Cross-departmental coalition that actively guides OncoKB development:</p> <ul style="list-style-type: none"> <li>• Director, Center for Molecular Oncology (CMO), Clinical Oncologist</li> <li>• Chief, Molecular Diagnostics Service, Pathology, Pathologist</li> <li>• Head, Knowledge Systems, CMO, Bioinformatician</li> <li>• Associate Director, CMO, Geneticist, Sequencing panel expertise</li> </ul>
<b>CGAC Member</b>	MD or MD, PhD	NA		<ul style="list-style-type: none"> <li>• Actively employed as an MD at Memorial Sloan Kettering Cancer Center (MSK)</li> <li>• Involved in translational research or clinical trial development</li> <li>• Members must include: <ul style="list-style-type: none"> <li>○ MSK physicians and physician-scientist from the following departments: <ul style="list-style-type: none"> <li>■ Prostate</li> <li>■ Breast</li> <li>■ Lung</li> <li>■ Sarcoma</li> <li>■ Head and Neck</li> <li>■ Genitourinary</li> <li>■ Colorectal</li> <li>■ Brain</li> <li>■ Gynecologic</li> <li>■ Myeloid</li> <li>■ Lymphoid</li> <li>■ Immunotherapy</li> <li>■ Pediatrics</li> <li>■ Clinical Genetics</li> </ul> </li> <li>○ MSK Leadership including the: <ul style="list-style-type: none"> <li>■ Physician-in-Chief</li> <li>■ Deputy Physician-in-Chief for Clinical Research</li> <li>■ Chair of the Department of Medicine</li> </ul> </li> </ul> </li> </ul>

## Protocol 2: Documentation of OncoKB staff training achievements, deficiencies and competencies

This protocol documents the procedures for OncoKB staff training, achievements, deficiencies and competencies. These procedures provide a method for OncoKB members to identify individuals or areas of the workflow that may require additional or newly established training.

- An overview of these procedures is outlined below in [Chapter 7: Table 2.1: Procedures for documenting the training achievements/deficiencies and competency of OncoKB staff members](#).

**Table 2.1: Procedures for documenting the training achievements/deficiencies and competency of OncoKB staff members**

The OncoKB staff and procedures for documenting training, achievements, deficiencies and competencies, including the frequency of each staff member's performance review and the details of the review process.

OncoKB Staff Member	Timeline for Review	Performance Review Process	Details of Performance Review Process	Review performed by:
Lead Scientist, OncoKB	Annually	MSK Performance Management Annual Review <sup>1</sup>	<p><i>The MSK Performance Management process is a mandatory annual review assessment required for all Memorial Sloan Kettering employees. It consists of 3 steps:</i></p> <ul style="list-style-type: none"> <li>○ <i>Manager Evaluation</i> - allows the manager to assess the employee's contributions as well as how his or her performance aligned with expectations</li> <li>○ <i>Face-to-Face Meeting</i> - allows the employee and his/her manager to engage in dialogue regarding the manager evaluation assessments. Provides the manager with an opportunity to highlight the employee's strengths and weaknesses, discuss future goals and expectations, and highlight plans for improvement and/or growth</li> <li>○ <i>ePerformance Sign off</i></li> </ul>	Head of Knowledge Systems and Director of the CMO
Lead Scientist, Knowledge Systems	Annually			Head of Knowledge Systems
Scientific Content Management Team (SCMT) member	Annually			Lead Scientist
Lead Data Curator	Annually			Lead Scientist, OncoKB
Lead Software Engineer	Annually			Lead Scientist, Knowledge Systems
Software Engineer	Annually			Lead Software Engineer
Curator	Bi-annually	Internal performance review <sup>1</sup>	<i>The Curator Internal Performance Review is a bi-annual evaluation of each curator's performance by the Lead Scientist and SCMT members. The specific areas that are assessed</i>	Lead Scientist, OncoKB and SCMT member

			<p>are:</p> <ul style="list-style-type: none"> <li>○ Quality and accuracy of assignments</li> <li>○ Efficiency of curation work</li> <li>○ Responsiveness/communication with SCMT members</li> <li>○ Ability to follow OncoKB Protocols when completing curation assignments</li> <li>○ Responsiveness to feedback from SCMT members</li> </ul>	
<b>CGAC Member</b>	Annually	Internal CGAC Member Review	<p>The <i>Internal CGAC Member Review</i> is an annual review of each CGAC member's:</p> <ul style="list-style-type: none"> <li>○ Current role at MSK</li> <li>○ Past OncoKB contributions including: <ul style="list-style-type: none"> <li>■ Responsiveness to requests for feedback from the Lead Scientist</li> <li>■ Engagement in the OncoKB process</li> </ul> </li> </ul>	Lead Scientist, OncoKB and the Director of the Center for Molecular Oncology (CMO)

<sup>1</sup>Following each evaluation, the reviewer provides the evaluatee with documentation of the assessment outcome, including the evaluatees: 1. strengths, 2. weaknesses, 3. plans for growth and/or improvement. If there is a valid reason to put the employee on probation or terminate his/her position, this decision and a valid reason behind the decision is reviewed and documented



# Protocol 3: OncoKB curator and SCMT member training

This protocol details the process for training OncoKB curators and new SCMT members.

OncoKB curators will have variable levels of variant interpretation experience. The Lead Scientist and SCMT members are responsible for coordinating and monitoring training and proficiency of curators in procuring the appropriate data, assessing the data in the context of variant interpretation, and entering the data with sufficient detail into the OncoKB curation platform. New curators and/or those curators deemed by the Lead Scientist and SCMT members to require additional training are paired with an SCMT member to receive one-on-one training via curation exercises and in person-training sessions.

1. The curator-in-training (CIT) meets with a senior SCMT member for a 2 hour in-person training session
2. The SCMT member reviews the curator training presentation: [Introduction to OncoKB](#)  
--The CIT is encouraged to ask questions throughout the training session
3. The SCMT member reviews the step-by-step process of each OncoKB curation protocol outlined in [Chapter 7: Table 3.1: Elements reviewed during the in-person OncoKB curator training session](#)
4. The SCMT member reviews the different tasks that may be assigned to an OncoKB curator (as outlined in [Chapter 7: Table 3.1: Elements reviewed during the in-person OncoKB curator training session](#))
5. At the end of the training session the SCMT provides the CIT with:
  - a. **The Curation Protocol Training Worksheet:** ([Chapter 7: Table S1: Validation exercise \(A\) and answer key \(B\) for Chapter 2, Protocol 1: Curation of tumor type specific variant clinical implications and Chapter 2, Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence](#))
  - b. **The Curation Protocol Proficiency Test:** ([Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence](#))  
--The CIT must complete this test within 1 week
  - c. The CIT is also required to watch the OncoKB training video available at [www.oncoKB.org](http://www.oncoKB.org)
6. One week after the initial training, The SCMT member and CIT meet to review the results of the **Curation Protocol Proficiency Test**
  - a. If the CIT receives an 80% or above on the **Curation Protocol Proficiency Test** and the SCMT believes s/he grasps the rationale for each assertion, the CIT may begin a trial curation period
  - b. If the CIT receives a score lower than 80% on the **Curation Protocol Proficiency Test**, the SCMT member may still grant a trial curation period if s/he believes the CIT has a firm grasp of the curation protocols following review of the test answers

7. The SCMT member assigns the CIT an OncoKB curation assignment to complete within 2 weeks
  - a. During the trial curation period, all CIT assignments are completed in spreadsheets where they can be reviewed by a member of the SCMT before being entered into the OncoKB curation platform
8. After completion of 3 curation assignments, the SCMT and Lead Scientist discuss the curator's proficiency and decide whether the CIT:
  - a. Becomes a full OncoKB curator
  - b. Requires additional in-person training
  - c. Is not qualified to be an OncoKB curator and is terminated

**Table 3.1: Elements reviewed during the in-person OncoKB curator training session**

OncoKB elements that are reviewed by an SCMT member during the in-person OncoKB curator training session. The various resources/documents used during the training session and the specific topics reviewed/discussed are also shown.

	OncoKB elements reviewed during in-person curator training	Resources used for education of the CIT	Specific topics reviewed/discussed
1	<b>Overview of OncoKB</b>	OncoKB curator training presentation: <a href="#">Introduction to OncoKB</a>	<ul style="list-style-type: none"> <li>● OncoKB is MSK's precision oncology knowledgebase</li> <li>● OncoKB Levels of Evidence</li> <li>● Organization of OncoKB data in the curation platform               <ul style="list-style-type: none"> <li>○ Gene</li> <li>○ Mutation</li> <li>○ Tumor type</li> <li>○ Clinical implications</li> </ul> </li> <li>● OncoKB curation platform</li> <li>● OncoKB outputs               <ul style="list-style-type: none"> <li>○ OncoKB public website</li> <li>○ cBioPortal for Cancer Genomics</li> <li>○ MSK IMPACT Reports</li> </ul> </li> </ul>
2	<b>OncoKB Curation Platform</b>	<a href="http://oncokb.mskcc.org">oncokb.mskcc.org</a>  <a href="#">Chapter 6: OncoKB curation, formatting and nomenclature in the curation platform</a>	<ul style="list-style-type: none"> <li>● Overview of how a Gene page in the curation platform is organized (per <a href="#">Chapter 6: Figure 2.1: Gene page.</a>)</li> <li>● Review how the various data elements are input into the curation platform. Note the:</li> <li>● Gene Name and aliases</li> <li>● Oncogene/Tumor Suppressor designation</li> </ul>

			<ul style="list-style-type: none"> <li>● Gene Summary</li> <li>● Gene Background</li> <li>● Mutations (review different ways mutations can be input into the system, per <a href="#">Chapter 6: Protocol 7: Examples of alteration formatting</a>) <ul style="list-style-type: none"> <li>○ Selection of biological effect</li> <li>○ Selection of oncogenic effect</li> <li>○ Description of mutation effect (and inclusion of references)</li> </ul> </li> <li>● Tumor Type selection (via drop-down menu of Oncotree cancer types)</li> <li>● Tumor-type specific clinical implications <ul style="list-style-type: none"> <li>○ Therapeutic, Diagnostic and Prognostic Summaries</li> <li>○ Standard implications for sensitivity to therapy</li> <li>○ Standard implications for resistance</li> <li>○ Investigational implications for sensitivity</li> <li>○ Investigational implications for resistance</li> </ul> </li> </ul>
3	<b>OncoKB Website</b> (see <a href="#">OncoKB SOP v1 Chapter 7.II. OncoKB Website</a> )	<a href="http://www.oncokb.org">www.oncokb.org</a>	<ul style="list-style-type: none"> <li>● Review Homepage and search feature</li> <li>● Review OncoKB Levels of Evidence</li> <li>● Review a gene page for an oncogene (BRAF) and tumor suppressor (BRCA2). Note the: <ul style="list-style-type: none"> <li>○ Gene Name and aliases</li> <li>○ Oncogene/Tumor Suppressor designation</li> <li>○ Highest Level of Evidence</li> <li>○ Gene Summary and Background</li> <li>○ Cancer type histogram</li> <li>○ Lollipop plot</li> <li>○ Annotated alterations tab (review data in each column)</li> <li>○ Clinically actionable alterations tab (review data in each column)</li> <li>○ FDA-recognized alterations tab and FDA Levels of Evidence</li> </ul> </li> </ul>
4	<b>OncoKB annotations on cBioPortal</b> (see <a href="#">OncoKB SOP v1 Chapter 7.V OncoKB Content Accessible through cBioPortal</a> )	<a href="http://cbioportal.org">cbioportal.org</a>	<ul style="list-style-type: none"> <li>● Query two genes in the MSK-clinical sequencing cohort (one oncogene, BRAF, and one tumor suppressor, BRCA2)</li> <li>● Review the Oncoprint tab <ul style="list-style-type: none"> <li>○ Note the OncoKB annotation when you hover over a sample in the oncoprint</li> </ul> </li> <li>● Review the mutations tab <ul style="list-style-type: none"> <li>○ Demo and describe the different</li> </ul> </li> </ul>

			<ul style="list-style-type: none"> <li>features of the lollipop plot <ul style="list-style-type: none"> <li>○ Engage the OncoKB and Hotspots annotation tracks</li> </ul> </li> <li>● Review the mutations table <ul style="list-style-type: none"> <li>○ Note the sample ID, the cancer type, protein change, and annotation column (review how the columns are sortable)</li> </ul> </li> <li>● Review in detail the different elements in the annotation column <ul style="list-style-type: none"> <li>○ OncoKB target icon and color codes (detailed in <a href="#">Appendix I: OncoKB icons in cBioPortal</a>)</li> <li>○ Level of Evidence icon</li> <li>○ Hotspot icon</li> </ul> </li> <li>● Review in detail the OncoKB card (BRAF V600E in melanoma can be used as an example) <ul style="list-style-type: none"> <li>○ Card title: states the gene, mutation and cancer type</li> <li>○ Oncogenic effect tab</li> <li>○ Biological effect tab</li> <li>○ Gene summary</li> <li>○ Mutation summary</li> <li>○ Therapeutic summary</li> <li>○ Clinical implications table <ul style="list-style-type: none"> <li>■ Level</li> <li>■ Alteration</li> <li>■ Drug</li> <li>■ Level-associated Cancer type</li> </ul> </li> </ul> </li> </ul>
5	<b>Literature sources</b>	PubMed ClinVar	<ul style="list-style-type: none"> <li>● <b>PubMed:</b> Review how to access and query the database for relevant literature, and how to properly cite sources (<a href="https://pubmed.ncbi.nlm.nih.gov/">https://pubmed.ncbi.nlm.nih.gov/</a>)</li> <li>● <b>ClinVar:</b> Review how to access the database and search for variant-specific information; review how to interpret information on the variant interpretation page (<a href="https://www.ncbi.nlm.nih.gov/clinvar/">https://www.ncbi.nlm.nih.gov/clinvar/</a>)</li> </ul>
6	<b>Other Levels of Evidence Systems</b>	<ul style="list-style-type: none"> <li>● ASCO-AMP-CAP consensus recommendations</li> <li>● ESCAT by ESMO</li> <li>● FDA levels of evidence</li> </ul>	<ul style="list-style-type: none"> <li>● Review each Level of Evidence System and the publications in which they are described</li> <li>● Review how the OncoKB Levels of Evidence map to each of the mentioned Level of Evidence Systems</li> <li>● <b>ASCO-AMP-CAP consensus:</b> <a href="#">Li, MM et al., J Mol Diagn 2017</a></li> </ul>

		<ul style="list-style-type: none"><li>• <b>ESCAT by ESMO:</b> <a href="#">Mateo, J. et al. Annal of Oncology 2018</a></li><li>• <b>FDA levels of evidence:</b> <a href="#">FDA Fact Sheet</a></li></ul>
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**Table 3.2: Protocols reviewed during the OncoKB curator training session**

OncoKB curation protocols that are reviewed by an SCMT member during the in-person OncoKB curator training session.

CIT protocol review	OncoKB curation elements covered in the review	Relevant OncoKB curator tasks <i>Curation of:</i>
<a href="#">Chapter 1: Protocol 1: Gene curation</a>	<ul style="list-style-type: none"> <li>● Identifying a Gene of Interest</li> <li>● Curation of gene summary</li> <li>● Curation of gene background                             <ul style="list-style-type: none"> <li>○ Formatting should be reviewed from <a href="#">Chapter 6: Protocol 2: Gene curation</a></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● Gene summary</li> <li>● Gene background</li> <li>● Identifying genes as Oncogenes or Tumor Suppressors</li> </ul>
<a href="#">Chapter 1: Table 1.3: Assertion of the function of a cancer gene</a>	<ul style="list-style-type: none"> <li>● Identifying a gene as an oncogene, tumor suppressor or neither</li> </ul>	
<a href="#">Chapter 1: Protocol 2: Variant curation</a>	<ul style="list-style-type: none"> <li>● Identifying a Variant of Interest</li> <li>● Identifying and defining the strength of functional evidence to categorize the mutation effect of a variant</li> <li>● Curation of the variant-specific Description of Mutation Effect                             <ul style="list-style-type: none"> <li>○ Formatting should be reviewed from <a href="#">Chapter 6: Table 3.2: Generation and formatting of mutation effect description</a></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● Identifying variants as VUS's or VI's</li> <li>● Assessing published data to find and assess functional evidence characterizing a variant's mutation effect</li> <li>● Determining a variant's biological effect based on functional data</li> <li>● Determining a variant's oncogenic effect based on functional data</li> <li>● Writing variant-specific Descriptions of Mutation Effects</li> </ul>
<a href="#">Chapter 1: Sub-Protocol 2.2: Defining variant type</a>	<ul style="list-style-type: none"> <li>● Identifying whether a variant is a VUS or VPS</li> </ul>	
<a href="#">Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS</a>	<ul style="list-style-type: none"> <li>● Curation of a variant's Biological Effect</li> </ul>	
<a href="#">Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS</a>	<ul style="list-style-type: none"> <li>● Curation of a variant's Oncogenic Effect</li> </ul>	
<a href="#">Chapter 2: Curation of variant and tumor type specific clinical implications</a>	<ul style="list-style-type: none"> <li>● Defining clinical significance<sup>1</sup> <ul style="list-style-type: none"> <li>○ Defining VPCS that are clinically actionable and assigning them an OncoKB and FDA level of evidence</li> <li>○ Formatting should be reviewed from <a href="#">Chapter 6: Table 5.1: Nomenclature, style and formatting of therapy-level data inputs in the OncoKB curation platform</a></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● Writing a therapeutic description of evidence</li> </ul>

<sup>1</sup>While it is important for OncoKB curators to understand the rationale and criteria for assigning gene-alteration-tumor type-drug combinations an appropriate OncoKB and FDA Level of evidence, this level of curation is always done by the

SCMT members in collaboration with the Lead Scientist following the appropriate protocols and approval from CGAC. An OncoKB curator would only be responsible for writing the therapeutic description of evidence after a Level of Evidence (OncoKB and FDA) has been appropriately assigned and approved following the protocols in [Chapter 2: Curation of variant and tumor type specific clinical implications](#).

