



Diagnostics Year in Review - 2022

January 2023

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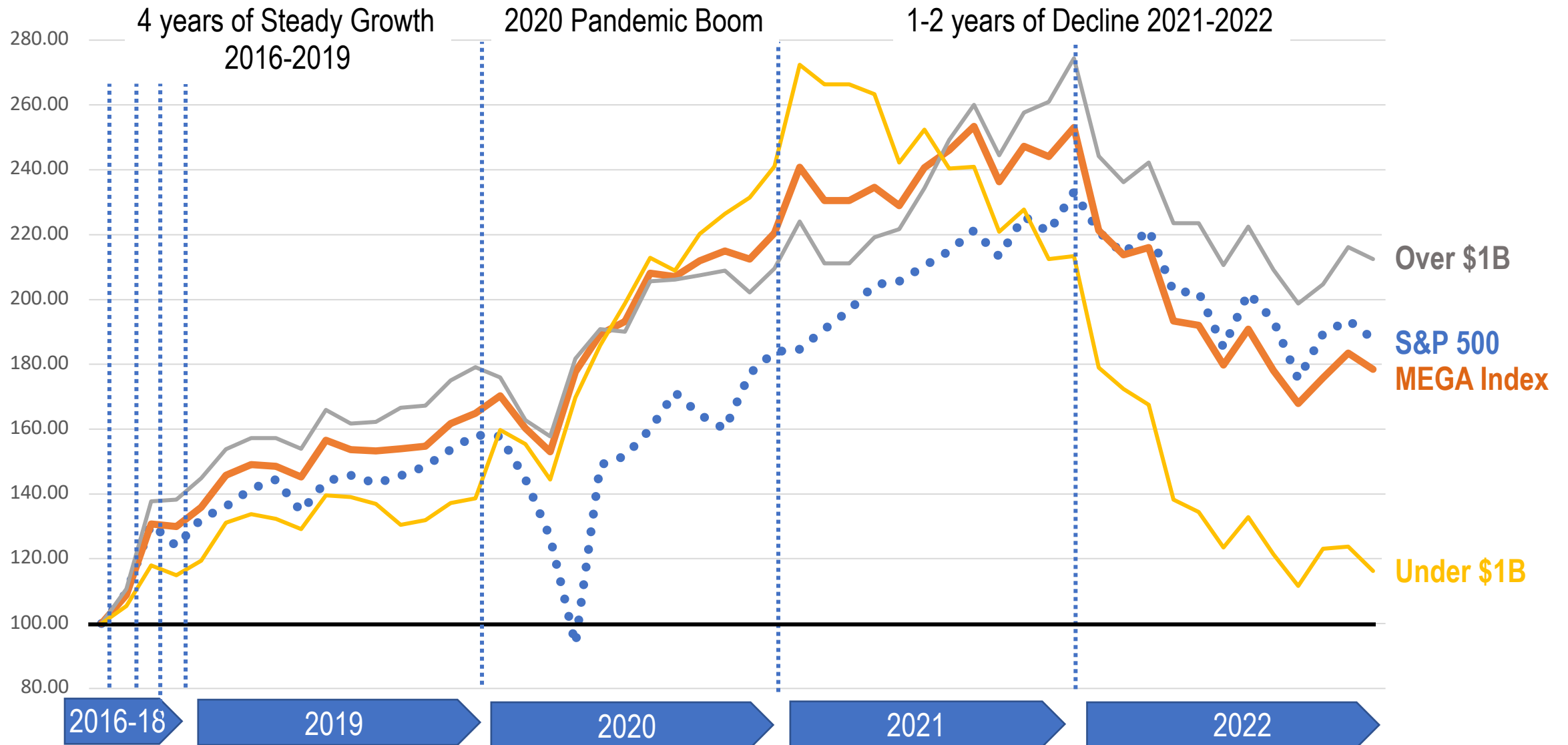
The Diagnostics World 2022

- Diagnostics in the Public Markets
 - The MEGA Public Company Index
 - Diagnostic IPO's
 - Diagnostic Mergers & Acquisitions
- Clinical Diagnostics
 - Overview
 - Specialized Testing
- COVID Diagnostics
 - EUA data from [TestingCommons.com](https://www.testingcommons.com)
 - COVID vs. Flu
 - COVID variants