**Table 3.3: Additional training modules required for an established OncoKB curator to qualify as an SCMT member.**

Additional training modules required for an established OncoKB curator to qualify as an SCMT member. The OncoKB Lead Scientist or a current SCMT member leads the training session.

	<b>Database elements reviewed during the training of a new SCMT member</b>	<b>Protocol in the OncoKB SOP v2 that is reviewed with the SCMT member in training</b>	<b>Additional details pertaining to the training</b>	<b>Is a proficiency test required?</b>  <i>If YES, provide a link to the test</i>
1	<i>Entering/curating data in the OncoKB curation platform</i>	<a href="#">Chapter 6: OncoKB curation, formatting and nomenclature in the curation platform</a>	<ul style="list-style-type: none"> <li>• Training includes a live demonstration of how to enter data into the gene-, variant, and tumor type-specific sections of the OncoKB curation platform</li> <li>• Data formatting and nomenclature is also reviewed in detail, including how to cite references</li> </ul>	NO
2	<i>Reviewing data in the OncoKB curation platform</i>	<a href="#">Chapter 3: Protocol 1: Data review</a>	<ul style="list-style-type: none"> <li>• Training includes a live demonstration of how to access and use <i>Review Mode</i></li> <li>• Specific rules about what OncoKB team member can review and approve data are carefully reviewed</li> </ul>	NO
3	<i>Assigning an OncoKB Levels of Evidence</i>	<a href="#">Chapter 2: Protocol 1: Curation of tumor type specific variant clinical implications</a>	<ul style="list-style-type: none"> <li>• Training includes a detailed review of the referenced protocols for assigning an OncoKB Level of Evidence 1, 2, 3A, 4, R1 and R2</li> <li>• Examples of OncoKB leveled alterations currently in OncoKB are reviewed, in addition to the specific data from the scientific literature that qualifies them for an OncoKB Level of Evidence</li> </ul>	YES  <a href="#">Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence</a>
4	<i>Assigning an FDA Levels of Evidence</i>	<a href="#">Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence</a>	<ul style="list-style-type: none"> <li>• Training includes a detailed review of the referenced protocols for assigning an FDA Level of Evidence 2 or 3</li> <li>• Examples of FDA leveled alterations currently in OncoKB are reviewed, in addition to the specific data from the scientific literature that qualifies them for an FDA Level of Evidence</li> </ul>	YES  <a href="#">Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB</a>

			<a href="#">and FDA Levels of Evidence</a>	
5	<i>Data re-analysis and re-evaluation</i>	<p><a href="#">Chapter 5: Protocol 1: Variant re-analysis and re-evaluation</a></p> <p><a href="#">Chapter 5: Protocol 2: Changing existing clinical implications</a></p>	<ul style="list-style-type: none"> <li>• Training includes a detailed review of the rules and processes outlined in <a href="#">Chapter 5: Protocol 1: Variant re-analysis and re-evaluation</a> and <a href="#">Chapter 5: Protocol 2: Changing existing clinical implications</a></li> </ul>	NO
6	<i>Data release into the OncoKB website</i>	<a href="#">Chapter 3: Protocol 2: Data release</a>	<ul style="list-style-type: none"> <li>• Training includes a live demonstration of how to use the <i>Data Validation</i> feature on the OncoKB curation platform</li> <li>• Examples of how to compose and format an OncoKB release candidate are reviewed in detail (past release candidates are provided as a reference)</li> <li>• Training also includes alive demonstration of the specific elements that need to be reviewed in the OncoKB beta release candidate (beta version of <a href="http://www.oncokb.org">www.oncokb.org</a>)</li> </ul>	NO
7	<i>Providing feedback to OncoKB end- users</i>	<a href="#">Chapter 7: Figure S1: Mechanism for user feedback</a>	<ul style="list-style-type: none"> <li>• As part of this training, the SCMT member in training is provided with examples of past feedback questions and OncoKB responses</li> </ul>	NO
8	<i>Composing consensus emails to CGAC to propose a new or change in a Level of Evidence</i>	<a href="#">Chapter 2: Table 2.1: Details and examples of how to compose a consensus email for CGAC approval of a proposed OncoKB leveled association</a>	<ul style="list-style-type: none"> <li>• As part of this training, the SCMT member in training may be asked to draft a consensus email for a current OncoKB leveled association</li> </ul>	NO
9	<i>Comprehensive review of the SOP (including major changes)</i>	<a href="#">Chapter 5: Protocol 3: Implementation processes for significant changes to the SOP</a>	<ul style="list-style-type: none"> <li>• As part of this training, the SCMT member in training is required to read over the OncoKB SOP. Each chapter of the SOP is then discussed in person during a live training session with the Lead Scientist or a current SCMT member</li> <li>• <a href="#">Chapter 5. Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature</a> describes various OncoKB database elements that may require a significant change to the SOP. For each database element, the OncoKB SOP protocols that would require re-evaluation and validation, and the data elements that would need to be updated are listed.</li> </ul>	NO



			<ul style="list-style-type: none"> <li>○ As part of their training, the SCMT member in training must have completed and passed each referenced validation test, either during curator training or SCMT training.</li> <li>● When a new major change to the SOP is implemented in the future, if any existing protocols are updated, the SCMT member will be required to 1) validate the updated protocol (see <a href="#">Chapter 5: Table 3.1: Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature</a> (column IV) and 2) use the validated, updated protocol to re-evaluate data elements that are affected by the change in the SOP (see <a href="#">Chapter 5: Table 3.1: Table 3.1: OncoKB database elements that may require a significant change to the SOP based on findings from the literature</a> (column V))</li> </ul>	
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## Protocol 4: Assessment of consistency of variant classification to OncoKB and FDA levels of evidence

- 1) Individuals with Curator competencies as described in [Chapter 7: Table 2.1: Procedures for documenting the training achievements/deficiencies and competency of OncoKB staff members](#) are recruited and given a 1.5 hour summary training by an SCMT member.
- 2) Individuals who have agreed to be part of the validation process are asked to take the Curation protocol proficiency test described in Table 4.1<sup>a</sup> following the summary training with the following instructions:
  - a) Review the following protocols in the OncoKB SOP v2.0
    - i) OncoKB Level 1 and R1 (FDA Level 2) variants are described in [Chapter 2: Sub-protocol 1.2: Rules and processes for using existing FDA drug labels](#)
    - ii) OncoKB Level 2 and R1 (FDA Level 2) variants are described in [Chapter 2: Sub-protocol 1.3: Rules/processes for using existing NCCN guidelines or guidelines from other expert panels](#)
    - iii) OncoKB Level 3A (FDA Level 3) variants are described in [Chapter 2: Sub-Protocol 1.4: Rules/processes for using peer-reviewed journals/conference proceedings/clinical trial eligibility criteria with mature clinical trial data](#)
    - iv) Mapping OncoKB Levels of Evidence to an FDA Level of Evidence [Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence](#)
  - b) Assign the gene-alterations (variants) listed in columns A and B of [Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence](#) an OncoKB (column E) and FDA (column F) level of evidence by filling out Columns E and F
    - i) Use the Flowchart described in [Chapter 7: Figure 4.1: Flowchart to determine the OncoKB and FDA Level of Evidence for a specified VPCS](#) to guide your analysis.
    - ii) **Column E:** Fill in Column E with the OncoKB Level of Evidence (Level 1, Level 2, Level 3A or Level R1) for each gene-variant-tumor type-drug combination. If the variant does not qualify for Level of Evidence, write “No Level”.
    - iii) **Column F:** Fill in Column F with the FDA Level of Evidence that (FDA Level 2 or FDA Level 3) for each gene-variant-tumor type-drug combination. The FDA Level will depend on the OncoKB Level of Evidence entered in Column E. If it does not qualify for Level of Evidence, write “No Level”.
- 3) [Chapter 7: Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence](#) is collected from individuals who have taken the Curation protocol proficiency test and the answers are scored against the established OncoKB and FDA levels of evidence already in the OncoKB database<sup>a</sup>.
- 4) The effectiveness of the Protocols (see Step 2,a,i-iv of this protocol) is measured as the percentage of answers from trained and appropriately qualified individuals that have taken the Curation Proficiency test that match the established Level of Evidence assignments already entered into OncoKB (refer to [Chapter 7: Table 4.2: Sample effectiveness measure by execution of SOP Chapter 7, Protocol 4](#)

for sample results of SOP [Chapter 7: Protocol 4: Assessment of consistency of variant classification to OncoKB and FDA levels of evidence](#)).

<sup>a</sup>[Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence](#) describes OncoKB variants that have been assigned OncoKB and FDA Levels of Evidence by SCMT members. These assignments have been reviewed by the OncoKB Lead Scientist and vetted by the CGAC process described in the [SOP Chapter 2: Protocol 2: CGAC approval of OncoKB level of evidence assignment](#).

### Table 4.1: Curation protocol proficiency test: OncoKB and FDA Levels of Evidence

Validation of OncoKB and FDA Levels of Evidence. This exercise is given to individuals (non-OncoKB staff) to validate the protocols in [Chapter 2: Curation of variant and tumor type specific clinical implications](#) which define how VPCS are assigned an OncoKB and FDA level of Evidence.

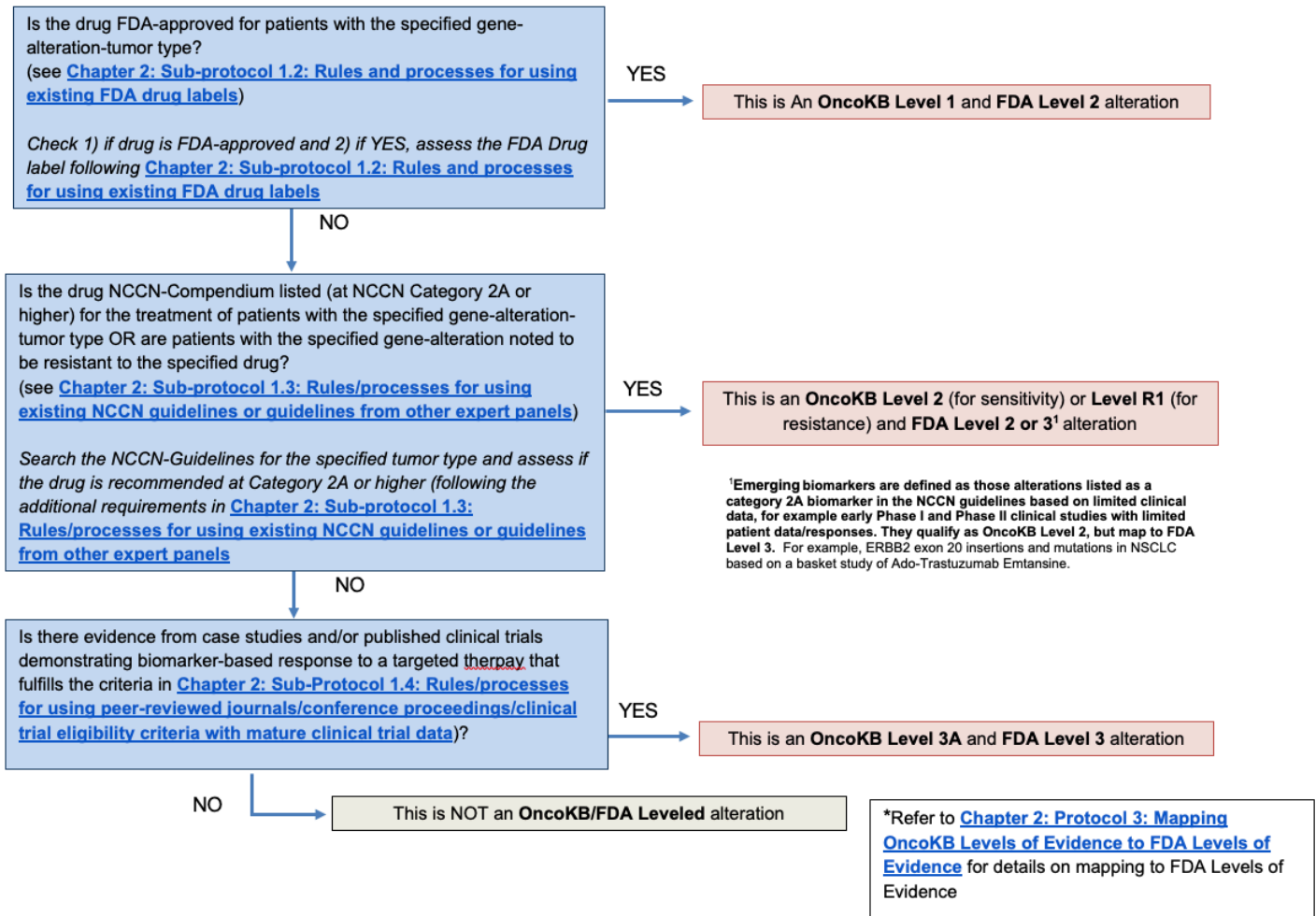
A. Gene	B. Alteration	C. Tumor Type	D. Drug	E. Assertion of OncoKB Level of Evidence (Level 1, 2, 3A, R1 or No Level)	F. Assertion of FDA Level of Evidence Level of Evidence (FDA Level 2 or 3 or No Level)
BRAF	V600E	Melanoma	Encorafenib + Binimetinib		
ERBB2	S310F	Non-Small Cell Lung Cancer	Ado-Trastuzumab Emtansine		
AKT1	E17K	Breast Cancer	AZD5363		
EGFR	T790M	Non-Small Cell Lung Cancer	Erlotinib		
TP53	R273L	Ovarian Cancer	NA		

**Table 4.2: Sample effectiveness measure by execution of SOP Chapter 7, Protocol 4.**

<b>Test variants for Level of Evidence assignments</b>	BRAF	ERBB2	AKT1	EGFR	TP53
	V600E	S310F	E17K	T790M	R273L
	Melanoma	NSCLC	Breast Cancer	Non-Small Cell Lung Cancer	Ovarian Cancer
	Encorafenib + Binimetinib	Ado-Trastuzumab Emtansine	AZD5363	Erlotinib	NA
<b>CGAC approved OncoKB level of evidence assignment</b>	Level 1	Level 2	Level 3A	Level R1	No level
<b>Mapped FDA level of evidence<sup>b</sup></b>	Level 2	Level 2	Level 3	Level 2	No level
<b>Validation individual (by initial) answers (OncoKB Level of Evidence/FDA Level of Evidence)</b>					
B.N.	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
C.T	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
S.S	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
S.C	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
S.N	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
W.C	Level 1/FDA Level 2	<b>Level 3A/FDA Level 3</b>	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
C.B	Level 1/FDA Level 2	Level 2/FDA level 2	Level 3A/FDA Level 3	Level R1/FDA Level 2	No Level
<b>% Effectiveness</b>	100	85.7	100	100	100

<sup>b</sup>By following [Chapter 2: Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence](#)

**Figure 4.1: Flowchart to determine the OncoKB and FDA Level of Evidence for a specified VPCS**



# Protocol 5: Procedure for continuing education and continued training of the tasks and skills required by the OncoKB Staff

The following meetings describe the processes in place for continuing education and continued training of the tasks and skills required by the OncoKB staff.

## 1. OncoKB Group Meetings:

1. **Attendees:** OncoKB Faculty (Head of Knowledge Systems) OncoKB Lead Scientist; Knowledge Systems Lead Scientist; Scientific Content Management Team (SCMT); Lead Software Engineer; Software Engineer; Data and Software Liaison
2. **Frequency:** Weekly
3. **Agenda:** Continued training and education for day-to-day maintenance of OncoKB comprised of elements described in [Chapter 7: Table 3.1: Elements reviewed during in-person OncoKB curator Training session](#).

## 2. SCMT Meetings:

1. **Attendees:** OncoKB Lead Scientist; Scientific Content Management Team (SCMT); Data and Software Liaison; Lead Software Engineer (as needed)
2. **Frequency:** Weekly
3. **Agenda:** Review of material from OncoKB Faculty Meetings; Review of material from OncoKB Group Meetings and assignment of work priorities; continued training and education for day-to-day maintenance of OncoKB comprised of elements described in [Chapter 7: Table 3.3: Additional training modules required for an established OncoKB curator to qualify as an SCMT member](#); Review of members and identifying members requiring retraining as needed.

## 3. Knowledge Systems Meetings:

1. **Attendees:** Knowledge Systems Lead Scientist; Lead Software Engineer; Software Engineer; Data and Software Liaison; OncoKB Faculty (Head of Knowledge Systems) (as needed) OncoKB Lead Scientist (as needed);
2. **Frequency:** Weekly
3. **Agenda:** Review of material from OncoKB Group Meetings and assignment of work priorities; Review of information provided in Attachments 7 and 8; Discussion of new features or curation platform elements; Review of members and identifying members requiring retraining as needed.

## 4. OncoKB Faculty Meeting:

1. **Attendees:** OncoKB Faculty (Director, Center for Molecular Oncology (CMO), Clinical Oncologist; Chief, Molecular Diagnostics Service, Pathology, Pathologist; Head, Knowledge Systems, CMO, Bioinformatician; Associate Director, CMO, Geneticist, Sequencing panel expertise); OncoKB Lead Scientist; SCMT (as needed)
2. **Frequency:** Quarterly

3. **Agenda:** Review of newly approved FDA drugs, newly included NCCN indications and clinical data from relevant clinical oncology and molecular pathology conferences. Review of SOP changes; Review of conflicts of interests; Review of significant process and content developments required and processes to execute per OncoKB SOP
5. **OncoKB External Advisory Board Meetings:**
  1. **Attendees:** OncoKB Faculty (Director, Center for Molecular Oncology (CMO), Clinical Oncologist; Chief, Molecular Diagnostics Service, Pathology, Pathologist; Head, Knowledge Systems, CMO, Bioinformatician; Associate Director, CMO, Geneticist, Sequencing panel expertise); OncoKB Lead Scientist; SCMT (as needed)
  2. **Frequency:** Quarterly
  3. **Agenda:** Review summarized OncoKB content, comment on any notable process or content changes based on the FDA-approval and clinical trial landscape, assess productivity of the OncoKB team, and advise on improvements to the OncoKB infrastructure, process, or content as necessary. Furthermore they will help mitigate and resolve any COI issues that may arise among members of CGAC.

# Chapter 8: The OncoKB™ website

## Introduction


The [OncoKB™ website](https://www.oncokb.org/) (<https://www.oncokb.org/>) is a publicly available platform that allows users to query and view OncoKB™ curated information about cancer genes and alterations. Within the OncoKB™ website, users can also register for an academic, commercial, or hospital license (depending on one's use case) to incorporate OncoKB data into their workflow.

## Protocol 1: OncoKB™ Website Homepage

This protocol describes the [OncoKB™ website homepage](#) on [oncokb.org](https://www.oncokb.org/).

The [OncoKB™ website homepage](#) allows the user to query the database for a gene, alteration, cancer type, or drug using the search bar (**Figure 8.1A**). The header of the homepage (**Figure 8.1B**) includes clickable links to various sub-pages of the website which include: **Levels of Evidence**, **Actionable Genes**, **Oncology Therapies**, **CDx**, **Cancer Genes**, **API/License**, **About**, **News** and **FAQ** pages. The user can view and explore the genes that are currently associated with therapeutic, diagnostic, prognostic, and FDA levels of evidence by clicking on the corresponding tab below the search bar on the homepage (**Figure 8.1C**). The current numbers of curated genes, alterations, cancer types and drugs (**Figure 8.1D**) are clickable links to various pages on the website. By clicking on the number of genes, the user will be directed to the Cancer Genes page. By Clicking on the number of alterations, cancer types, or drugs the user will be directed to the Actionable Genes page. The footer of the homepage (**Figure 8.1E**) contains links to: [OncoKB™ terms of use](#), papers to be cited when using OncoKB™ ([Suehnholz et al., Cancer Discovery 2023](#) and [Chakarvarty et al., JCO PO 2017](#)), the [Memorial Sloan Kettering \(MSK\) Cancer Center](#) and [Center for Molecular Oncology \(CMO\)](#) webpages, [cBioPortal](#), and [OncoTree](#).



**OncoKB™** Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ [Account](#)  Memorial Sloan Kettering Cancer Center

## Welcome to OncoKB™

MSK's Precision Oncology Knowledge Base  
An FDA-Recognized Human Genetic Variant Database\*

**D** **870** Genes **7794** Alterations **139** Cancer Types **140** Drugs


**A**

**C** **Therapeutic Levels** Diagnostic Levels Prognostic Levels FDA Levels

- Level 1**  
FDA-approved drugs  
53 Genes
- Level 2**  
Standard care  
29 Genes
- Level 3**  
Clinical evidence  
34 Genes
- Level 4**  
Biological evidence  
27 Genes
- Level R1/R2**  
Resistance  
11 Genes

Powered by the clinical expertise of Memorial Sloan Kettering Cancer Center  
When using OncoKB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).  
\*FDA recognition of OncoKB™ is for the content that is clearly marked

Please review the [terms of use](#) before continuing.  
When using OncoKB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).  
MSK [MSK](#) | CMO [CMO](#) | cBioPortal [cBioPortal](#) | OncoTree [OncoTree](#)

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Last data update: 06/04/2024  Memorial Sloan Kettering Cancer Center © 2024 Memorial Sloan Kettering Cancer Center

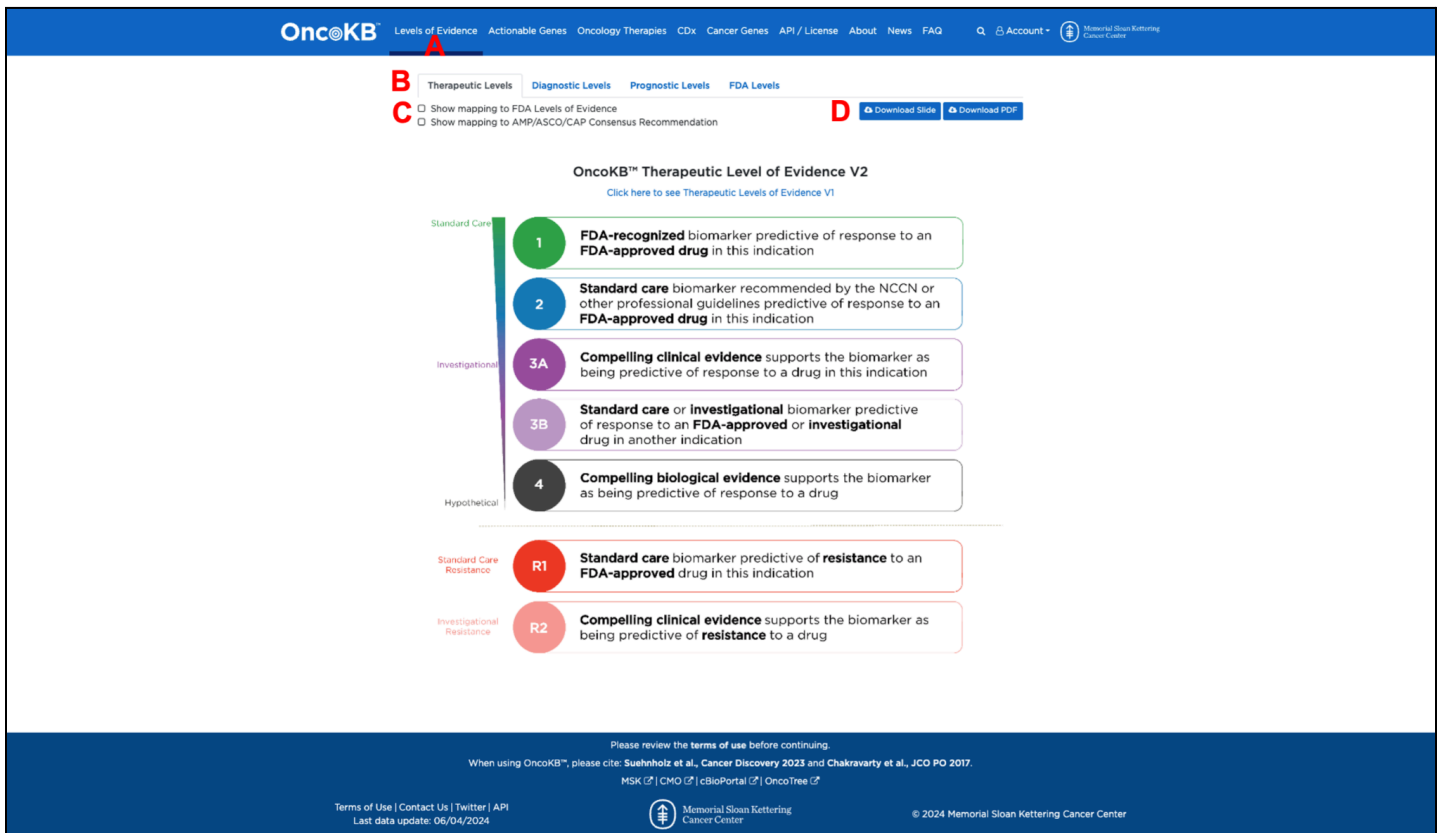
**Figure 8.1: OncoKB™ Website Homepage**

(A) Search bar. (B) Header. (C) Levels of Evidence tabs. (D) Current number of genes, alterations, cancer types, drugs. (E) Footer.

# Protocol 2: Levels of Evidence Page

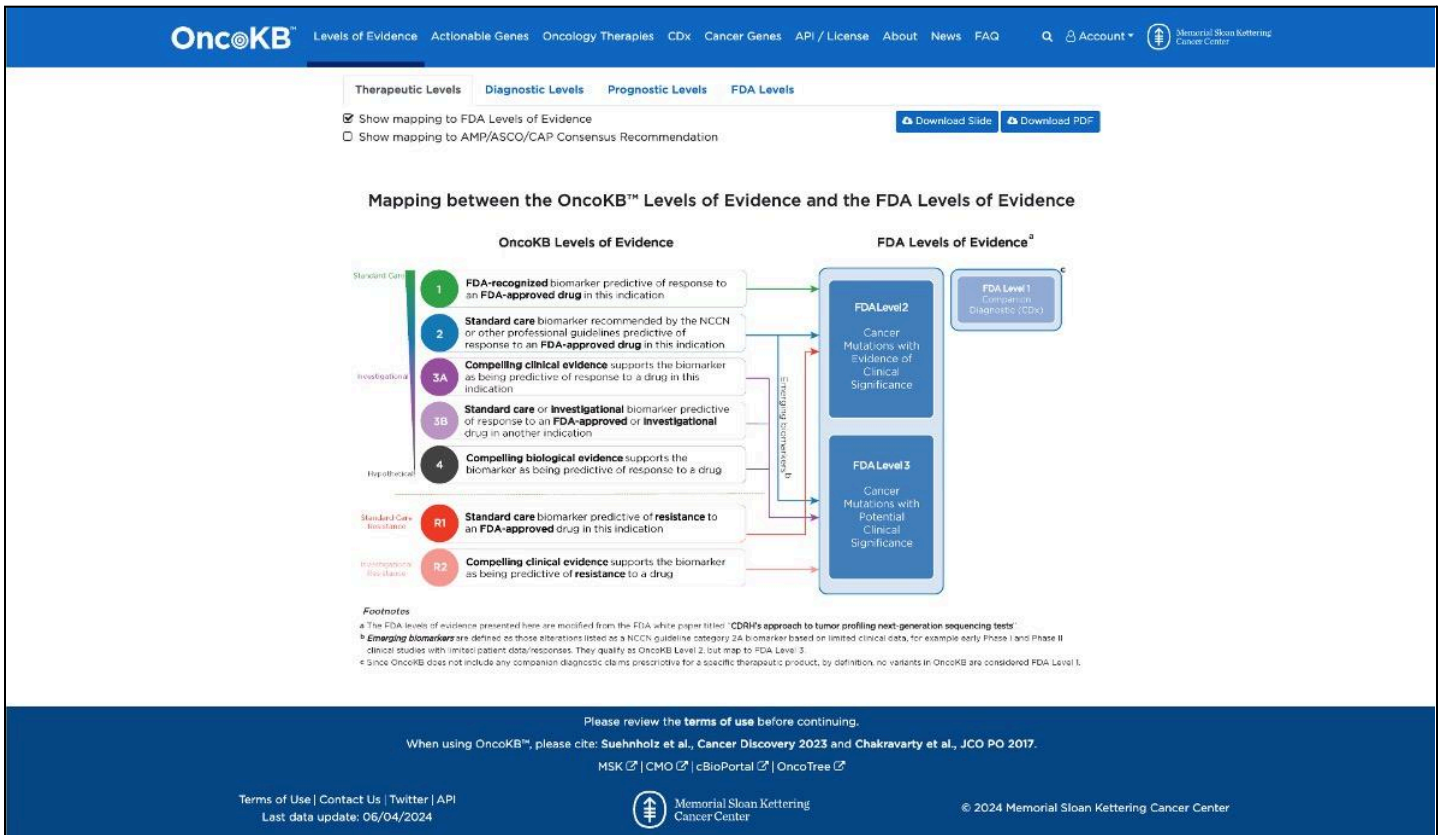
This protocol describes the [Levels of Evidence page](#) on [oncokb.org](#).

The [Levels of Evidence page](#) can be accessed from the header of OncoKB.org (**Figure 8.2A**). This page presents graphical representations of OncoKB™ therapeutic, diagnostic and prognostic levels of evidence as well as the FDA Levels of Evidence. The tabs (**Therapeutic Levels**, **Diagnostic Levels**, **Prognostic Levels**, and **FDA Levels**) on the top of the page (**Figure 8.2B**) allow the user to toggle between different levels of evidence for easy visualization. Under the **Therapeutic Levels** tab there are checkboxes (**Figure 8.2C**) that allow for visualization of the one to one mapping between OncoKB™ Levels of Evidence and FDA Levels of Evidence (**Figure 8.2.1**) and AMP/ASCO/CAP Consensus Recommendation (**Figure 8.2.2**), respectively. There is a button on the right side of the page (**Figure 8.2D**) that allows the user to download the graphical representations as a slide or PDF, providing a convenient way to access and share information. The **Diagnostic Levels** tab (**Figure 8.3**) and **Prognostic Levels** tab (**Figure 8.4**) display the OncoKB™ diagnostic and prognostic levels of evidence, respectively, and can be downloaded as a slide or PDF (**Figure 8.3A**, **Figure 8.4A**). A summary of the FDA's levels of evidence can be found on the **FDA Levels** tab (**Figure 8.5**) and can be downloaded as a PDF (**Figure 8.5A**).



**Figure 8.2: Levels of Evidence Page: Therapeutic Levels**

(A) Access to the Levels of Evidence Page. (B) Levels of Evidence tabs. (C) Checkboxes for various mapping options. (D) Download button.



**Figure 8.2.1: Mapping between the OncoKB™ Levels of Evidence and the FDA Levels of Evidence**

Screenshot of mapping between the OncoKB™ Levels of Evidence and the FDA Levels of Evidence on the Therapeutic Levels tab on the Levels of Evidence page.

OncoKB™ Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ Account + Memorial Sloan Kettering Cancer Center

Therapeutic Levels **Diagnostic Levels** Prognostic Levels FDA Levels

Show mapping to FDA Levels of Evidence  Show mapping to AMP/ASCO/CAP Consensus Recommendation

Download Slide Download PDF

### Mapping between the OncoKB™ Levels of Evidence and the AMP/ASCO/CAP Consensus Recommendation

**OncoKB Levels of Evidence**

- 1** FDA-recognized biomarker predictive of response to an FDA-approved drug in this indication
- 2** Standard care biomarker recommended by the NCCN or other professional guidelines predictive of response to an FDA-approved drug in this indication
- 3A** Compelling clinical evidence supports the biomarker as being predictive of response to a drug in this indication
- 3B** Standard care or Investigational biomarker predictive of response to an FDA-approved or Investigational drug in another indication
- 4** Compelling biological evidence supports the biomarker as being predictive of response to a drug
- R1** Standard care biomarker predictive of resistance to an FDA-approved drug in this indication
- R2** Compelling clinical evidence supports the biomarker as being predictive of resistance to a drug

**AMP/ASCO/CAP Variant Categorization<sup>1</sup>**

- Tier I: Variants of Strong Clinical Significance**
  - Level A Evidence: FDA-approved therapy included in professional guidelines
  - Level B Evidence: Well-powered studies with consensus from experts in the field
- Tier II: Variants of Potential Clinical Significance**
  - Level C Evidence: FDA-approved therapies for different tumor types or investigational therapies. Multiple small published studies with some consensus
  - Level D Evidence: Preclinical trials or a few case reports without consensus

<sup>1</sup> Li, MM et al., J Mol Diagn 2017

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When using OncoKB™, please cite: [Suehholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

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**Figure 8.2.2: Mapping between the OncoKB™ Levels of Evidence and the AMP/ASCO/CAP Consensus Recommendation**

Screenshot of mapping between the OncoKB™ Levels of Evidence and AMP/ASCO/CAP Consensus Recommendation on the Therapeutic Levels tab on the Levels of Evidence page.

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Therapeutic Levels Diagnostic Levels Prognostic Levels FDA Levels

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### OncoKB™ Diagnostic Levels of Evidence

Dx1	FDA and/or professional guideline-recognized biomarker required for diagnosis in this indication
Dx2	FDA and/or professional guideline-recognized biomarker that supports diagnosis in this indication
Dx3	Biomarker that <b>may assist disease diagnosis</b> in this indication based on <b>clinical evidence</b>

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When using OncoKB™, please cite: Suehnholz et al., Cancer Discovery 2023 and Chakravarty et al., JCO PO 2017.  
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**Figure 8.3: Levels of Evidence Page: Diagnostic Levels**  
(A) Download button.

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Therapeutic Levels Diagnostic Levels Prognostic Levels FDA Levels

Download Slide Download PDF **A**

### OncoKB™ Prognostic Levels of Evidence

- Px1** FDA and/or professional guideline-recognized biomarker prognostic in this indication based on a **well-powered study (or studies)**
- Px2** FDA and/or professional guideline-recognized biomarker prognostic in this indication based on a **single or multiple small studies**
- Px3** Biomarker is prognostic in this indication based on **clinical evidence in well-powered studies**

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When using OncoKB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

[MSK](#) | [CMO](#) | [cBioPortal](#) | [OncoTree](#)

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**Figure 8.4: Levels of Evidence Page: Prognostic Levels**  
(A) Download button.