Diagnostics in the Public Markets

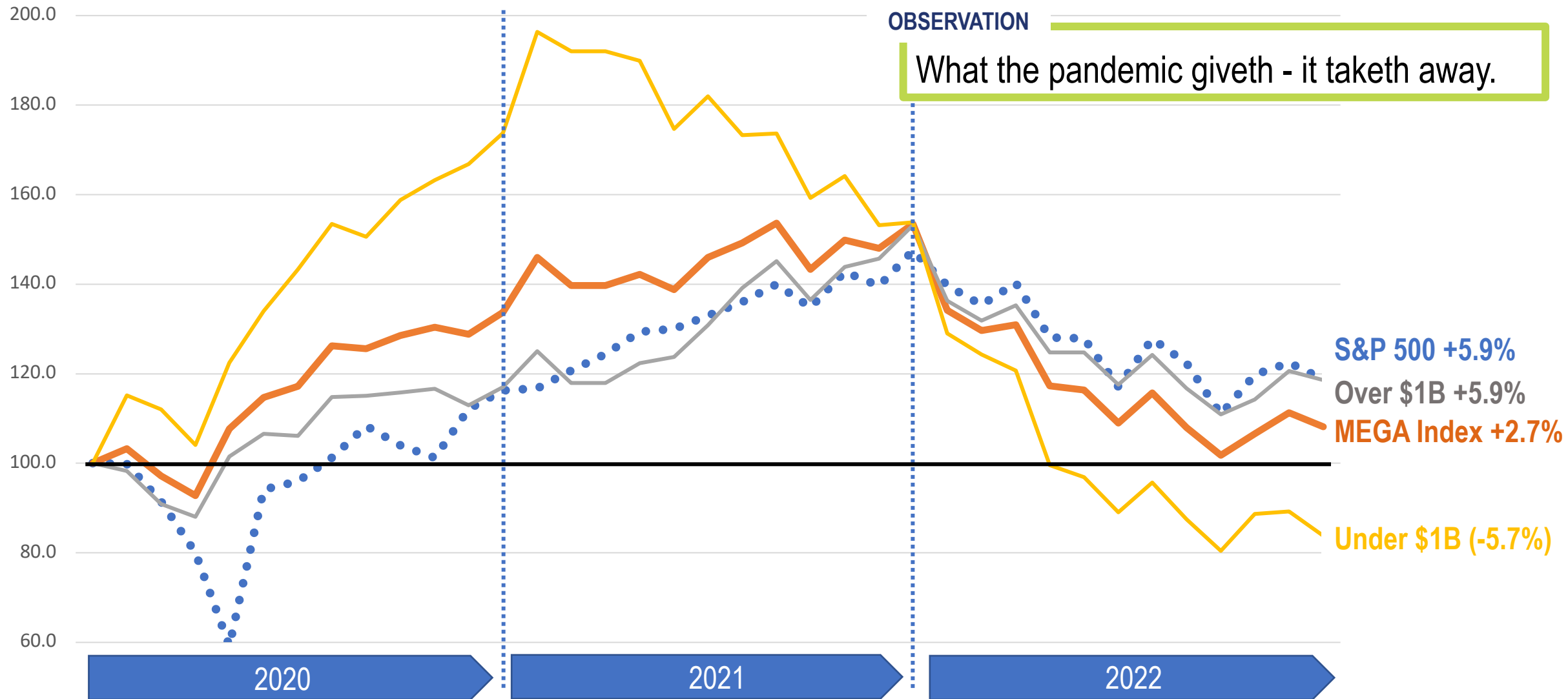


Diagnostics MEGA Market Value Index: 2015-2022





Diagnostics MEGA Market Value Index: 2020 to 2022



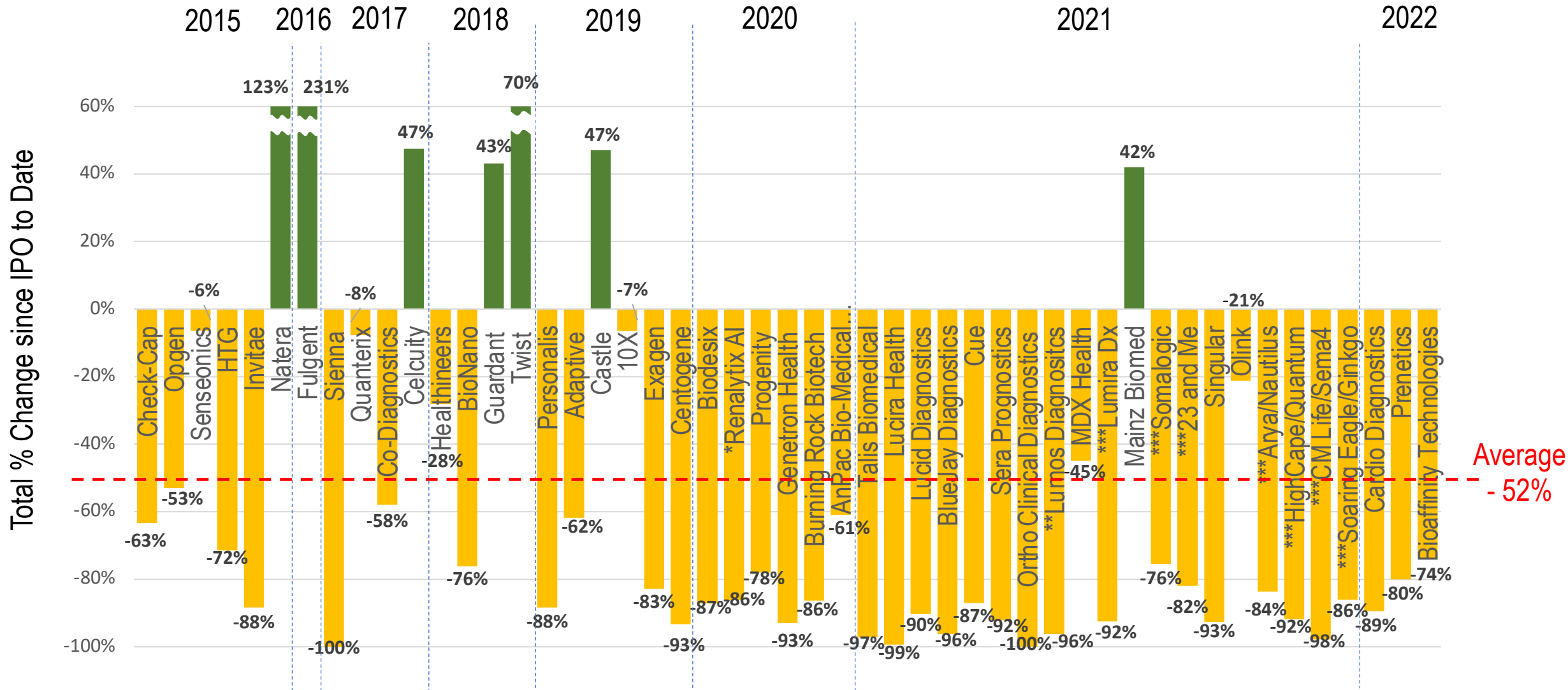


The MEGA Diagnostics Index Explained

- Health Catalysts Group maintains a database and associated index of changes in the market value of the most inclusive collection of public companies that participate in the clinical in-vitro diagnostic industry worldwide:
 - 135 Independent public companies tracked for 2022: 87 headquartered in the US, 20 in China, and 28 elsewhere
 - Bias toward inclusion: included if the clinical diagnostics market is, or is stated to be, important to future revenues
 - Participation in the index, per cent Dx updated each January
 - Many of the largest Dx participants have revenues in other industries. The MEGA index includes their market value based on proportion of Dx revenues to total (e.g. 31% of Roche)
 - Constant currency rates maintained throughout the year, re-calculated each January.

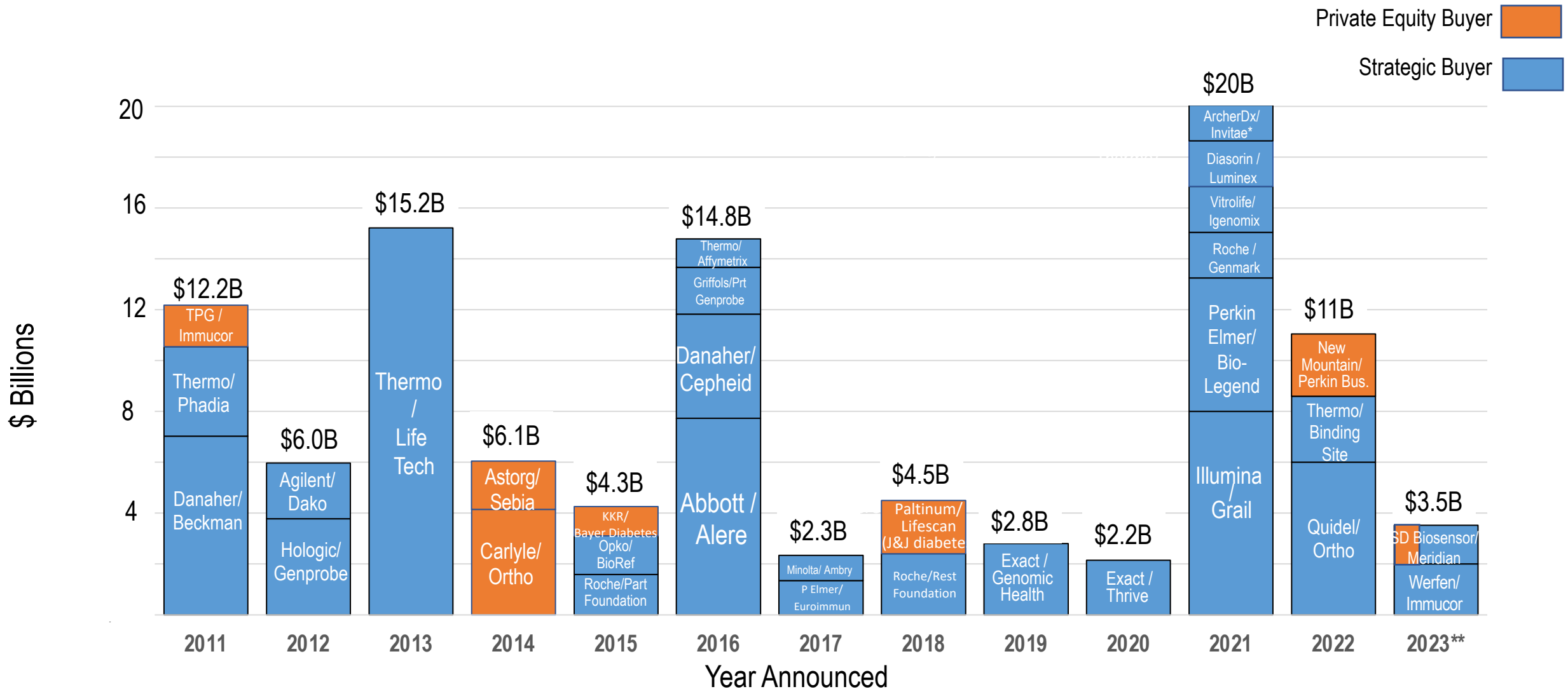


Diagnostic IPOs: Price Performance from IPO through 2022





Diagnostic Industry Transforming Acquisitions (>\$1 Billion)



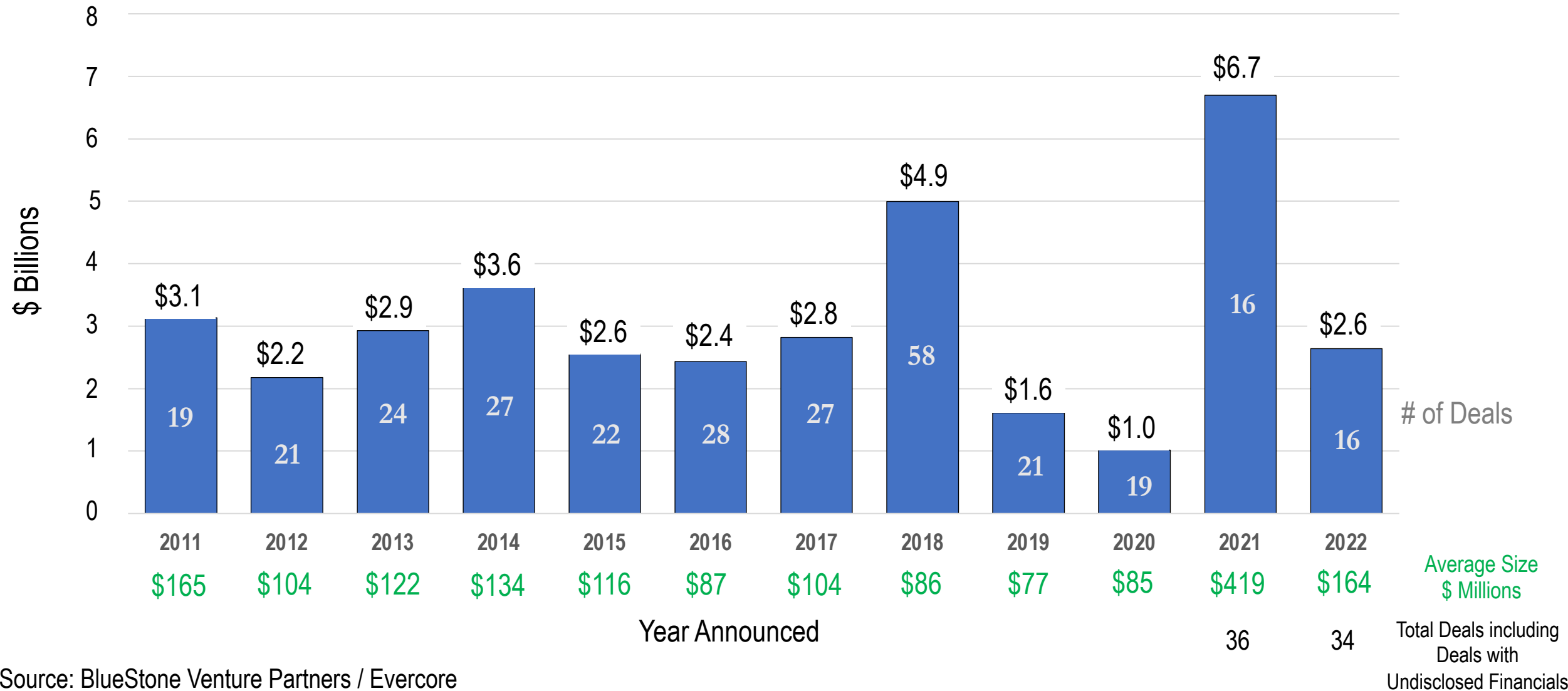
Source: BlueStone Venture Partners / Evercore

* ArcherDx up to \$2.7 billion with earnouts. See Appendix for details.

** Deals announced in 2022 expected to close in 2023



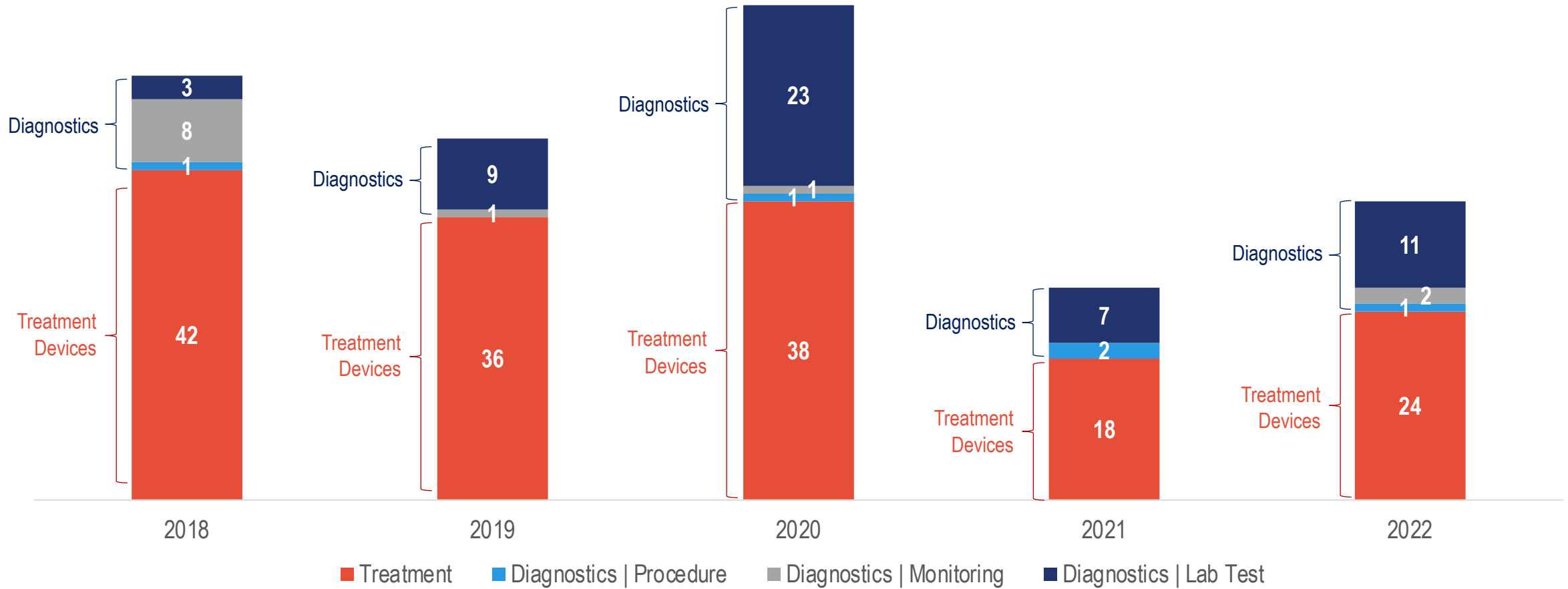
Smaller Diagnostic Acquisitions (<\$1 Billion)



Clinical Diagnostics Overview



Diagnostics and Medical Device Approvals 2018-2022



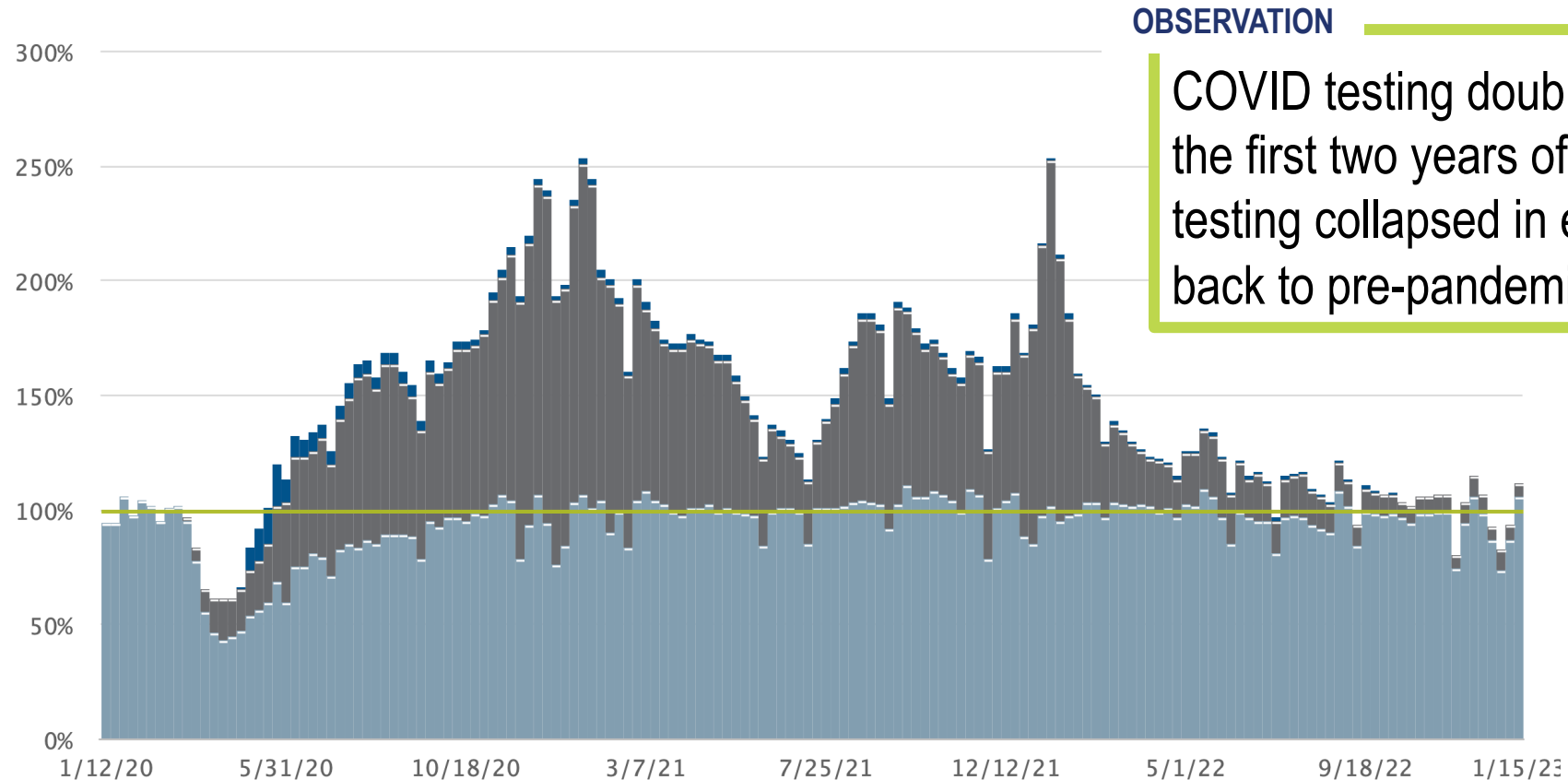


Laboratory Volume Index: Xifin



Laboratory Volume Index Total Lab Tests as % of Baseline Average

Total Pathology Clinical Hospital Molecular Pain/Tox



OBSERVATION

COVID testing doubled lab volumes during the first two years of the pandemic. Routine testing collapsed in early 2020 but came back to pre-pandemic levels in 2021.