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Therapeutic Levels Diagnostic Levels Prognostic Levels **FDA Levels**

[Download PDF](#) **A**

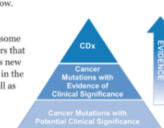
FDA U.S. FOOD & DRUG ADMINISTRATION

## FDA FACT SHEET

### CDRH'S APPROACH TO TUMOR PROFILING NEXT GENERATION SEQUENCING TESTS

The Food and Drug Administration (FDA) has recently announced the marketing authorization of three tumor profiling next generation sequencing (NGS) tests: Thermo Fisher Scientific's OncoPrint Dx Target Test, MSK-IMPACT™ and Foundation Medicine's FoundationOne CDx, which are important advancements in the real-world application of precision oncology. The approach taken to the regulation of these tumor profiling NGS tests includes several key features described below.

**Three-Tiered Approach for Reporting Biomarkers in Tumor Profiling NGS Tests**  
 FDA is committed to and works individually with test developers to use the least burdensome approach for its review of tests. Multiplexed tumor profiling tests assess many biomarkers that may have a range of clinical evidence associated with them that is constantly changing as new science emerges. Below, we discuss the three levels of biomarkers addressed collectively in the OncoPrint Dx Target Test, MSK-IMPACT, and FoundationOne CDx authorizations, as well as the analytical and clinical evidence used to support claims for those biomarkers.



**Level 1: Companion Diagnostics**  
 Companion diagnostics (CDs) are test that provide information that is essential for the safe and effective use of a corresponding therapeutic product, such as a drug. Tumor profiling NGS tests may include CDx claims that are prescriptive for a specific therapeutic product, such as the Table 1 claims listed in the intended use for the OncoPrint Dx Target Test and FoundationOne CDx. Such claims are supported by analytical validity of the test for each specific biomarker and a clinical study establishing either the link between the result of that test and patient outcomes or clinical concordance to a previously approved CDx.

**New Level 2: Cancer Mutations with Evidence of Clinical Significance**  
 Tests for biomarkers described as cancer mutations with evidence of clinical significance enable health care professionals to use information about their patients' tumors in accordance with the clinical evidence, such as clinical evidence presented in professional guidelines, as appropriate. Such claims are supported by a demonstration of analytical validity (either on the mutation itself or via a representative approach, when appropriate) and clinical validity (typically based on publicly available clinical evidence, such as professional guidelines and/or peer-reviewed publications).

**Level 3: Cancer Mutations with Potential Clinical Significance**  
 Mutations not considered biomarkers in Level 1 or Level 2 can be described as cancer mutations with potential clinical significance. These mutations may be informational or used to direct patients towards clinical trials for which they may be eligible. Such claims are supported by analytical validation, principally through a representative approach, when appropriate, and clinical or mechanistic rationale for inclusion in the panel. Such rationales would include peer-reviewed publications or in vitro pre-clinical models.

**A Fluid Approach to Reporting within Levels 2 and 3**  
 Following FDA review and authorization of a tumor profiling NGS test, the test developers will be able to report additional variants of the same type post-market within the existing analytically validated genes in the panel, for claims consistent with the clinical criteria established in the original submission, without an additional FDA submission. As evidence of clinical significance becomes recognized by the clinical community, and provided that the analytical validity of the test was reviewed and established in the initial or subsequent submission, mutations can be moved from Level 2 to Level 3 without an additional FDA submission.

**Figure 8.5: Levels of Evidence Page: FDA Levels**  
**(A)** Download button.

# Protocol 3: Actionable Genes Page

This protocol describes the [Actionable Genes page](#) on [oncokb.org](#).

The [Actionable Genes page](#) can be accessed from the header of OncoKB.org (**Figure 8.6A**) and presents the user with a sortable and searchable table (**Figure 8.6B**) of all clinically actionable genes (those associated with a therapeutic, diagnostic or prognostic level of evidence) curated in OncoKB™. The table includes the following columns: level of evidence, gene, alterations, cancer types, and drugs.

Using the search bars above the table (**Figure 8.6C**), the user can query for an actionable gene, cancer type, or drug, and the table will be filtered according to that search term. Additionally, at the top of the page the user has the option to filter the table based on Therapeutic, Diagnostic, Prognostic or FDA Levels by clicking the desired 'Level Button(s)' (**Figure 8.6D**). The number of associations displayed (**Figure 8.6E**) will change based on the number of filters selected. Users can also download the data from the actionable genes table in TSV format by clicking on the download button (**Figure 8.6F**). An example of how the table can be filtered is shown in (**Figure 8.7**) and clicking the "Reset filters" button (**Figure 8.7A**) will clear all selections and return the table to displaying all associations.

The screenshot shows the OncoKB website interface. At the top, there is a navigation bar with the OncoKB logo and links for Levels of Evidence, Actionable Genes, Oncology Therapies, CDx, Cancer Genes, API/License, About, News, and FAQ. Below the navigation bar, there are several filter buttons for Level of Evidence: Level 1 (FDA-approved drugs, 53 Genes), Level 2 (Standard care, 29 Genes), Level 3 (Clinical evidence, 34 Genes), Level 4 (Biological evidence, 27 Genes), Level R1 (Standard care, 8 Genes), and Level R2 (Clinical evidence, 6 Genes). Below these filters, there are search bars for Diagnostic (for hematologic malignancies only), Prognostic (for hematologic malignancies only), and FDA-Recognized Content. A search bar for '169 actionable genes' is also present. Below the search bars, there is a table of actionable genes. The table has columns for Level, Gene, Alterations, Cancer Types, and Drugs. The table shows 140 drugs and 747 clinical implications. A download button is visible at the bottom right of the table. The footer of the page includes the Memorial Sloan Kettering Cancer Center logo and copyright information.

Level	Gene	Alterations	Cancer Types	Drugs
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Dasatinib
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Imatinib
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Ponatinib
1	ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Asciminib
1	ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Bosutinib
1	ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Dasatinib
1	ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Imatinib
1	ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Nilotinib
1	ABL1	T315I	B-Lymphoblastic Leukemia/Lymphoma	Ponatinib
1	ABL1	T315I	Chronic Myelogenous Leukemia	Asciminib
1	ABL1	T315I	Chronic Myelogenous Leukemia	Ponatinib
1	AKT1	E17K	Breast Cancer	Capivasertib + Fulvestrant
1	ALK	Fusions	Anaplastic Large-Cell Lymphoma ALK Positive	Crizotinib
1	ALK	Fusions	Inflammatory Myofibroblastic Tumor	Crizotinib
1	ALK	Fusions	Non-Small Cell Lung Cancer	Alectinib

**Figure 8.6: Actionable Genes Page**

(A) Access to the Actionable Genes Page. (B) Actionable Genes table. (C) Search bars. (D) Level of Evidence buttons. (E) Number of displayed associations. (F) Download button.



Onc@KB™ Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ Account Memorial Sloan Kettering Cancer Center

Therapeutic

- Level 1: FDA-approved drugs (1 Gene)
- Level 2: Standard care (1 Gene)
- Level 3: Clinical evidence (0 Genes)
- Level 4: Biological evidence (0 Genes)
- Level R1: Standard care (1 Gene)
- Level R2: Clinical evidence (0 Genes)

Diagnostic (for hematologic malignancies only)

Prognostic (for hematologic malignancies only)

FDA-Recognized Content

ABL1 x B-Lymphoblastic Leukemia/Lymphoma x 5 drugs

Showing 17 clinical implications (1 gene, 3 cancer types, 5 levels of evidence) Associations Reset filters **A**

Level	Gene	Alterations	Cancer Types	Drugs
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Dasatinib
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Imatinib
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Ponatinib
1	ABL1	T315I	B-Lymphoblastic Leukemia/Lymphoma	Ponatinib
R1	ABL1	E255K and 12 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Imatinib
R1	ABL1	E255K and 6 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Nilotinib
R1	ABL1	F317C and 5 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Dasatinib
R1	ABL1	F317L, G250E, V299L	B-Lymphoblastic Leukemia/Lymphoma	Bosutinib
R1	ABL1	T315I	B-Lymphoblastic Leukemia/Lymphoma	Imatinib, Dasatinib, Nilotinib, Bosutinib
2	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Bosutinib
2	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma	Nilotinib
2	ABL1	E255K and 9 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Bosutinib
2	ABL1	E255K and 5 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Dasatinib
2	ABL1	F317C and 5 other alterations	B-Lymphoblastic Leukemia/Lymphoma	Nilotinib
1	ABL1	BCR-ABL1 Fusion	B-Lymphoblastic Leukemia/Lymphoma with	

Figure 8.7: Actionable Genes Page: Filtered Search

(A) Reset button.

## Protocol 4: Oncology Therapies Page

This protocol describes the [Oncology Therapies page](#) on [oncokb.org](#).

The [Oncology Therapies page](#) can be accessed from the header of OncoKB.org (**Figure 8.8A**) and includes a detailed table (**Figure 8.8B**) that documents novel US Food and Drug Administration (FDA)-approved oncology drugs post June 1998 and categorizes each drug by class and mechanism of action. Each drug is further classified as to whether it qualifies as a targeted therapy or precision oncology therapy (definitions below) based on [Suehnholz et al., Cancer Discovery 2023](#).

The table includes the the following following columns: Year of drug's first FDA-approval, FDA-approved drug(s), FDA label listed biomarker(s), Class of agent(s), Mechanism of actions or drug target, Targeted therapy, Precision oncology therapy, Can a DNA/NGS-based method be used for biomarker detection?. At the top of the table, by selecting the corresponding button (**Figure 8.8C**), the user has the option to filter the table by the following categories: 1. FDA-approved precision oncology therapies, 2. FDA-approved targeted therapies, or 3. FDA-approved oncology therapies, (definitions in **Table 8.1**). The user can also filter the FDA-approved Oncology Therapies table by drug, class of agent, mechanism of action or biomarker using the respective search bars (**Figure 8.8D**). The user can download the data in the FDA-approved Oncology Therapies table by clicking the 'Download Table' button located on the top right of the table (**Figure 8.8E**). This data will download in Xlsx format.

**OncoKB** Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ Account - Memorial Sloan Kettering Cancer Center

## FDA-Approved Oncology Therapies

Content current as of 4/23/2024

The following US Food and Drug Administration (FDA)-approved oncology drugs post June 1998 are categorized by drug class and mechanism of action. Each drug is further classified as to whether it qualifies as a targeted therapy or precision oncology therapy based on Suelhholz et al., Cancer Discovery 2023 (definitions below).

Show definitions @

**C** FDA-Approved Precision Oncology Therapies  
96 therapies

FDA-Approved Targeted Therapies  
Targeted Therapies therapies

FDA-Approved Oncology Therapies  
220 therapies

**D** Select drug(s)

Select class of agent(s)

Select mechanism of action

Search biomarker

Showing 96 therapies: (95 Targeted therapies, 96 Precision oncology therapies, 79 therapies with a biomarker that can be identified by a DNA/NGS-based detection method) @

**E** [Download Table](#)

<b>B</b> Year of drug's first FDA-approval	FDA-approved drug(s)	FDA drug label listed biomarker(s) @	Class of agent(s) @	Mechanism of action or drug target @	Targeted therapy	Precision oncology therapy	Can a DNA/NGS-based method be used for biomarker detection? @
2024	Tovorafenib	BRAF Fusions, BRAF Rearrangement, BRAF V600	Small molecule kinase inhibitor	RAF inhibitor	✓	✓	Y
2023	Repotrectinib	ROS1 Fusions	Small molecule kinase inhibitor	Multi-targeted kinase inhibitor (targets include ROS1 and NTRK1/2/3)	✓	✓	Y
2023	Quizartinib	FLT3 ITD Mutations	Small molecule inhibitor	FLT3 inhibitor	✓	✓	Y
2023	Elaeestrant	ESR1 Ligand-binding domain missense mutations and ER+/HER2-	Hormone therapy	Selective estrogen receptor degrader (SERD)	✓	✓	Y
2023	Capivasertib	PIK3CA, AKT1 or PTEN Oncogenic Mutations and HR+/HER2-	Small molecule kinase inhibitor	AKT1/2/3 inhibitor	✓	✓	Y
2022	Tebentafusp	HLA-A*02:01-positivity	Bispecific T-cell engager	Bispecific gp100 peptide-HLA-A*02:01-directed T-cell receptor CD3 T	✓	✓	N

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When using OncoKB™, please cite: Suelhholz et al., Cancer Discovery 2023 and Chakravarty et al., JCO PO 2017.  
MSK | CMO | cBioPortal | OncoTree

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**Figure 8.8: Oncology Therapies Page**

(A) Access to the Oncology Therapies Page. (B) Oncology Therapies table. (C) Therapy filter buttons. (D) Search bars. (E) Download button.

## Table 8.1: Definitions of terms describing oncology therapies

The following terms are used to describe oncology therapies listed on the OncoKB™ Oncology Therapies page.

Term	Description
Oncology drug	A drug approved by the US-Food and Drug Administration (FDA) for the treatment of cancer
Targeted therapy	A cancer drug that binds to or inhibits a specific protein target
Precision Oncology therapy	A drug that is most effective in a molecularly defined subset of patients and for which pre-treatment molecular profiling is required for optimal patient selection

### Sub-Protocol 4.1: Updating and Maintaining the Oncology Therapies page on oncokb.org

This protocol describes how the OncoKB™ FDA-approved Oncology Therapies table is updated and maintained.

Three sources were used to create the master list of all FDA-approved oncology drugs between September 1998 and November 2022:

1. FDA drug approval notifications posted to the [Oncology \(Cancer\) / Hematologic Malignancies Approval Notifications](#) page (drugs approved between June 14th, 2006, and November 4th, 2022, were collected and reviewed).
2. Sun J, Wei Q, Zhou Y, Wang J, Liu Q, Xu H. A systematic analysis of FDA-approved anticancer drugs. *BMC Syst Biol.* 2017;11:87 (drugs listed in [Table 1](#): Summary of FDA-approved anticancer drugs from 1949 to 2014, were collected and reviewed). Exact methods of FDA-approved anticancer drug curation are provided in Supplementary Note 1 in the Supplementary Methods.
3. [Olivier T, Haslam A, Prasad V. Anticancer drugs approved by the US Food and Drug Administration from 2009 to 2020 according to their mechanism of action. \*JAMA Netw Open\* 2021;4:e2138793](#) (FDA drug approvals between January 1st, 2017, and April 28th, 2017, were missing from the FDA.gov website, and this review was used to complete the drug list). Exact methods of FDA-approved anticancer drug curation are provided in Supplementary Note 2 in the Supplementary Methods.

FDA drug approval notifications (from sources 1–3 above, if present) and FDA drug labels (from [Drugs@FDA](#)) for all drugs included in the three sources above were reviewed. Novel FDA-approved drug(s) and drug combinations updated to the FDA's [Oncology \(Cancer\) / Hematologic Malignancies Approval Notifications](#) page are reviewed and incorporated into OncoKB's FDA-approved Oncology Therapies Table every two months.

For each oncology drug listed by OncoKB™, the following information is included in a tabular format (Note, that the bullets below represent columns in FDA-approved Oncology Therapies Table):

- **Year of drug's first FDA-approval:** Date of drug's original FDA-approval per [Drugs@FDA](#)
- **FDA-approved Drug:** Drug name as listed on the FDA drug label
- **FDA drug label listed biomarker(s):** Biomarker(s) specified in the FDA label and/or used to select patients for treatment with the drug (if there is a corresponding FDA-approved companion diagnostic (CDx) test for biomarker identification, the biomarker(s) detected by the CDx are listed).
- **Class of agent:** Drug "class" was determined based on information in each drug's [FDA drug label](#) and [NCI Drug Dictionary](#).
- **Mechanism of action or drug target:** Drug mechanism of action/drug target was determined based on information in each drug's [FDA drug label](#) and [NCI Drug Dictionary](#).
- **Targeted therapy (Y/N):** refer to definition in Table 8.1
- **Precision oncology Therapy (Y/N):** refer to definition in Table 8.1
- **Can a DNA/NGS-based method be used for biomarker detection:** Classification applies only to drugs labeled as Precision oncology therapies. If at least one of the listed biomarkers can be detected by DNA/NGS-based method, this column will be marked as Y.

Criteria for including or excluding FDA-approved drugs from OncoKB™'s FDA-approved Oncology Therapies Table:

- Drugs listed in the [Oncology \(Cancer\) / Hematologic Malignancies Approval Notifications](#) page that are excluded from FDA-approved Oncology Therapies Table include:
  1. Drugs FDA approved for conditions related to cancer, although not the cancer itself (e.g., abatacept for prophylaxis of acute graft versus host disease)
  2. Oncology drugs first FDA approved prior to 1998
  3. Oncology drugs noted to be "biosimilars" in the FDA-approval notification
- Additional criteria for counting FDA-approved oncology drugs include:
  1. Oncology drugs FDA approved for multiple indications are counted only once
  2. Oncology drugs FDA approved as a single agent and also in combination with a nontargeted agent(s)\* are counted once
  3. Oncology drugs FDA approved only in combination(s) with a nontargeted agent(s)\* are counted once
  4. If two precision oncology therapies were FDA approved as single agents, and also in combination with each other, we counted each single agent as well as the drug combination separately (e.g. dabrafenib, trametinib, and dabrafenib + trametinib, count = 3).

\*Note: The following drugs were considered non targeted agents: chemotherapy, radiation, hormone/endocrine therapy, steroids, bevacizumab, axitinib, lenvatinib, cabozantinib, rituximab, ramucirumab, interferon alpha, proteasome inhibitor, antifolate, hyaluronidase, and pomalidomide.