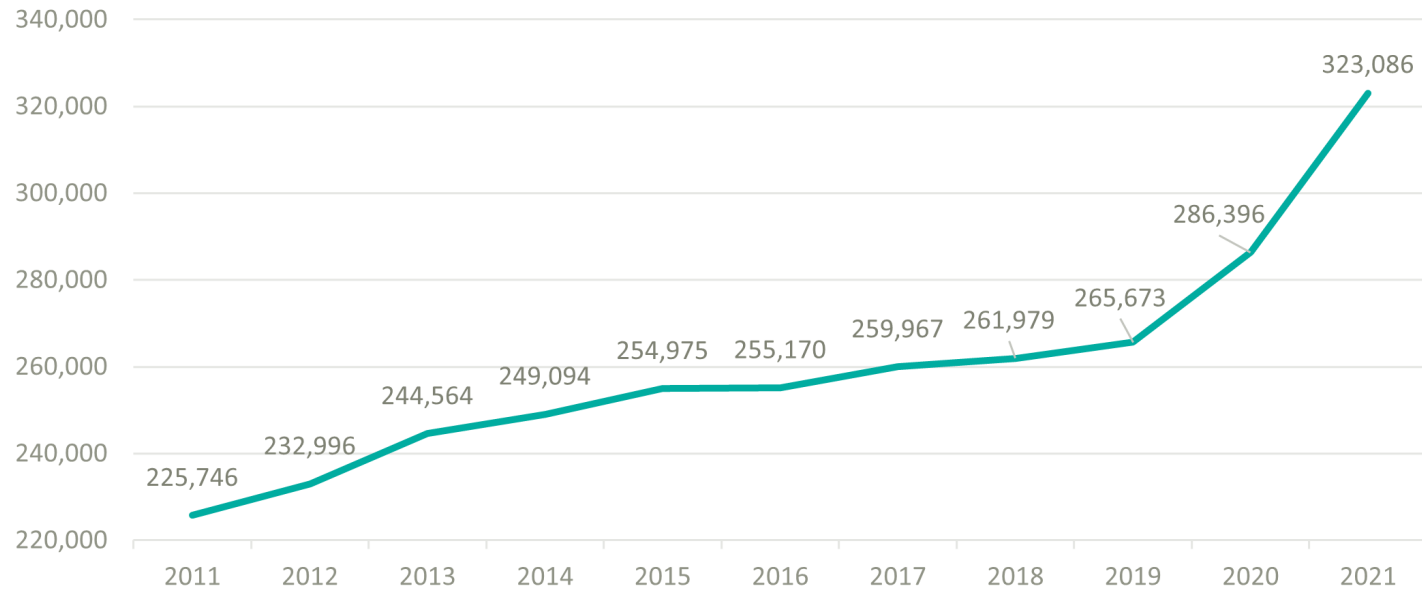
Xifin Lab Volume Index Explained

- XIFIN analyzes its diagnostic billing data to measure laboratory testing volumes as compared to a baseline pre-Coronavirus testing average. Currently, XIFIN sees 15 - 20% of all COVID-19 and antibody testing claims nationwide, and analysis includes data representative of four out of five top integrated delivery networks (IDNs) and 10 of the top 12 public laboratories nationwide.
- The charts on Xifin.com are [interactive](#). For the Laboratory Volume Index, you can adjust the timeframe plotted in the chart. You can select a single laboratory segment and see the data for that segment. You can also toggle on/off each of the testing categories (routine, COVID, and antibody).



CLIA Labs Growth and LDTs Focus

Total Number of CLIA Labs (2011 - 2021)

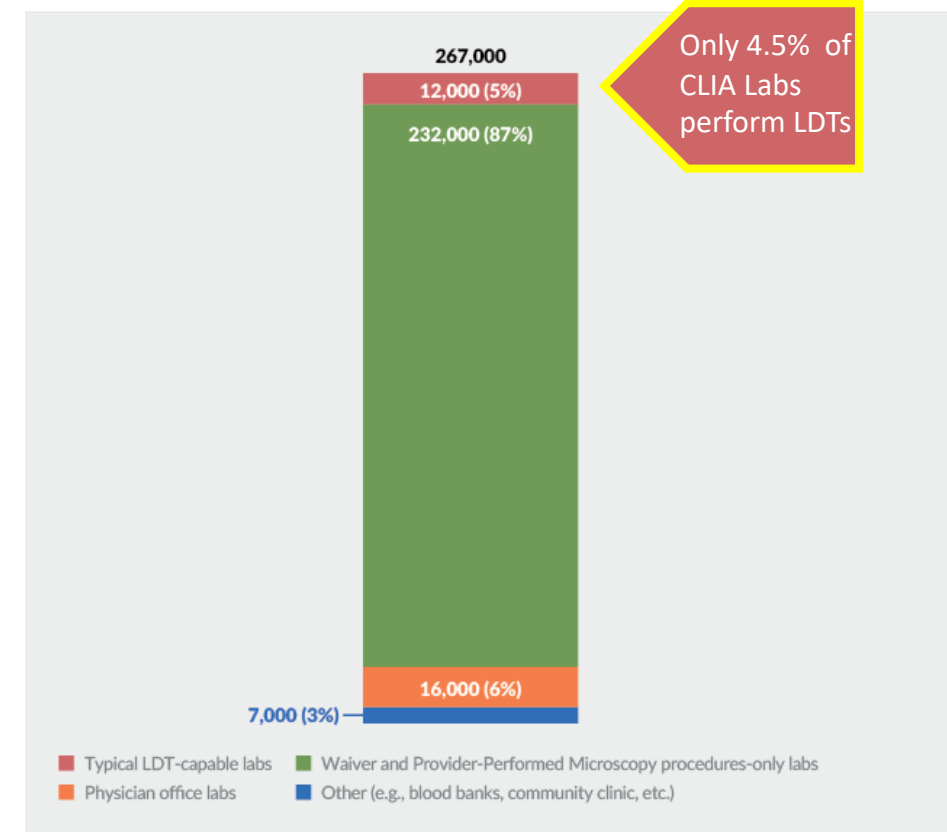


OBSERVATION

Over 50,000 new CLIA labs authorized to deal with COVID Dx surge. The question for 2023, is how many will stay in business now that Lab volumes are down to pre-pandemic levels? (COVID Dx now primarily DTC / OTC.)

Only Certain Laboratories Develop LDTs

Of approximately 267,000 lab facilities in the U.S., an estimated 12,000 are likely to use LDTs



Source: BCG analysis of the Quality Improvement and Evaluation System (QIES) database
© The Pew Charitable Trusts 2021



First in Class Diagnostic approvals in 2022



ABBOTT OBTAINS FDA CLEARANCE FOR FIRST TEST THAT SIMULTANEOUSLY DETECTS FOUR COMMON SEXUALLY TRANSMITTED INFECTIONS (STIS) AS CASES ARE ON THE RISE



FDA grants marketing authorization to Fujirebio's diagnostic test for Alzheimer's disease



The First Diagnostic Test for Long COVID Will Formally Launch in Europe in September 2022



Viome launches early detection test for oral and throat cancers with saliva self collection

*At home saliva collection



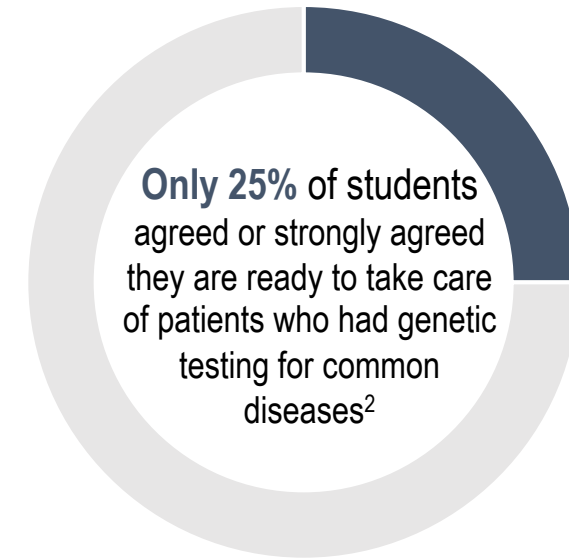
Medical Schools Lack Depth in Diagnostics and Genetic Testing Education

“ Precision medicine is becoming an integral part of care in every area of medicine, and it is vital to prepare our future physician workforce to use genomics to improve health.

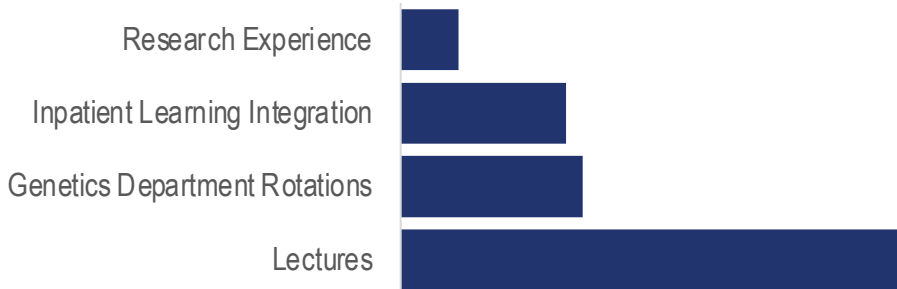
Alison Whelan, MD, AAMC chief medical education officer⁴



94% of students felt that their medical education had inadequately prepared them to practice personalized medicine¹



To improve the genetic education component coursework, students want medical schools to provide more³:



“ There’s a specific deficit in training about how to use the information clinically.... We know about the human genome. But how do I apply that to my patients?

Kristin Weitzel, PharmD. University of Florida College of Pharmacy⁴

“ Companies come and go. Education lasts forever.

Mara Aspinall, Professor of Practice, Arizona State University

1. 2016 study - Icahn School of Medicine at Mount Sinai (Source). 2. 2018 study of 488 primary care providers in the state of New York (Source) (Source). 3. 2022 survey of WVU residency training programs (Source) 4. AAMC (Source)

Specialized Diagnostics (A,B,C & D)

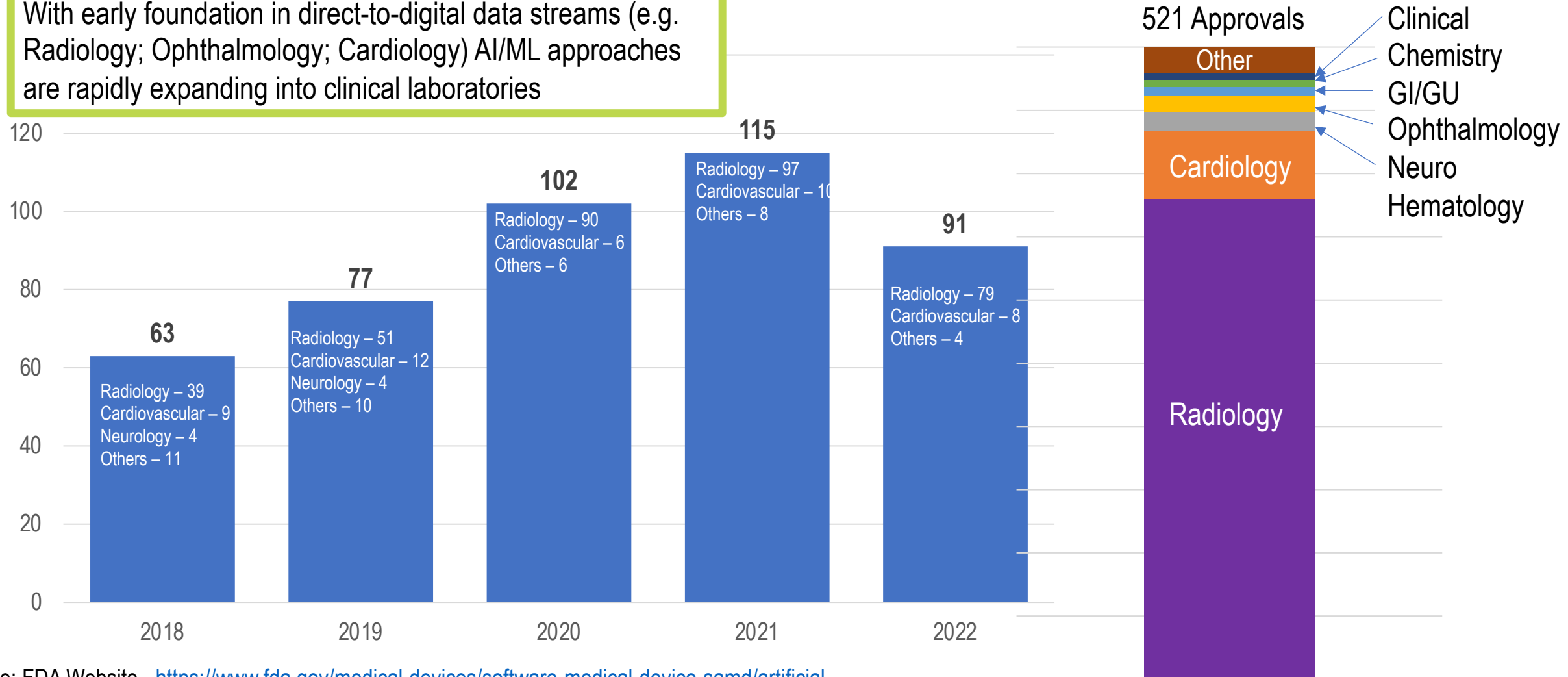
- Artificial Intelligence
- Biomarker Dependent Tests
- Companion Diagnostics
- Direct to Consumer Testing



Artificial Intelligence and Machine Learning-Enabled Device Approvals

OBSERVATION

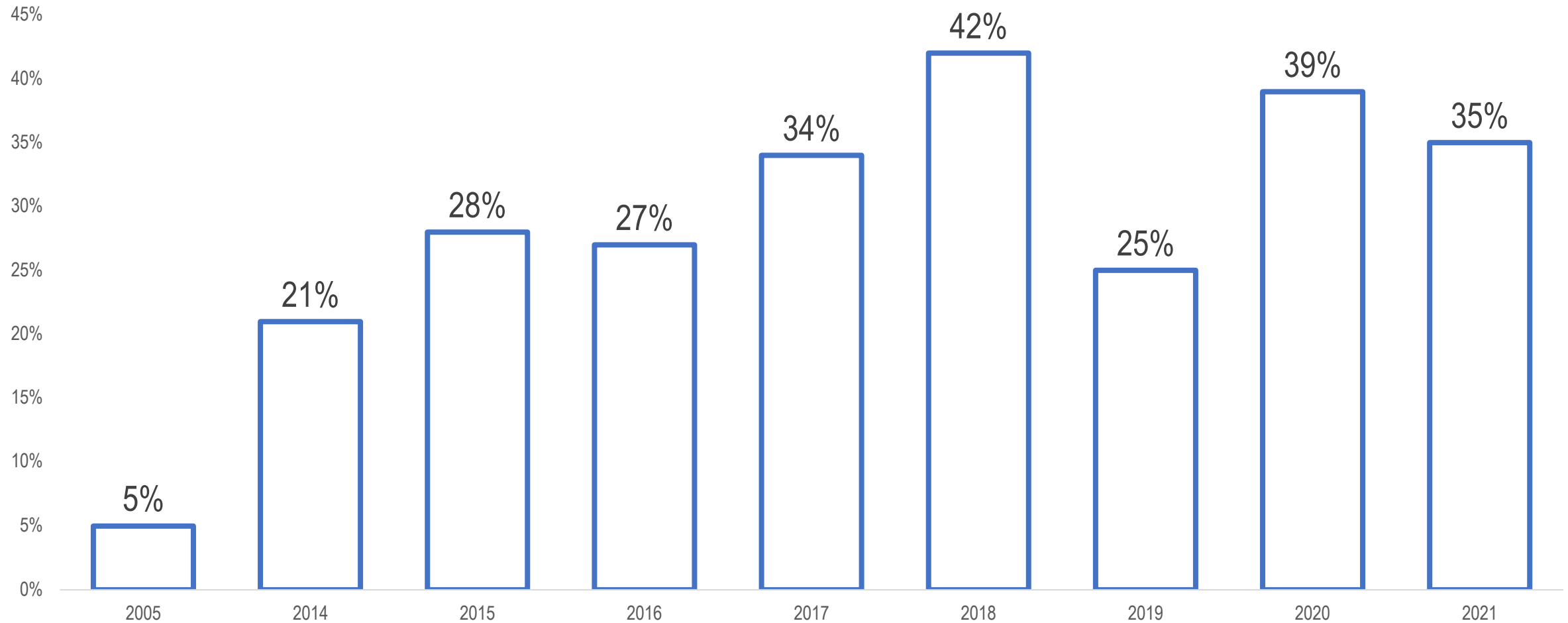
With early foundation in direct-to-digital data streams (e.g. Radiology; Ophthalmology; Cardiology) AI/ML approaches are rapidly expanding into clinical laboratories