# Protocol 5: CDx Page

This protocol describes the [FDA-approved cleared or approved companion diagnostic devices \(CDx\)](#) page on [oncokb.org](#), including the processes for its maintenance and updates

The [CDx page](#) can be accessed from the header of OncoKB.org (**Figure 8.9A**) and provides information on FDA-approved or cleared companion diagnostics used to guide treatment decisions in cancer for the safe and efficient use of oncology drugs (per the FDA's [List of Cleared or Approved Companion Diagnostic Devices \(In Vitro and Imaging Tools\)](#)). Only the companion diagnostics that are included in the FDA drug labels of OncoKB™ level 1 precision oncology drugs and determine the list of OncoKB™ level 1 biomarkers are listed on the page.

For each CDx listed by OncoKB™, the following information is included in a tabular format (**Figure 8.9B**): Note that the bullets below represent columns in OncoKB's CDx Table, and data in this table is derived from the FDA's CDx Table listed on the FDA's [List of Cleared or Approved Companion Diagnostic Devices \(In Vitro and Imaging Tools\)](#) page (referred to as "the FDA CDx page").

- **Gene:** Maps the 'biomarker' referenced in the FDA [CDx page](#) to the OncoKB™ gene name.
- **Alteration(s):** Maps the 'biomarker(s) (Details)' referenced in the FDA CDx page to an OncoKB™ alteration(s).
- **Cancer Type(s):** Maps the 'indication' from the 'Indication-Sample Type' column in the FDA CDx page to cancer type(s) from OncoKB™.
- **Drug(s):** Maps the FDA generic drug name referenced in the FDA CDx page to the OncoKB™ drug name.
- **Companion Diagnostic Device:** Lists the device's name; derived from the 'Diagnostic Name' and the manufacturer's name listed on the FDA CDx page.
- **Specimen Type(s):** Lists the specimen type required by the device (ie. FFPE, Whole Blood, etc.); derived from the sample type listed on the 'Indication-Sample Type' column on the FDA page.
- **Platform Type:** Lists the platform required by the device for biomarker detection (ie. PCR, NGS, etc.); derived from the approval order statement in the device's premarket approval (PMA).
- **Reference(s):** Links to the approved PMA and the approval date of the CDx on the appropriate FDA medical device database.

The table can be filtered by gene, alteration, cancer type, drug, or CDx by using the respective search bar (**Figure 8.9C**), and the data can be downloaded in TSV format by clicking the download button (**Figure 8.9D**).

The page is updated every two months, with new entries mapped to OncoKB™ terms as described above.

### FDA Cleared or Approved Companion Diagnostic Devices

Companion diagnostic devices (CDx) that are US- Food and Drug Administration (FDA) approved or cleared to guide treatment decisions in cancer for the safe and efficient use of oncology drugs (per the FDA's [List of Cleared or Approved Companion Diagnostic Devices \(In Vitro and Imaging Tools\)](#)). Only the companion diagnostics that are included in the FDA-drug labels of Onc@KB™ level 1 precision oncology drugs and determine the list of Onc@KB™ level 1 biomarkers are listed below.

**C** Gene(s)  Alteration(s)  Cancer Type(s)  Drug(s)  CDx

Showing 157 biomarker and cancer type-specific CDx associations (38 genes, 20 cancer types, 51 drugs, 39 companion diagnostic devices) **D** [Download Table](#)

**B**

Gene	Alteration(s)	Cancer Type(s)	Drug(s)	Companion Diagnostic Device	Specimen Type(s)	Platform Type	Reference(s)
ABL1	BCR-ABL1 Fusion	Chronic Myelogenous Leukemia	Nilotinib	MRDx BCR-ABL Test (MolecularMD Corporation)	Peripheral Blood	PCR	K173492 (12/21/2017)
ALK	Fusions	Non-Small Cell Lung Cancer	Alectinib	FoundationOne CDx (Foundation Medicine, Inc.)	FFPE	NGS	P170019 (11/29/2017)
ALK	Fusions	Non-Small Cell Lung Cancer	Crizotinib	FoundationOne CDx (Foundation Medicine, Inc.)	FFPE	NGS	P170019 (11/29/2017)
ALK	Fusions	Non-Small Cell Lung Cancer	Ceritinib	FoundationOne CDx (Foundation Medicine, Inc.)	FFPE	NGS	P170019 (11/29/2017)
ALK	Fusions	Non-Small Cell Lung Cancer	Alectinib	FoundationOne Liquid CDx (Foundation Medicine, Inc.)	cfDNA from plasma	NGS	P200006 (10/25/2020)
ALK	Fusions	Non-Small Cell Lung Cancer	Crizotinib	Vysis ALK Break Apart FISH Probe Kit (Abbott Molecular Inc.)	FFPE	FISH	P110012 (08/25/2011)
ALK	Fusions	Non-Small Cell Lung Cancer	Brigatinib	Vysis ALK Break Apart FISH Probe Kit (Abbott Molecular Inc.)	FFPE	FISH	P110012/S020 (05/21/2020)
ATM	Oncogenic Mutations	Prostate Cancer, Prostate Cancer, NOS	Olaparib	FoundationOne CDx (Foundation Medicine, Inc.)	FFPE	NGS	P170019/S015 (05/18/2020)
ATM	Oncogenic Mutations	Prostate Cancer, Prostate Cancer, NOS	Olaparib	FoundationOne Liquid CDx (Foundation Medicine, Inc.)	cfDNA from plasma	NGS	P200006 (10/25/2020)

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When using Onc@KB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

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**Figure 8.9: CDx Page**

(A) Access to the CDx Page. (B) CDx table. (C) Search bars. (D) Download button.

# Protocol 6: Cancer Genes Page

This protocol describes the [Cancer Genes page](#) on [oncokb.org](#).

The [Cancer Genes page](#) can be accessed from the header of OncoKB.org (**Figure 8.10A**) and presents the user with the OncoKB™ Cancer Gene List. This list is presented as a table (**Figure 8.10B**) that includes genes that are identified as cancer genes by OncoKB™, based on their presence in various sequencing panels (MSK-IMPACT™, MSK IMPACT™ Heme, Foundation One CDx and Foundation One Heme), the Sanger Cancer Gene Census or [Vogelstein et al. \(2013\)](#). The table specifies whether each gene has been annotated by OncoKB™ and its classification as an oncogene or tumor suppressor gene, when known. The information icon (**Figure 8.10C**) next to the gene name provides alternate aliases of the gene. The Cancer Gene List can also be downloaded in TSV format by clicking on the button on the top right of the page (**Figure 8.10D**).

**OncoKB™ Cancer Gene List**  
 1151 genes, last update 06/04/2024  
 The following genes are considered to be cancer genes by OncoKB™, based on their inclusion in various different sequencing panels, the Sanger Cancer Gene Census, or [Vogelstein et al. \(2013\)](#).

Gene	OncoKB™ Annotated	Oncogene/TSG	MSK-IMPACT™	MSK-IMPACT™ Heme	Foundation One CDx	Foundation One Heme	Vogelstein et al. 2013	COSMIC Cancer Gene Census Tier 1	# of Sources
<a href="#">ABLI</a> ⓘ	✓	Oncogene	✓	✓	✓	✓	✓	✓	7
<a href="#">AKTI</a> ⓘ	✓	Oncogene	✓	✓	✓	✓	✓	✓	7
<a href="#">ALK</a> ⓘ	✓	Oncogene	✓	✓	✓	✓	✓	✓	7
<a href="#">AMERI</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7
<a href="#">APC</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7
<a href="#">AR</a> ⓘ	✓	Oncogene	✓	✓	✓	✓	✓	✓	7
<a href="#">ARIDIA</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7
<a href="#">ASXLI</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7
<a href="#">ATM</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7
<a href="#">ATRX</a> ⓘ	✓	TSG	✓	✓	✓	✓	✓	✓	7

Previous Page 1 of 116 10 rows Next

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**Figure 8.10: Cancer Gene Page**

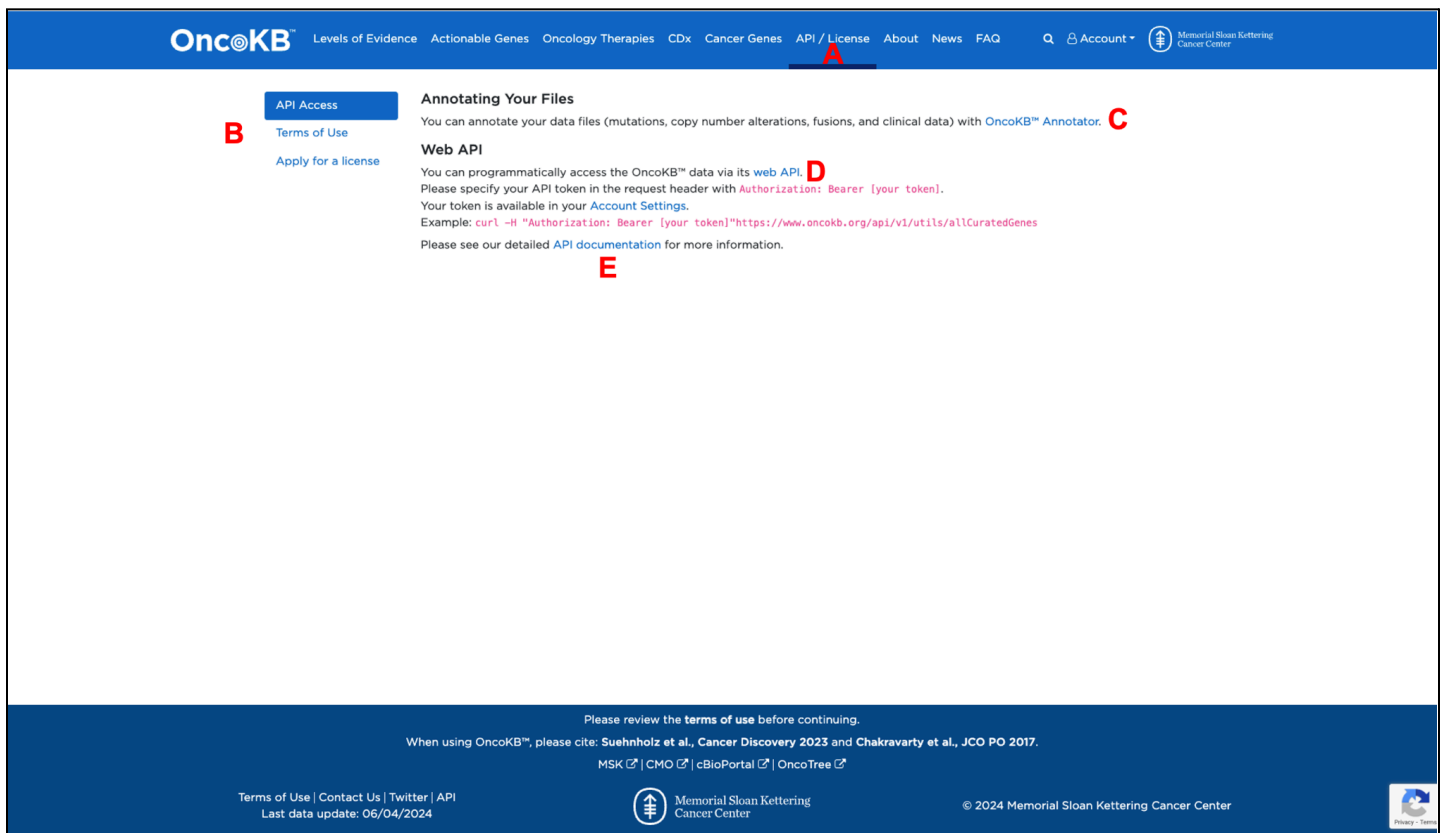
(A) Access to the Cancer Gene Page. (B) Cancer Gene List table. (C) Icon button. (D) Download button.



# Protocol 7: API/License Page

This protocol describes the [API/License page](#) on [oncokb.org](#).

The [API/License page](#) can be accessed from the header of OncoKB.org (**Figure 8.11A**). The page is split into three sections which are organized in tabs on the left side of the page (**API Access**, **Terms of Use** and **Apply for a license**) (**Figure 8.11B**). The **API Access** tab provides resources to help the user annotate data with OncoKB™ Annotator and API. The [OncoKB™ Annotator](#) link (**Figure 8.11C**) directs the user to the GitHub page (**Figure 8.11.1**) that allows for annotation of MAF files using the OncoKB™ annotator. The [web API](#) link (**Figure 8.11D**) allows the user to programmatically access OncoKB™ data via its web API by directing the user to a REST API (Swagger Page) (**Figure 8.11.2**). Detailed information on how to use the OncoKB™ Annotator and API can be found by clicking on the [API documentation](#) link (**Figure 8.11E**), which directs the user to OncoKB™ API Documentation (**Figure 8.11.3**). The **Terms of Use** tab outlines the conditions for an academic or commercial license (**Figure 8.12**). The **Apply for a license** tab allows the user to create an account for a license that best suits their workflow (**Figure 8.13**).



**Figure 8.11: API/License Page: API Access**

(A) Access to the API/License Page. (B) API/License Page tabs. (C) OncoKB™ Annotator link. (D) Web API link. (E) API Documentation link.

Product Solutions Resources Open Source Enterprise Pricing

Search or jump to... 7 Sign in Sign up

oncoKB / oncoKB-annotator Public

Code Issues 13 Pull requests 2 Actions Projects Security Insights

master 6 Branches 43 Tags

oncoKB-bot Update action files to align the version level to patch 4427d91 · 4 months ago 286 Commits

.github	Update action files to align the version level to patch	4 months ago
data	Minor updates on the example script	2 years ago
requirements	Bump requests from 2.27.1 to 2.31.0 in /requirements	7 months ago
.editorconfig	Support reference genome	4 years ago
.gitignore	Shorten the example MAF to include essential columns only	4 years ago
.version-level	Update .version-level	4 months ago
AnnotatorCore.py	Support Tumor_Sample_Barcode as column name in clini...	4 months ago
ClinicalDataAnnotator.py	Flake 8 updates	2 years ago
CnaAnnotator.py	Add descriptions into appended column list (#204)	last year
FusionAnnotator.py	Add descriptions into appended column list (#204)	last year
GenerateReadMe.py	Flake 8 updates	2 years ago
LICENSE	Initial commit	7 years ago
MafAnnotator.py	Add descriptions into appended column list (#204)	last year
OncoKBPlots.py	Flake 8 updates	2 years ago
README.md	Update README.md	6 months ago
StructuralVariantAnnotator.py	Add descriptions into appended column list (#204)	last year
actionability_functions_msi_tmb_manuscrip...	Add R script to generate the actionability figure	10 months ago
example.sh	Remove matplotlib from dependency	last year
flake8.ini	Update tests & Format code	7 months ago
test_Annotation.py	Update tests & Format code	7 months ago

**About**  
Annotates variants in MAF with OncoKB annotation.  
Readme  
AGPL-3.0 license  
Activity  
Custom properties  
119 stars  
10 watching  
56 forks  
Report repository

**Releases** 42  
v3.4.1 Latest on Feb 14  
+ 41 releases

**Packages**  
No packages published

**Contributors** 10

**Languages**  
Python 72.3% R 26.7% Shell 1.0%

**Figure 8.11.1: OncoKB™ Annotator**  
Screenshot of GitHub webpage for OncoKB™ Annotator.

Swagger THE OPEN SOURCE

Select a definition **Public APIs**

## OncoKB APIs v1.4.1

[ Base URL: [www.oncokb.org/api/v1](http://www.oncokb.org/api/v1) ]  
[api/v1/2/api-docs?group=Public%20APIs](#)

OncoKB, a comprehensive and curated precision oncology knowledge base, offers oncologists detailed, evidence-based information about individual somatic mutations and structural alterations present in patient tumors with the goal of supporting optimal treatment decisions.