Source: FDA Website - <https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-aiml-enabled-medical-devices>



Biomarker-Dependent Drug Approvals as a % of Total Drug Approvals

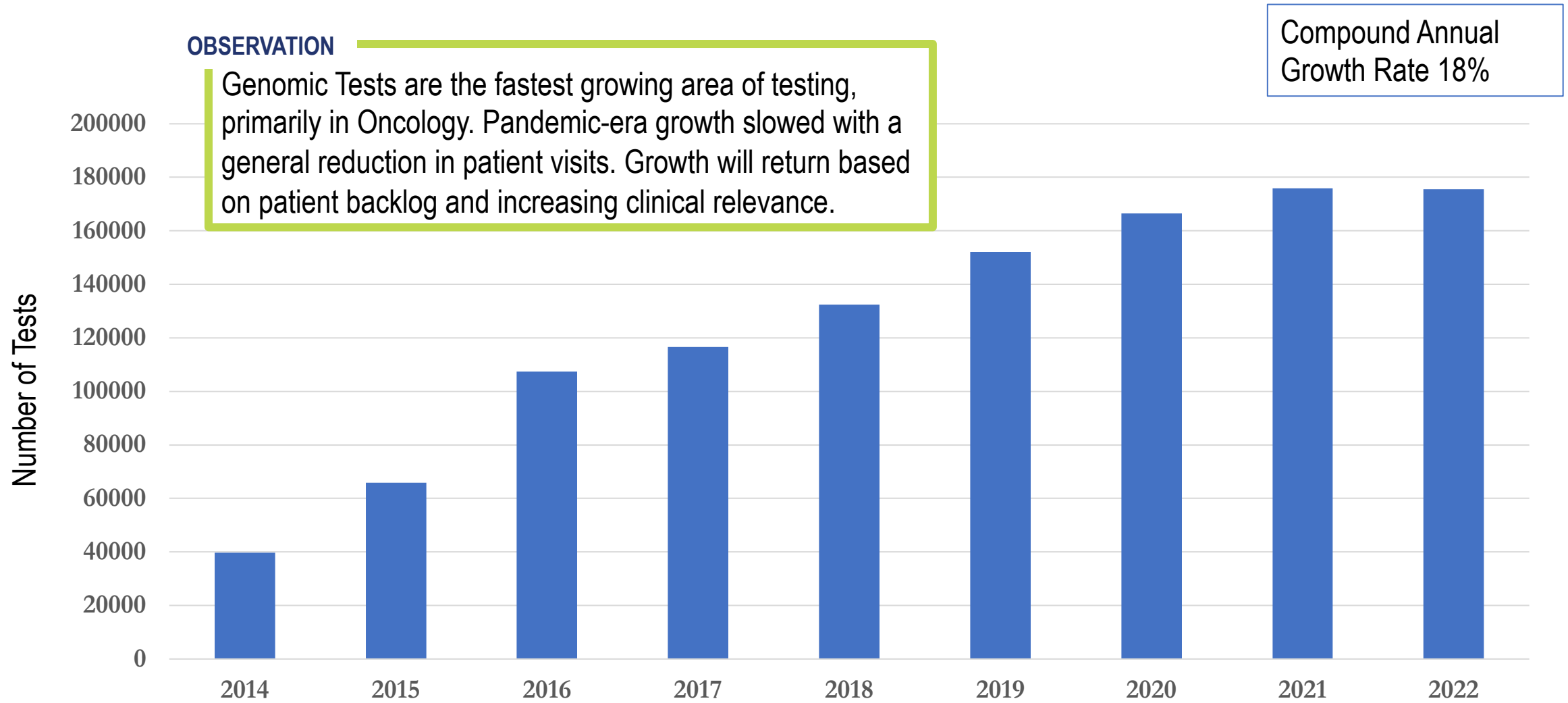


Source: Personalized Medicine Coalition –
The Scope and Significance of Progress in 2021

Methodology: When evaluating NMEs, PMC categorizes personalized medicines as those therapeutic products for which the label includes reference to specific biological markers, often identified by diagnostic tools, that help guide decisions and/or procedures for their use in individual patients.



Clinically Available Genomic Tests: Concert Genetics



Source: [Concert Genetics](#) Test Database

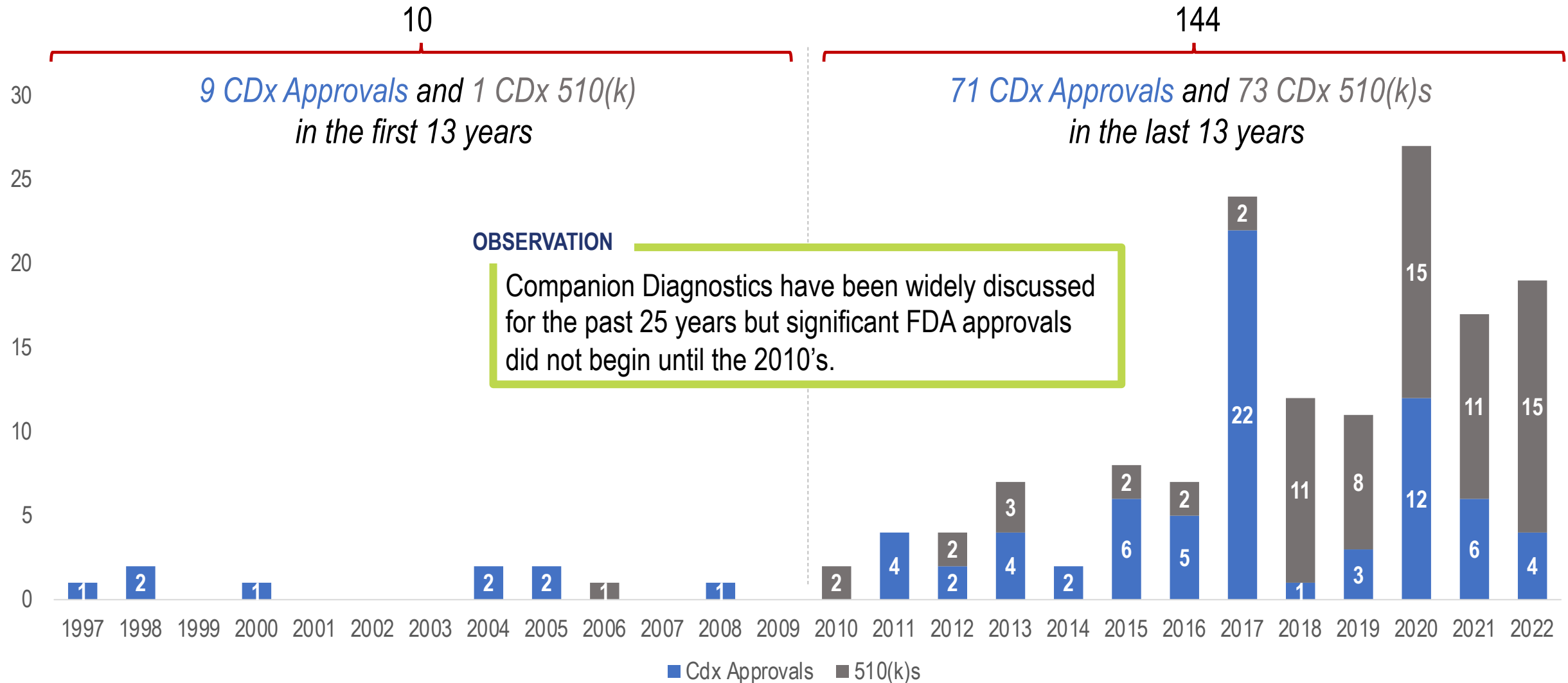
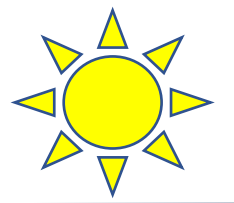


Concert Genetics Testing Database Explained

- Concert Genetics maintains a database of all genomic tests available from CLIA-certified laboratories:
 - The Concert Genetics Platform offers a database to serve clinical participants seeking to understand the genomic Dx landscape. Year to year growth has been extracted here to chart some of the basic trends in this increasingly essential genomic testing marketplace
 - The basic element of this data base is a single, distinct, orderable, genetic test performed by a specific laboratory: A genetic testing unit (GTU)
 - A single GTU represents an orderable test. This varies broadly from a test investigating just one (or a very few) mutations in one specific gene offered by one laboratory, to a panel of genes, to a whole exome. Each offering is counted as 1 GTU independent of how comprehensive or expensive each order might be.
 - A GTU is technology agnostic. A test may be performed on an NGS instrument (batched and barcoded or not) or by Amplicon identification, or a mix of the two by different laboratories.
 - A test may be for any type of genomic alteration: heritable (germline) or not (e.g. autosomal variation in oncology), single variants, insertions, deletions, copy number variants, and epigenetic chemistry.