[Terms of service](#)  
[OncoKB - Website](#)  
[Send email to OncoKB](#)  
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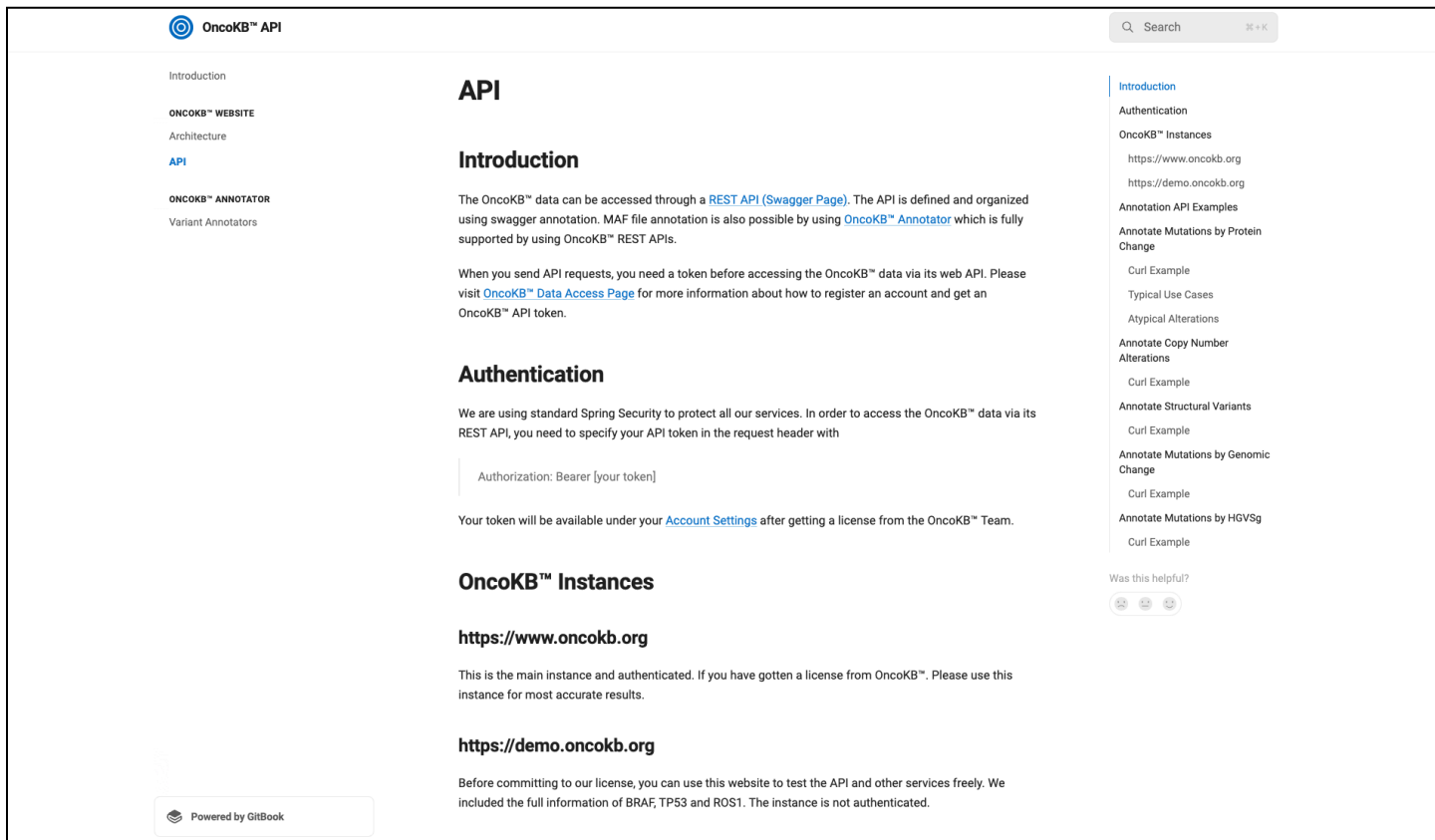
Schemes **HTTPS**

Filter by tag

### Annotations Providing annotation services

- GET** `/annotate/copyNumberAlterations` `annotateCopyNumberAlterationsGet`
- POST** `/annotate/copyNumberAlterations` `annotateCopyNumberAlterationsPost`
- GET** `/annotate/mutations/byGenomicChange` `annotateMutationsByGenomicChangeGet`
- POST** `/annotate/mutations/byGenomicChange` `annotateMutationsByGenomicChangePost`
- GET** `/annotate/mutations/byHGVSg` `annotateMutationsByHGVSgGet`
- POST** `/annotate/mutations/byHGVSg` `annotateMutationsByHGVSgPost`
- GET** `/annotate/mutations/byProteinChange` `annotateMutationsByProteinChangeGet`
- POST** `/annotate/mutations/byProteinChange` `annotateMutationsByProteinChangePost`
- GET** `/annotate/structuralVariants` `annotateStructuralVariantsGet`

**Figure 8.11.2: OncoKB™ APIs**  
 Screenshot of Swagger web page for OncoKB™ API.



**Figure 8.11.3: OncoKB™ API Documentation**  
Screenshot of OncoKB™ API Documentation.

**Onc@KB** Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ Account + Memorial Sloan Kettering Cancer Center

API Access  
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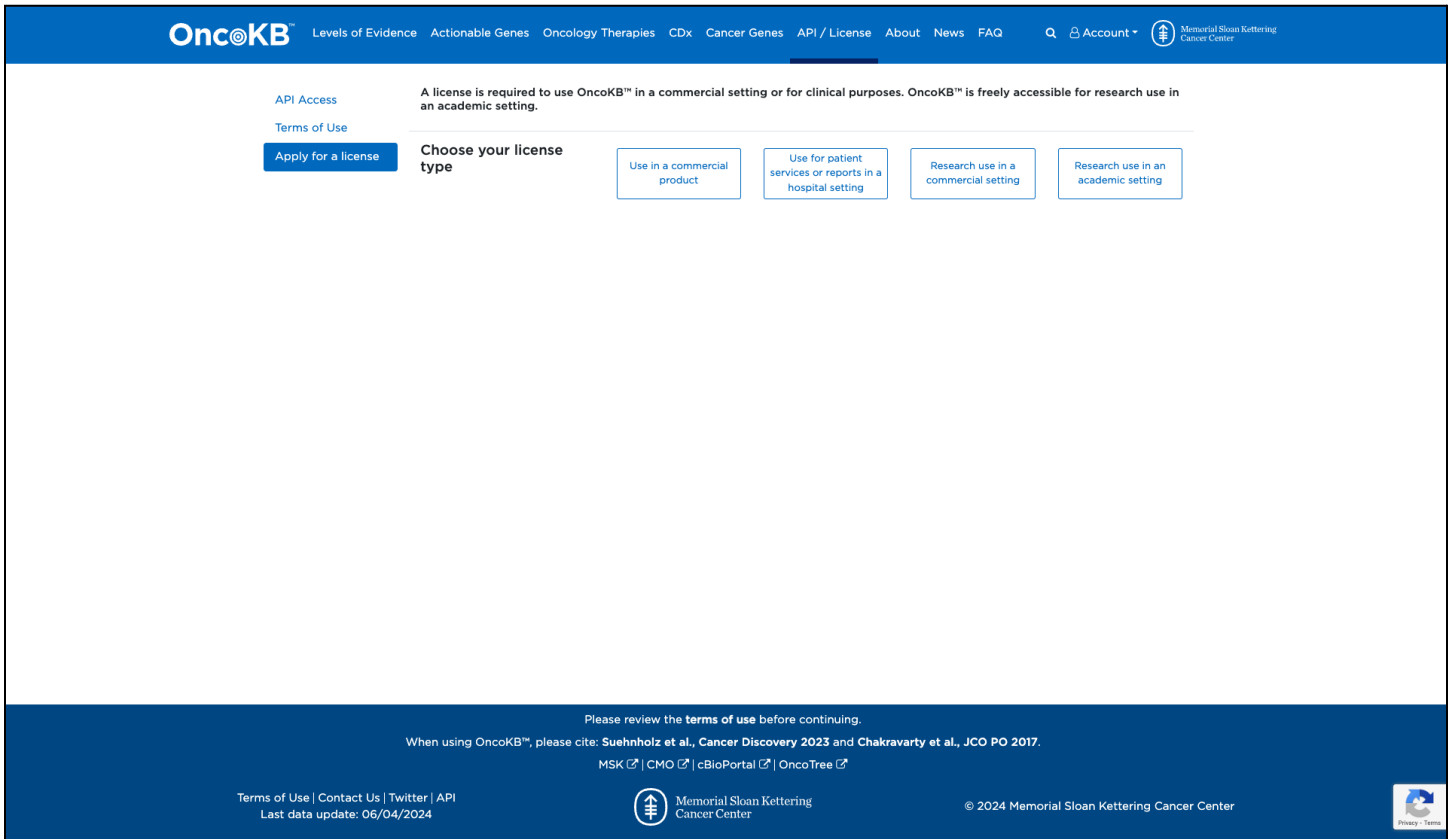
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## Figure 8.12: API/License Page: Terms of Use

Screenshot of Terms of Use of OncoKB™ in an academic research or commercial setting.



**Figure 8.13: API/License Page: Apply for a license**  
Screenshot of selection of license types when applying for a license for OncoKB™.

# Protocol 8: About Page

This protocol describes the [About page](#) on [oncokb.org](#).

The [About page](#) can be accessed from the header of OncoKB.org (**Figure 8.14A**) and provides the user with a comprehensive overview of the website’s features and resources. The user can navigate through the tabs (**About, Team, FDA Recognition and SOP**) located on the left side of the page (**Figure 8.14B**). The **About** tab also features informative videos including an introduction, demonstration and tutorials to enhance user understanding (**Figure 8.14C**). The user can view present and past OncoKB™ members that are involved in Design & Development, the External Advisory Board, or Clinical Genomics Annotation Committee and their COIs if applicable on the **Team** tab (**Figure 8.15**). The **FDA Recognition** tab (**Figure 8.16**) explains the significance of OncoKB™ being partially recognized by the FDA and the scope of this recognition. The most current version of the OncoKB™ SOP can be found on the **SOP** tab (**Figure 8.17**) and all versions of the SOP can be accessed via the version dropdown menu (**Figure 8.17A**).

**OncoKB™** Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ Account Memorial Sloan Kettering Cancer Center

**B** About  
Team  
FDA Recognition  
SOP

**About OncoKB™**

OncoKB™ is a precision oncology knowledge base developed at Memorial Sloan Kettering Cancer Center that contains biological and clinical information about genomic alterations in cancer.

Alteration- and tumor type-specific therapeutic implications are classified using the OncoKB™ Levels of Evidence system, which assigns clinical actionability to individual mutational events.

For additional details about the OncoKB™ curation process, please refer to the version-controlled OncoKB™ Curation Standard Operating Procedure. When using OncoKB™, please cite: Suehnholz et al., Cancer Discovery 2023 and Chakravarty et al., JCO PO 2017.

**Intro Demo Tutorials C**

**0** **Q** OncoKB Introduction

Welcome to OncoKB  
MSK's Precision Oncology Knowledge Base  
An FDA-Recognized Human Genetic Variant Database

682 Genes 5685 Variants 137 Therapies 104 CDx

Level 1: High-quality evidence 28 Genes  
Level 2: Moderate evidence 28 Genes  
Level 3: Limited evidence 28 Genes  
Level 4: Research evidence 28 Genes  
Level 5: Evidence not available 28 Genes

**Overview of OncoKB™ Process**

**Oversight and Governance**  
External Advisory Board (EAB)  
Clinical Genomics Annotation Committee (CGAC) → Clinical Insights → Lead Scientist  
Update Requests

**Variant Databases**  
Statistical Recurrence  
Treatment Guidelines  
Scientific Literature  
Data Sources

**OncoKB Curation Interface**

GENE	VARIANT	TUMOR TYPE	CLINICAL IMPLICATIONS
Gene Summary Gene Background	Variant Summary Oncogenicity Mutation Effect	Summary of Clinical Implications	Standard Therapies Investigational Therapies
AKT1	E17K E40K E40V L52R Q79E	Breast cancer Ovarian cancer Lung cancer Amplification	Diagnostic implications Prognostic implications Standard therapy Investigational therapy



**Variant Curation**  
Curators  
Lead Scientist  
Curation Review  
Scientific Content Management Team (SCMT)  
Curators

**OncoKB Access**  
oncoKB.org website  
OncoKB API  
cBioPortal  
MSK Clinical Reports

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**Figure 8.14: About Page: About OncoKB™**  
(A) Access to the About Page. (B) About Page tabs. (C) Videos.

OncoKB™ Levels of Evidence Actionable Genes Oncology Therapies CDx Cancer Genes API / License About News FAQ  Account  Memorial Sloan Kettering Cancer Center

**About**

**Team**

FDA Recognition

SOP

### OncoKB™ Team

OncoKB™ is developed and maintained by the Knowledge Systems group in the Marie Josée and Henry R. Kravis Center for Molecular Oncology at Memorial Sloan Kettering Cancer Center.

#### Design & Development

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- Sarah Suehnholz, PhD [COIS](#) [↗](#)
- Hongxin Zhang, MSc [COIS](#) [↗](#)
- Ritika Kundra, MSc [COIS](#) [↗](#)
- Moriah Nissan, PhD [COIS](#) [↗](#)
- Calvin Lu, BSc [COIS](#) [↗](#)
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When using OncoKB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

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**Figure 8.15: About Page: OncoKB™ Team**  
 Screenshot of the OncoKB™ Team tab on the About page.



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[About](#)  
[Team](#)  
**[FDA Recognition](#)**  
[SOP](#)

## OncoKB™ is now an FDA-recognized Public Human Genetic Variant Database\*

*"FDA recognition of OncoKB™ is for the content that is clearly marked"*

In October 2021, OncoKB™ became the first somatic human variant database to be recognized by the FDA. FDA recognition of OncoKB™ is "partial" and is limited to the information provided in the "FDA-Recognized Content" tab which can be found on the [Actionable Genes](#) page and on each individual gene page within OncoKB™.

As background, in April 2018, the FDA announced their regulatory approach for the [Use of Public Human Genetic Variant Database](#) to support the Agency's precision medicine initiatives. "The goal of this effort is to help ensure patients receive accurate, reliable, and clinically meaningful test results, while promoting innovation in test development".

Data and assertions within an FDA-recognized database are considered valid scientific evidence that can be used to streamline the next generation sequencing (NGS)-based tumor profiling test development and validation processes. FDA recognition also incentivizes human variant data-sharing by recognizing the importance of transparency and peer-review for accurate human variant interpretation and pathogenicity classification. Thus, all data in an FDA-recognized human variant database is expected to be publicly accessible, including the variant curation and interpretation processes as well as the curated evidence to support the final variant classifications.

### Important Database Links

[OncoKB™ SOP v2](#)  
[Mapping to the FDA Levels of Evidence](#)  
[FAQs about FDA Recognition](#)  
 For a full list of FDA recognized variants in OncoKB™ please see the [Actionable Genes](#) page

### OncoKB™ Application Links

[FDA Recognition Letter](#)  
[FDA Decision Summary for OncoKB™](#)

### Press Releases

[FDA Recognition Announcement](#)  
[MSK Press Release](#)  
[ASCO Post Update](#)

### Scope of OncoKB™ Recognition

The FDA has reviewed all OncoKB™ processes documented in the [OncoKB™ SOP v2](#), which include the following:

1. Part of the OncoKB™ annotation content: Annotation of variants curated in OncoKB™ with an FDA level of evidence. FDA-recognized content is clearly marked on the website and a pop-up message will appear when the user exits an FDA-recognized portion of the OncoKB™ website.
2. Mapping of OncoKB™ levels of evidence to the FDA levels of evidence.
3. OncoKB™'s processes and validation studies for variant evaluation and assertion, data integrity and security, and transparency of all evidence.
4. OncoKB™'s administration policies for hiring, training and continuing the education of its curators and Scientific Content Management Team who evaluate and approve inclusion of variants into the database.
5. OncoKB™'s policies of oversight and governance.
6. OncoKB™'s processes for ensuring its members' conflicts of interest are minimized and transparent.

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When using OncoKB™, please cite: [Suehholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

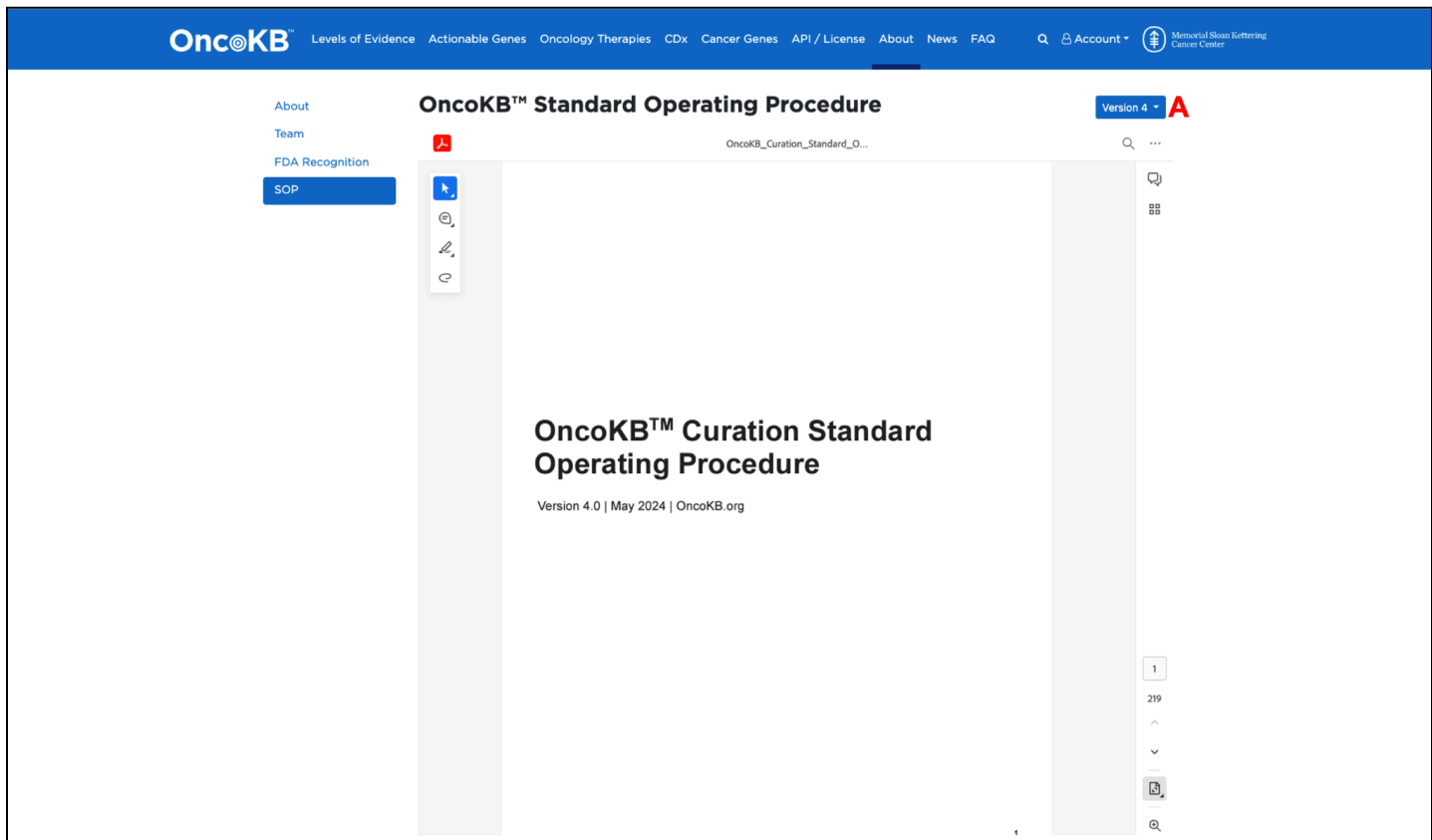
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**Figure 8.16: About Page: FDA Recognition**  
 Screenshot of FDA Recognition tab on the About page.



**Figure 8.17: About Page: OncoKB™ Standard Operating Procedure**  
(A) Version dropdown menu.

# Protocol 9: News Page

This protocol describes the [News page](#) on [oncokb.org](#).

The [News page](#) can be accessed from the header of OncoKB.org (**Figure 8.18A**) and allows the user to explore our latest news and annual summary by browsing through the tabs (**Latest News** and **Year End Summary**) located on the left side of the page (**Figure 8.18B**). The **Latest News** tab (**Figure 8.18**) provides updates from data releases, including new FDA approvals, updated therapeutic implications, addition and removal of therapies and addition of new genes. The **Year End Summary** tab (**Figure 8.19**) provides a comprehensive review of updates to leveled and discontinued biomarkers starting in 2022.

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**B** Latest News Year End Summary

While we aim to keep the information up to date and correct, there will inevitably be gaps or mistakes. Please help us to identify any issues by **sending an email** to [contact@oncokb.org](mailto:contact@oncokb.org), or use the feedback button that appears next to alterations in cBioPortal.

**Stay tuned** for future data updates (improved annotations, new alterations), as well as new features. You can follow us on Twitter (@OncoKB) or subscribe to our [low-volume email list](#) for updates.

When using OncoKB™, please cite: [Suehnholz et al., Cancer Discovery 2023](#) and [Chakravarty et al., JCO PO 2017](#).

**June 4, 2024** Data version: v4.17

🔗 Release of OncoKB™ SOP v4.0

🔗 Updated therapeutic implications - New alteration(s) with a tumor type-specific level of evidence

Level	Gene	Mutation	Cancer Type	Drug(s)	Evidence
2	POLE	Exonuclease Domain Missense Mutations (268_471mis)	Colorectal Cancer, Small Bowel Cancer	Pembrolizumab, Nivolumab, Ipilimumab + Nivolumab, Dostarlimab	Inclusion in Colon Cancer NCCN Guidelines V2.2024 and in Small Bowel Adenocarcinoma NCCN Guidelines V3.2024; PMID: 26028255, 31682550, 28734759, 37917058; Abstract: Chae et al. Abstract# 3417, AACR 2020
2	POLD1	Exonuclease Domain Missense Mutations (304_533mis)	Colorectal Cancer, Small Bowel Cancer	Pembrolizumab, Nivolumab, Ipilimumab + Nivolumab, Dostarlimab	Inclusion in Colon Cancer NCCN Guidelines V2.2024 and in Small Bowel Adenocarcinoma NCCN Guidelines V3.2024; PMID: 26028255, 31682550, 28734759, 37917058; Abstract: Chae et al. Abstract# 3417, AACR 2020
3A	MTAP	Deletion	All Solid Tumors	AMG193, MRTX1719	PMID: 37552839; Abstract: Rodon, J. et al. Abstract# PR006, AACR-NCI-EORTC 2023

🔗 Updated therapeutic implications - Addition of sensitivity-associated therapy(s) for an alteration(s) with a tumor type-specific resistance level of evidence

Gene	Mutation	Cancer Type	Drug(s) currently in OncoKB™	Drug(s) added to OncoKB™	Updated Sensitivity Level	Updated Resistance Level	Evidence
ALK	G1202R	Non-Small Cell Lung Cancer	Alectinib (Level R2)	Lorlatinib (Level 2)	2	R2	Inclusion in the NCCN Non-Small Cell Lung Cancer Guidelines V5.2024; PMID: 30892989

**Figure 8.18: News Page: Latest News**

(A) Access to the News Page. (B) News Page tabs.

Latest News

Year End Summary

2023

2022

### Year End Summary

2023

Level 1: Biomarkers listed in the tumor type specific "Indications and Usage" section of the FDA-drug label in 2023

Molecular Biomarker	Cancer Type	Drug	Significance (Reason for inclusion in OncoKB™)
ERBB2 Amplification	Colorectal Cancer	Tucatinib + Trastuzumab	Novel Level 1 clinically actionable biomarker in this cancer type
ESR1 Oncogenic Ligand-Binding Domain Missense Mutations (310_547)	Breast Cancer	Elacestrant	Novel Level 1 clinically actionable biomarker
ATM, CDK12, CHEK2, PALB2, RAD51C Oncogenic Mutations	Prostate Cancer	Talazoparib + Enzalutamide	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
ATR, FANCA, MLH1, MRE11, NBN Oncogenic Mutations	Prostate Cancer	Talazoparib + Enzalutamide	Novel Level 1 clinically actionable biomarker
BRCA1/2 Oncogenic Mutations	Prostate Cancer	Talazoparib + Enzalutamide	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
BRCA1/2 Oncogenic Mutations	Prostate Cancer	Olaparib + Abiraterone + Prednisone/ Prednisolone	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
BRCA1/2 Oncogenic Mutations	Prostate Cancer	Niraparib + Abiraterone Acetate + Prednisone	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
FLT3 Internal Tandem Duplication	Acute Myeloid Leukemia	Quizartinib	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
MSI-H	Endometrial Cancer	Dostarlimab + Carboplatin + Paclitaxel	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
BRAF V600E	Non-Small Cell Lung Cancer	Encorafenib + Binimetinib	Addition of a novel drug to an existing Level 1 clinically actionable biomarker
IDH1 R132	Myelodysplastic Syndrome	Ivosidenib	Novel Level 1 clinically actionable biomarker in this cancer type

**Figure 8.19: News Page: Year End Summary**

Screenshot of Year End Summary tab on the News page.

# Protocol 10: FAQ Page

This protocol describes the [FAQ \(frequently asked questions\) page](#) on [oncokb.org](#).

The [FAQ \(frequently asked questions\) page](#) can be accessed from the header of OncoKB.org (**Figure 8.20A**) and provides the user with detailed answers to common questions about OncoKB™. The user can browse through the questions organized by topic (**General, Data Curation, Data Updates, Licensing, FDA Recognition and Technical**) located on the left side of the page (**Figure 8.20B**) to learn more about the knowledge base. These questions cover topics such as data curation and updates, licensing options for academic, commercial or hospital use, FDA recognition of OncoKB and technical details of the API.

The screenshot displays the OncoKB website's FAQ page. The top navigation bar includes the OncoKB logo and links for Levels of Evidence, Actionable Genes, Oncology Therapies, CDx, Cancer Genes, API / License, About, News, and FAQ. A search bar and account options are also present. The main content area is titled 'OncoKB™ FAQs' and features a sidebar with a 'General' section highlighted in blue. The 'General' section contains three FAQ items: 'What is OncoKB™?', 'Does OncoKB™ curate both somatic and germline variants?', and 'What are the differences between OncoKB™ and cBioPortal?'. Each item has a brief introductory paragraph. A right-hand sidebar lists more questions under the heading 'What is OncoKB™?' and includes a 'Was this helpful?' feedback section with three smiley face icons. A 'Powered by GitBook' logo is visible in the bottom left corner of the page content.

**Figure 8.20: FAQ Page: General**  
(A) Access to the FAQ Page. (B) FAQ topics.

# Supplemental Material

**Table S1: Validation exercise (A) and answer key (B) for Chapter 2, Protocol 1: Curation of tumor type specific variant clinical implications and Chapter 2, Protocol 3: Mapping OncoKB Levels of Evidence to FDA Levels of Evidence**

Validation exercise (A) and answer key (B) allows curators to practice using the protocols in [Chapter 2: Curation of variant and tumor type specific clinical implications](#) to assign a VPCS an OncoKB and FDA Level of Evidence.

**(A)**

Gene	Alteration	Tumor Type	Drug	OncoKB Level of Evidence	FDA Level of Evidence	Rationale
EGFR	L858R	NSCLC	Afatinib			
BRAF	V600E	Hairy Cell Leukemia	Vemurafenib			
KRAS	G12C	NSCLC	AMG-510 (Sotorasib)			
NRAS	Q61K	Colorectal Cancer	Cetuximab			

**(B)**

Gene	Alteration	Tumor Type	Drug	OncoKB Level of Evidence	FDA Level of Evidence	Rationale
EGFR	L858R	NSCLC	Afatinib	1	2	This is an FDA approved biomarker in the specified tumor type for the indicated drug
BRAF	V600E	Hairy Cell Leukemia	Vemurafenib	2	2	Vemurafenib is recommended in the NCCN Guidelines for HCL at Category 2A for pts with BRAF V600E mt disease
KRAS	G12C	NSCLC	AMG-510 (Sotorasib)	3A	3	There is strong clinical data showing that pts with KRAS G12C mt NSCLC have responded to AMG-510
NRAS	Q61K	Colorectal Cancer	Cetuximab	R1	2	As stated in the NCCN Guidelines for CRC, pts with NRAS mt CRC should not be treated with Cetuximab



**Table S2: Validation exercise (A) and answer key (B) for Chapter 1, Protocol 1, Table 1.3: Assertion of the function of a cancer gene**

Validation exercise (A) and answer key (B) allows curators to practice using the protocols in [Chapter 1: Protocol 1: Gene curation](#) to assert whether a cancer gene is an oncogene, tumor suppressor, both or neither.

**(A)**

Gene	Applicable Rule(s)	Evidence (Comments)	ASSERTION (OG/TSG/Both/Neither)
ALK			
ZFH3			
FOXP1			
BIRC3			

**(B)**



Gene	Applicable Rule(s)	Evidence (Comments)	ASSERTION (OG/TSG/Both/Neither)
ALK	OG1: "A gene that can transform cells by increasing the selective growth advantage of the cell in which it resides as demonstrated by the scientific literature in $\geq 1$ study."	ALK is an RTK; ALK fusions transform cells (PMID: 24060861, 20451371, 24715763, 17625570). Ligand binding to ALK results in activation of downstream signaling including the JAK-STAT, RAS-MAPK, PI3K-mTOR and JUN pathways. ALK fusions transform cells (PMID: 24060861, 20451371, 24715763, 17625570); CBioPortal (more amplifications; more point mutations than TMs; hotspots); (PMID: 25079552) (amplifications common)	OG
ZFH3	TSG1: "A gene whose partial or complete inactivation by mutation, occurring in either the germline or the genome of a somatic cell, leads to an increased likelihood of cancer development by increasing the selective growth advantage of the cell in which it resides "	ZFH3 conditional knockout mouse develops hyperplasia and prostatic intraepithelial neoplasia (PMID: 24934715). Suppression of ZFH3 in a prostate cell line increases proliferation, while exogenous expression of ZFH3 decreases soft agar colony formation (PMID: 15750593); More TMs, deletions (cBioPortal, 1/31/20)	TS
FOXP1	TSGOG-1: "A gene that can transform cells by increasing the selective growth advantage of the cell in which it resides as demonstrated by the scientific literature in $\geq 1$ study." and "A gene whose partial or complete inactivation by mutation, occurring in either the germline or the genome of a somatic cell, leads to an increased likelihood of cancer development by increasing the selective	Loss of functional FOXP1 protein is inactivating and likely oncogenic as measured by accelerated androgen-dependent cell proliferation and enhanced cell migration compared to control (PMID: 25329375). However, FOXP1 fusions in MALT lymphoma are oncogenic and lead to FOXP1 overexpression (PMID: 31815635). Truncating mutations are prevalent in cBioPortal, 28FEB2020;	Both

**Table S3: Validation exercise (A) and answer key (B) for defining a variant as a VPS or VUS**

Validation exercise (A) and answer key (B) allows curators to practice using the protocols in Chapter 1, Protocol 2: Variant curation to assert whether a gene variant is a VPS or VUS.

(A)

Gene	Alteration	VPS or VUS	Rationale
NRAS	G13R		
TP53	R158H		
EGFR	A822T		
NF1	R2450*		
PIK3CA	E110del		
NRAS	X150_splice		

(B)

Gene	Alteration	VPS or VUS	Rationale
NRAS	G13R	VPS	Recurrent missense mt in an oncogene
TP53	R158H	VPS	Hotspot missense mt in a tumor suppressor gene
EGFR	A822T	VUS	Although a missense mt in an oncogene, there is no functional data describing the oncogenic effect of this variant
NF1	R2450*	VPS	Truncating mts in tumor suppressor genes are defined as likely oncogenic
PIK3CA	E110del	VPS	Although a truncating mt in an oncogene, this in-frame deletion is a hotspot and shown to be oncogenic
NRAS	X150_splice	VUS	A truncating mt in an oncogene is a VUS (unless there is a special circumstance in which it is characterized as oncogenic, ex: MET exon 14 splice mts)

## Table S4: Validation exercise (A) and answer key (B) for Chapter 1, Sub-protocol 2.4: Assertion of the biological effect of a VPS

Validation exercise (A) and answer key (B) allows curators to practice using the protocols in Chapter 1, Sub-Protocol 2.4: Assertion of the biological effect of a VPS.

(A)

Gene	Alteration	Assertion Type I (A/B/C/D/E) based on Criteria (1/2/3...) e.g. A1, A4	Assertion Type II (A/B/C) based on Criteria (1/2/3...) E.g. A1, A3	Evidence	FINAL ASSERTION
ALK	S1206F				
ERCC2	M42V				
ERCC2	Y24C				
BRAF	L597V				
FOXP1	R514C				
BIRC3	R172I				

(B)

Gene	Alteration	Assertion Type I (A/B/C/D/E) based on Criteria (1/2/3...) e.g. A1, A4	Assertion Type II (A/B/C) based on Criteria (1/2/3...) E.g. A1, A3	Evidence	FINAL ASSERTION
ALK	S1206F	E.3: Data is limited to studies demonstrating patient and/or in vitro sensitivity/resistance to a drug.		Resistance mt and no functional assays for biological effect (PMID: 27565908, 27780853)	Inconclusive
ERCC2	M42V	B.1: The alteration is associated with decreased function of the protein	B.1: A single or multiple experimental studies from one publication including but not limited to experimental data or statistical recurrence establishing the function of the mutation	Expression of this mutation in an ERCC2-deficient fibroblast cell line demonstrated that it was inactivating (PMID: 29980530)	Likely Loss of Function
ERCC2	Y24C	B.1: The alteration is associated with decreased function of the protein	A.3: The alteration is a known hotspot (Chang et al., 2016. Chang et al., 2018) AND at least one experimental study provides strong evidence that the alteration confers gain-, loss-, or switch-of or neutral function.	Hotspot and inactivating by in vitro studies; pt with the mut responded to cisplatin (PMID: 29980530, 25096233)	Know Loss of Function
BRAF	L597V	A.1: The alteration is associated with increased function of the protein		Biological characterization of BRAF L597V mutation has demonstrated that it activates the downstream MAPK pathway independent of RAS (PMID: 12068308, 15035987, 22798288, 26343582, 28783719) and renders BRAF active as a dimer with CRAF and itself (PMID: 20179705).	Known Gain of Function
FOXP1	R514C	B.1: The alteration is associated with decreased function of the protein	A.3: The alteration is a known hotspot (Chang et al., 2016. Chang et al., 2018) AND at least one experimental study provides strong evidence that the alteration confers gain-, loss-, or switch-of or neutral function.	This is a hotspot and expression of this mutation in HEK293 cells demonstrated that it is likely inactivating, as shown by disrupted localization and decreased transcriptional activity compared to wildtype FOXP1 (PMID: 26647308).	Know loss of function

BIRC3	R172I	D.2: There is no difference in measurable cell attributes expressing either the wildtype or mutant form of the gene.	IB.1: A single or multiple experimental studies from one publication including but not limited to experimental data or statistical recurrence establishing the function of the mutation	Lack of foci formation and downstream signaling comparable to wild type BIRC3 (PMID: 26094954).	Likely Neutral
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**Table S5: Validation exercise (A) and answer key (B) for Chapter 1, Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS**

Validation exercise (A) and answer key (B) allows curators to practice using the protocols in **Chapter 1, Sub-Protocol 2.5: Assertion of the oncogenic effect of a VPS.**

**(A)**

Gene	Alteration	Applicable Criteria <i>Example: I.3, IV.2, etc.</i>	Evidence	ASSERTION (Oncogenic/Likely Oncogenic/Likely Neutral/Inconclusive)
ALK	S1206F			
ERCC2	Y24C			
FOXP1	R514C			
BIRC3	R172I			

**(B)**

<b>Gene</b>	<b>Alteration</b>	<b>Applicable Criteria</b>	<b>Evidence</b>	<b>ASSERTION (Oncogenic/Likely Oncogenic/Likely Neutral/Inconclusive)</b>
ALK	S1206F	D.3: Data is limited to studies demonstrating either patient and/or in vitro sensitivity/resistance to a targeted drug.	a patient with non-small cell lung cancer harboring this mutation in combination with an EML4-ALK rearrangement exhibited resistance to crizotinib (PMID: 27565908, 27780853). - no other data	Inconclusive
ERCC2	Y24C	A.2, 3: The alteration is a known hotspot (Chang et al, 2018) AND there is at least one experimental study suggesting the alteration is oncogenic. The alteration has been identified in a patient who responded to a targeted inhibitor, AND at least one experimental study provides strong evidence that the alteration is oncogenic.	Hotspot and inactivating by in vitro studies; also found in pts with muscle-invasive urothelial carcinoma of the bladder who were complete responders to neoadjuvant cisplatin-based chemotherapy (PMID: 29980530, 25096233)	Oncogenic
FOXP1	R514C	B.3: The alteration is a known hotspot (Chang et al, 2016; Chang et al, 2018) AND there are no known functional studies describing the oncogenic potential of the alteration.	This is a hotspot with no test for oncogenicity – it is likely LOF as expression of this mutation in HEK293 cells demonstrated that it is likely inactivating, as shown by disrupted localization and decreased transcriptional activity compared to wildtype FOXP1 (PMID: 26647308).	Likely Oncogenic
BIRC3	R172I	C.1,2: The mutation effect of the alteration is neutral or likely neutral. At least one experimental study provides reasonable evidence suggesting the alteration is likely neutral.	Lack of foci formation and downstream signaling comparable to wild type BIRC3 (PMID: 26094954).	Likely Neutral

## Table S6: Curation protocol proficiency test: 1. Defining a variant as a VPS or VUS and 2. Assigning a VPS an oncogenic and biological effect

Validation of Variant curation. This exercise is given to individuals (non-OncoKB staff) to validate the protocols in [Chapter 1: Protocol 2: Variant Curation](#) which defines how to determine if a variant is a VPS or VUS, and also determine the biological and oncogenic effect of a VPS.