Companion Diagnostics with FDA Approval 1998-2022





FDA Approved Companion Diagnostic Devices | 2018 & 2019

Diagnostic Name	Biomarker	Indication – Sample (Drug Trade Name)
Abbott RealTime IDH1	IDH1	Acute Myeloid Leukemia - Peripheral Blood or Bone Marrow (Tibsovo)
QIAGEN therascreen FGFR RGQ RT-PCR Kit	FGFR	Urothelial Cancer – Tissue (Balversa)
QIAGEN therascreen PIK3CA RGQ PCR Kit	PIK3CA	Breast cancer - Tissue and Plasma (Piqray)
Myriad myChoice CDx	BRCA 1 & 2 Variants + Instability	Ovarian Cancer (Zejula)

Source: FDA Website: <https://www.fda.gov/medical-devices/in-vitro-diagnostics/list-cleared-or-approved-companion-diagnostic-devices-in-vitro-and-imaging-tools>



FDA Approved Companion Diagnostic Devices | 2020

Diagnostic Name	Biomarker	Indication – Sample (Drug Trade Name)
QIAGEN therascreen BRAF V600E RGQ PCR Kit	BRAF	Colorectal Cancer - Tissue (Braftovi)
Roche cobas EZH2 Mutation Test	EZH2	Follicular Lymphoma Tumor - Tissue (Tazverik)
Ventana HER2 Dual ISH DNA Probe Cocktail	ERBB2 (HER2)	Breast Cancer - Tissue (Herceptin)
Guardant360 CDx	EGFR (HER1)	Non-Small Cell Lung Cancer (NSCLC) - Plasma (Tagrisso)
FoundationOne Liquid CDx	EGFR (HER1)	Non-Small Cell Lung Cancer (NSCLC) - Plasma (Iressa, Tagrisso, Tarceva)
FoundationOne Liquid CDx	BRCA1 and BRCA2	Metastatic Castrate Resistant Prostate Cancer (mCRPC) - Plasma (Rubraca) Ovarian Cancer - Plasma (Rubraca)
FoundationOne Liquid CDx	ALK	Non-Small Cell Lung Cancer (NSCLC) - Plasma (Alecensa)
FoundationOne Liquid CDx	PIK3CA	Breast Cancer - Plasma (Piqray)
FoundationOne Liquid CDx	BRCA1, BRCA2 and ATM	Metastatic Castrate Resistant Prostate Cancer (mCRPC) - Plasma (Lynparza)

Source: FDA Website: <https://www.fda.gov/medical-devices/in-vitro-diagnostics/list-cleared-or-approved-companion-diagnostic-devices-in-vitro-and-imaging-tools>



FDA Approved Companion Diagnostic Devices | 2021 & 2022

Diagnostic Name	Biomarker	Indication – Sample (Drug Trade Name)
Pillar ONCO/Reveal Dx Lung & Colon Cancer Assay(O/RDx-LCCA)	EGFR (HER1)	Non-Small Cell Lung Cancer (NSCLC) - Tissue (A tyrosine kinase inhibitor approved by FDA for that indication)
Pillar ONCO/Reveal Dx Lung & Colon Cancer Assay(O/RDx-LCCA)	KRAS	Colorectal Cancer - Tissue (Erbix, Vectibix)
Ventana MMR RxDx Panel	deficient mismatch repair (dMMR) proteins	Endometrial Carcinoma (EC) - Tissue (Jemperli) Solid Tumors (Jemperli)
Agilent Ki-67 IHC MIB-1 pharmDx(Dako Omnis)	Ki-67	Breast Cancer - Tissue (Verzenio)
PreventionGenetics POMC/PCSK1/LEPR CDx Panel	POMC, PCSK1 and LEPR	Obesity - Blood or Saliva (Imcivree)
Ventana FOLR1(FOLR-2.1) RxDx Assay	FOLR1	Epithelial Ovarian Cancer, Fallopian Tube Cancer or Primary Peritoneal Cancer-Tissue (Elahere)
One Almbda SeCore CDx HLA Sequencing System	HLA	Uveal Melanoma – Whole Blood (Kimmtrak)
Resolution Bioscience Agilent Resolution ctDx FIRST assay	KRAS	Non-Small Cell Lung Cancer (NSCLC) - Plasma (Krazati)



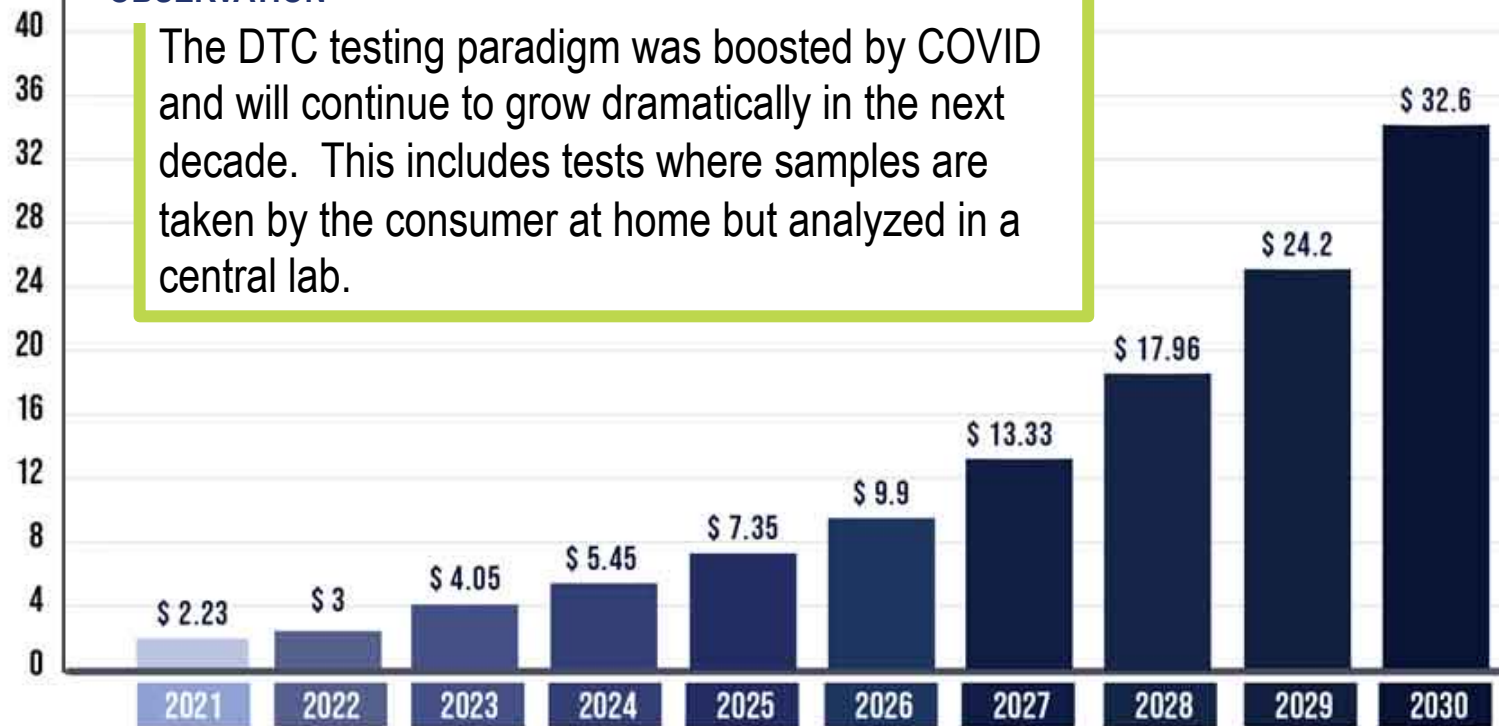
Direct-to-Consumer Testing Market Outlook

PRECEDENCE
RESEARCH

DIRECT-TO-CONSUMER LABORATORY TESTING MARKET SIZE, 2021 TO 2030 (USD BILLION)

OBSERVATION

The DTC testing paradigm was boosted by COVID and will continue to grow dramatically in the next decade. This includes tests where samples are taken by the consumer at home but analyzed in a central lab.