A. Gene	B. Oncogene or Tumor Suppressor	C. Alteration	D. Variant of Potential Significance (VPS) or Variant of Unknown Significance (VUS) <i>Enter: VPS or VUS</i>	E. Oncogenic Effect <i>Enter: Oncogenic, Likely Oncogenic, Likely Neutral or Inconclusive</i>	F. Biological Effect <i>Enter: GOF, LOF, SOF, Likely GOF, Likely LOF, Likely SOF, Neutral, Likely Neutral, Inconclusive</i>
BRAF		V600E			
ERBB2		S310F			
AKT1		E17K			
EGFR		T790M			
TP53		R273L			
BAP1		E31del			
KDR		R787W			
ERBB4		R114*			
CBL		R420Q			

Instructions for Curation protocol proficiency test in [Table S7](#):

**Fill in Columns B, D and E.**

**Column B:** Enter *Oncogene, Tumor Suppressor, Both or Neither*

Use [Chapter 1: Table 1.3: Assertion of the function of a cancer gene](#) to determine if each gene is an oncogene, tumor suppressor, both or neither

**Column D:** Enter *VPS or VUS*

**Column E:** For each VPS, Enter *Oncogenic*, *Likely Oncogenic*, *Likely Neutral*, or *Inconclusive* (Enter *NA* if the variant is a VUS)

Use [Chapter 1: Sub-protocol 2.5: Assertion of the oncogenic effect of a VPS](#) to determine the oncogenicity of each VPS.

\*Remember to check if the variant is a known hotspot (<https://www.cancerhotspots.org>) as this factors into its oncogenicity.

**Column F:** For each VPS, Enter *Gain-of-Function (GOF)*, *Loss-of-Function (LOF)*, *Switch-of-Function (SOF)*, *Likely Gain-of-Function (GOF)*, *Likely Loss-of-Function (LOF)*, *Likely Switch-of-Function (SOF)*, *Neutral*, *Likely Neutral* or *Inconclusive*

Use [Chapter 1: Sub-protocol 2.4: Assertion of the biological effect of a VPS](#) to determine the oncogenicity of each VPS.

\*Remember to check if the variant is a known hotspot (<https://www.cancerhotspots.org>) as this factors into its biological effect.

## Figure S1: Mechanism for user feedback

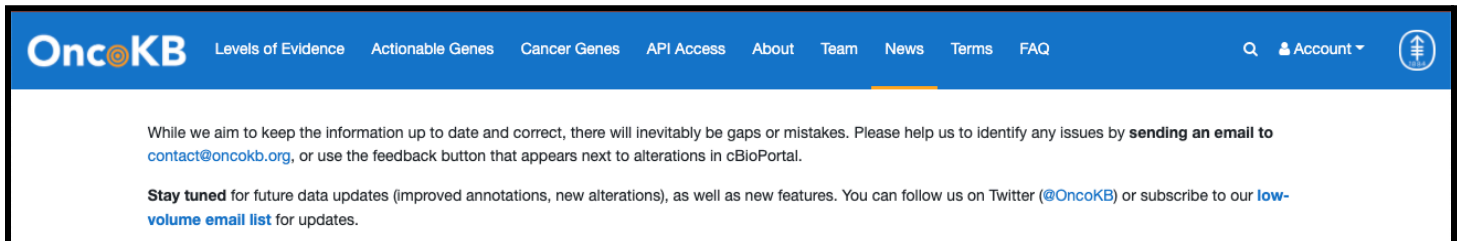
Assertion feedback by OncoKB users is an important feature of the knowledge base. There are two web-based mechanisms through which users may provide feedback on OncoKB content: 1) The OncoKB website (**A**) and the cBioPortal for Cancer Genomics (**B**).

Feedback, comments or questions may be sent via email to [contact@oncokb.org](mailto:contact@oncokb.org), which is provided in multiple places within the OncoKB website (**A**). Emails sent to [contact@oncokb.org](mailto:contact@oncokb.org) are received by the Lead Scientist and all SCMT members and answered within 72 hours.

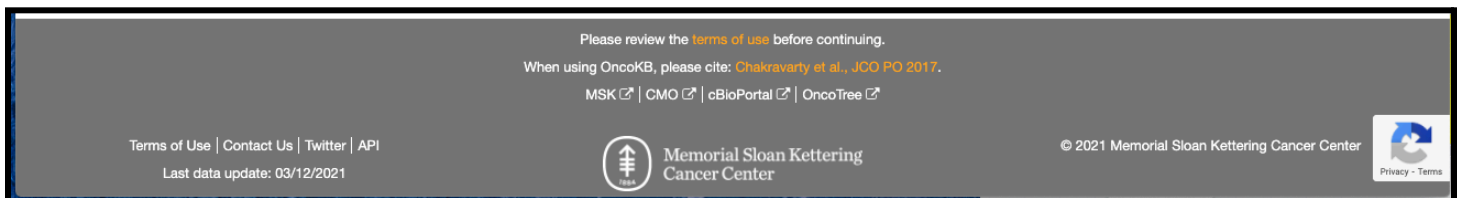
In cBioPortal, variants in both the patient view and Mutations tab are annotated with OncoKB information. Users may either click the OncoKB icon to access the OncoKB webpage to provide feedback or click the Feedback button in the OncoKB dialog box. In the “OncoKB Annotation Feedback” pop-up form (**B, i**), information about the Gene and Alteration, the email address used to log-into the portal, and web-address of the specific portal instance will be pre-populated. Users may then enter specific feedback and associated references in the Feedback and References fields before submitting the feedback.

Submission of feedback by a cBioPortal user will auto-populate in a Google spreadsheet (**B, ii**). Changes to this Google Sheet will trigger an automatic email sent to the Lead Scientist and SCMT alerting them of user feedback via cBioPortal. User feedback is answered within 72 hours of its receipt. Upon completion of any necessary deliverables as suggested by the feedback (either curation or software related), the appropriate OncoKB staff member fills in the “Complete” column and adds their initials as well as any comments related to the feedback item. The Feedback Page collates all cBioPortal user feedback related to OncoKB assertions and is a log of OncoKB development based on cBioPortal user-feedback

### (A)



The screenshot shows the OncoKB website interface. The top navigation bar is blue with the OncoKB logo on the left and links for Levels of Evidence, Actionable Genes, Cancer Genes, API Access, About, Team, News, Terms, and FAQ on the right. A search icon and an Account dropdown are also present. Below the navigation bar, a white box contains the following text: "While we aim to keep the information up to date and correct, there will inevitably be gaps or mistakes. Please help us to identify any issues by sending an email to [contact@oncokb.org](mailto:contact@oncokb.org), or use the feedback button that appears next to alterations in cBioPortal. Stay tuned for future data updates (improved annotations, new alterations), as well as new features. You can follow us on Twitter (@OncoKB) or subscribe to our [low-volume email list](#) for updates."



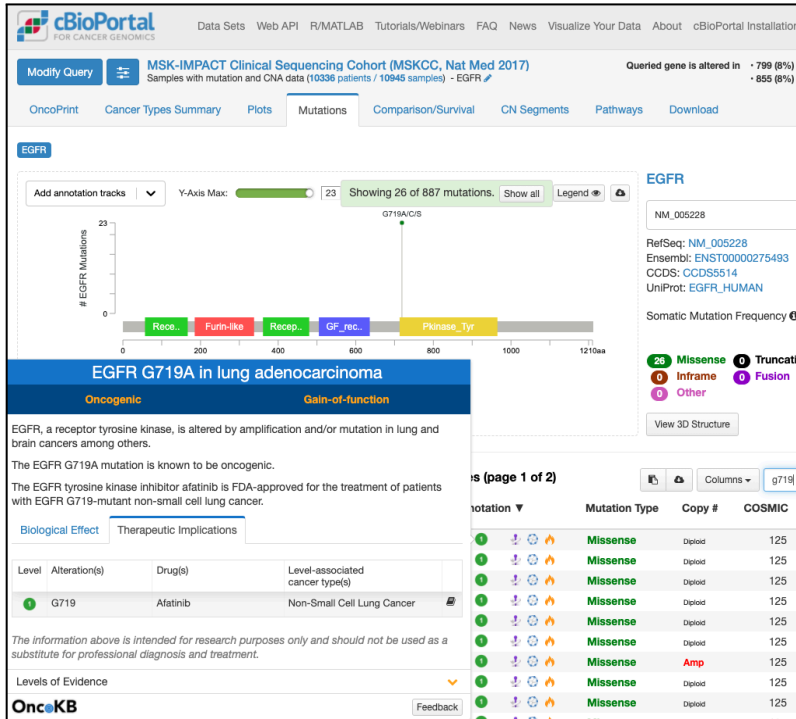
The screenshot shows the footer of the OncoKB website. It features a dark grey background with white text. The footer includes: "Please review the [terms of use](#) before continuing." followed by "When using OncoKB, please cite: [Chakravarty et al., JCO PO 2017.](#)" and a row of links: "MSK | CMO | cBioPortal | OncoTree". On the left, it says "Terms of Use | Contact Us | Twitter | API" and "Last data update: 03/12/2021". In the center is the Memorial Sloan Kettering Cancer Center logo. On the right, it says "© 2021 Memorial Sloan Kettering Cancer Center" and has a "Privacy - Terms" link with a small icon.

Users of [oncokb.org](http://oncokb.org) may provide feedback on the website by clicking the email link for [contact@oncokb.org](mailto:contact@oncokb.org) in the News section, in the Usage Terms section, or by clicking “Contact Us” in the OncoKB webpage footer.



(B)

(i)



### OncoKB Annotation Feedback

Please let us know if you noticed an error or missing annotation about this variant by completing the form below.

\* Required

Gene \*

EGFR

Alteration

G719A

(ii)







Timestamp	Gene	Alteration	Feedback	References	User	COMPLETE
240	2/4/2020 15:21:40	BRCA2	X3086_splice	Shouldn't this alteration be classified as level 2b, since olaparib is FDA-approved for breast cancer with BRCA2?	VargasPD@mskcc.org	
241	2/25/2020 17:33:59	POLE	A456P	This mutation is recurrent in the MSK-IMPACT data set (9 times), always in POLE associated cancers w/ <a href="https://clincancerres.aacr.org/">https://clincancerres.aacr.org/</a>	schultzrn@mskcc.org	Y-MN
242	3/16/2020 7:29:07	AXIN1	R103M	Driver mutation based on mechanistic data: Expression of this mutant failed to inhibit $\beta$ -catenin-mediated	J.m.bugter-2@umcutrecht.nl	
243	3/16/2020 7:29:55	AXIN1	L101P	Driver mutation based on mechanistic data: Expression of this mutant failed to inhibit $\beta$ -catenin-mediated	J.m.bugter-2@umcutrecht.nl	
244	3/16/2020 7:30:36	AXIN1	L106R	Driver mutation based on mechanistic data: Expression of this mutant failed to inhibit $\beta$ -catenin-mediated	J.m.bugter-2@umcutrecht.nl	
245	3/16/2020 7:31:12	AXIN1	K203M	Driver mutation based on mechanistic data: Expression of this mutant failed to inhibit $\beta$ -catenin-mediated	J.m.bugter-2@umcutrecht.nl	
246	3/16/2020 7:32:38	AXIN1	T122A	Passenger mutation based on mechanistic data: Expression of this mutant normally inhibits $\beta$ -catenin-m	J.m.bugter-2@umcutrecht.nl	
247	3/16/2020 7:33:13	AXIN1	S215L	Passenger mutation based on mechanistic data: Expression of this mutant normally inhibits $\beta$ -catenin-m	J.m.bugter-2@umcutrecht.nl	
248	8/11/2020 3:17:04	RNF43	R519*	Truncating RNF43 mutations in the region D504-Q563 have and oncogenic role. These mutants activate	<a href="https://doi.org/10.1521/jmbugter@gmail.com">https://doi.org/10.1521/jmbugter@gmail.com</a>	
249	8/11/2020 3:17:41	RNF43	D516Gfs*10	Truncating RNF43 mutations in the region D504-Q563 have and oncogenic role. These mutants activate	<a href="https://doi.org/10.1521/jmbugter@gmail.com">https://doi.org/10.1521/jmbugter@gmail.com</a>	
250	9/2/2020 12:50:42	MAP2K4	R134Q	You cited this mutation as being likely oncogenic because of studies by Jonathan Kurie and colleagues	21896780 Hunter Shain (hunter.shain@ucsf.edu)	
251	10/15/2020 12:35:42	ALK	G1202R	Type in drug sensitivity description: lorlatinib	nschultz@gmail.com	Y-MN
252	11/6/2020 11:14:23	H3F3A	K28M	There are an error i think about the notation of this mutation, because the most commune mutation in H3F3A gene is K27M. Sc	anonymousUser	
253	11/9/2020 13:13:23	GNAQ	Q209P	This mutation induces constitutive activation of GNAQ and is oncogenic in uveal melanoma	PMID: 25304237 Michael Onken	Y-MN
254	11/13/2020 14:57:39	SRC	S6N	his gene was not screen out with "Exclude mutations and copy number alterations of unknown significance" but all the variants	anonymousUser	
255	11/13/2020 14:58:05	VEGFA	*233Sext*?	his gene was not screen out with "Exclude mutations and copy number alterations of unknown significance" but all the variants	anonymousUser	
256	11/13/2020 14:58:43	GLI1	Q169E	his gene was not screen out with "Exclude mutations and copy number alterations of unknown significan his gene was not scre	anonymousUser	
257	2/15/2021 6:06:55	MYO1D1	L122R	The primary study that described this mutation in adult and with the definitive relation to spinde cell rhal	PMID: 24272621 Karoly Szuhai	Y-MN
258	2/25/2021 17:50:55	BCL2L12	R18W	I DONT KNOW	PUBMED anonymousUser	
259	3/23/2021 6:37:36	CTNNB1	K335I	Last year we have published a paper in Gastroenterology in which we extensively studied this and other. The PMID of this papr	anonymousUser	*

On cBioPortal, if hovering over the OncoKB icon, a pop up with OncoKB information appears, clicking on the "Feedback" button in cBioPortal results in a pop-up comment card (i) that allows the user to provide feedback about the OncoKB annotation on the specific variant. User feedback is auto-populated into a google spreadsheet (ii) which the OncoKB SCMT accesses and answers user questions within a 72-hour turn-around period.

# APPENDIX







## Appendix I. OncoKB icons in cBioPortal.

For each oncogenic effect, the most common biological effects assigned to OncoKB variants are shown.

OncoKB Icon	Oncogenic Effect	Biological Effect
	Oncogenic	Gain-of-Function (GOF) / Likely GOF
		Loss-of-Function (LOF) / Likely LOF
		Switch-of-Function (SOF) / Likely SOF
	Likely Oncogenic	Likely GOF
		Likely LOF
		Likely SOF
	Likely Neutral	Neutral
		Likely Neutral
	Inconclusive	Inconclusive
	SCMT reviewed Variant of Unknown Significance (VUS)	SCMT reviewed VUS
	Unknown (SCMT non-reviewed VUS)	Unknown (SCMT non-reviewed VUS)

# Appendix II. OncoKB Levels of Evidence icons in cBioPortal.

Variants with clinical implications are given a specific OncoKB icon in cBioPortal as described here.

Level of Evidence (per Chakravarty et al., 2017)	OncoKB Icon in cBioPortal
<b>1</b> <b>FDA-recognized</b> biomarker predictive of response to an <b>FDA-approved drug</b> in this indication	
<b>2</b> <b>Standard care</b> biomarker recommended by the NCCN or other professional guidelines predictive of response to an <b>FDA-approved drug</b> in this indication	
<b>3A</b> <b>Compelling clinical evidence</b> supports the biomarker as being predictive of response to a drug in this indication	
<b>3B</b> <b>Standard care</b> or <b>investigational</b> biomarker predictive of response to an <b>FDA-approved</b> or <b>investigational</b> drug in another indication	
<b>4</b> <b>Compelling biological evidence</b> supports the biomarker as being predictive of response to a drug	
<b>R1</b> <b>Standard care</b> biomarker predictive of <b>resistance</b> to an <b>FDA-approved</b> drug in this indication	
<b>R2</b> <b>Compelling clinical evidence</b> supports the biomarker as being predictive of <b>resistance</b> to a drug	