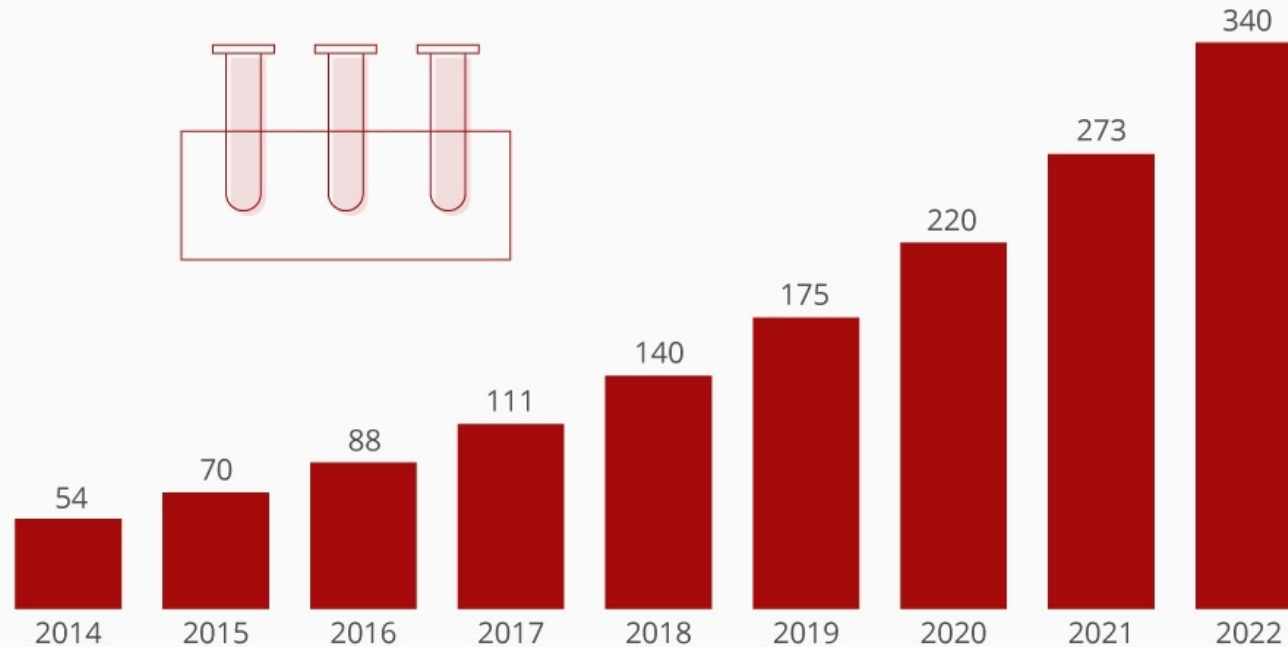
Source: www.precedenceresearch.com



Direct-to-Consumer Genetic Testing Market Growth – until 2022

Consumer Genetic Testing Grows in Popularity

Size of the global direct-to-consumer genetic testing market (in million U.S. dollars)



CC BY ND
@StatistaCharts

Includes forecasts

Sources: Credence Research, Statista

statista

OBSERVATION

Direct-to-Consumer Genetic Testing, continues to see strong and steady growth in the market.

COVID Diagnostics



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TestingCommons.com

A one-stop source for reliable and comprehensive information about COVID-19 tests worldwide. Search tests on the market and in the research pipeline using multiple parameters, including test type, technology, regulatory status, country of origin and more.

TestingCommons.com is part of the COVID Diagnostics Commons initiative at Arizona State University's College of Health Solutions.

Testing Commons is made possible with support from The Rockefeller Foundation and Rapid Acceleration of Diagnostics Underserved Population (RADxUP)

Questions: Mara G. Aspinall Professor of Practice / Dr. Sarah Igoe Research Associate

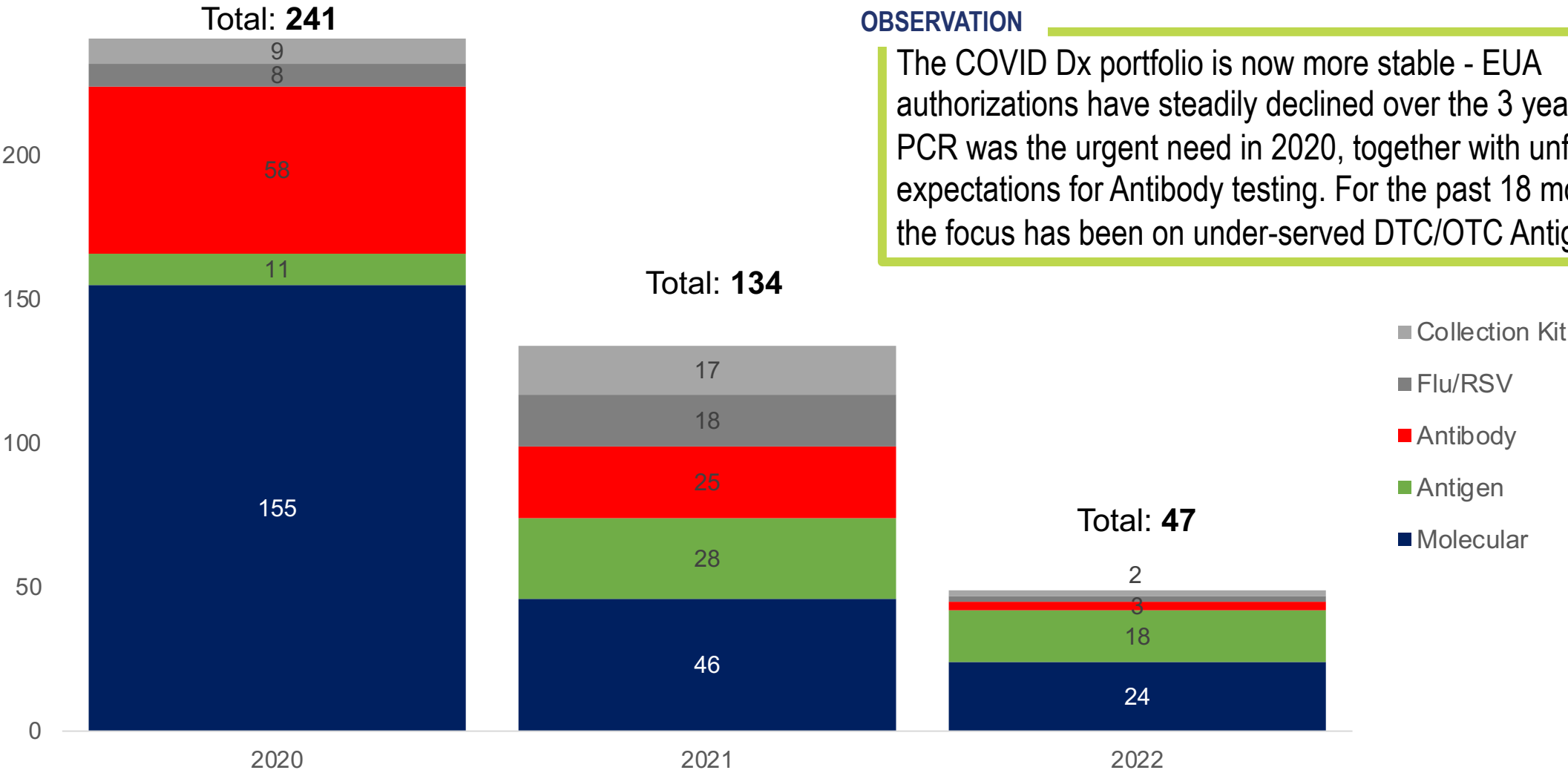
2022 Observations and Takeaways

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Based on the information aggregated on TestingCommons.com, we've seen the following trends in 2022:

- **Decline in COVID EUA Activity** | 2022 saw another dramatic decline in new EUA approvals
 - 47 in 2022, 134 in 2021, and 233 in 2020
- **Transition Away from Lab-based to Self Tests** | 2022 confirmed the transition away from lab-based tests to OTC / Self Tests as well as away from the more invasive nasopharyngeal swabs to anterior nasal swabs. The focus also pivoted away from pooled specimen tests with no new EUA's for pooling in 2022.
- **New Test Categories** | The FDA added two new categories for unique tests in 2022 – but issued only one EUA in each category: one for a Point of Care breath analysis test and one for a Lab-based test for genotypic lineage identification.
- **Increased Quality Focus** | The FDA also dedicated much focus in 2022 to quality control: they issued 32 warning letters to companies making false COVID-related claims, and they revoked 20 EUAs including PCR assays to reagents, antibody tests, and OTC antigen tests.

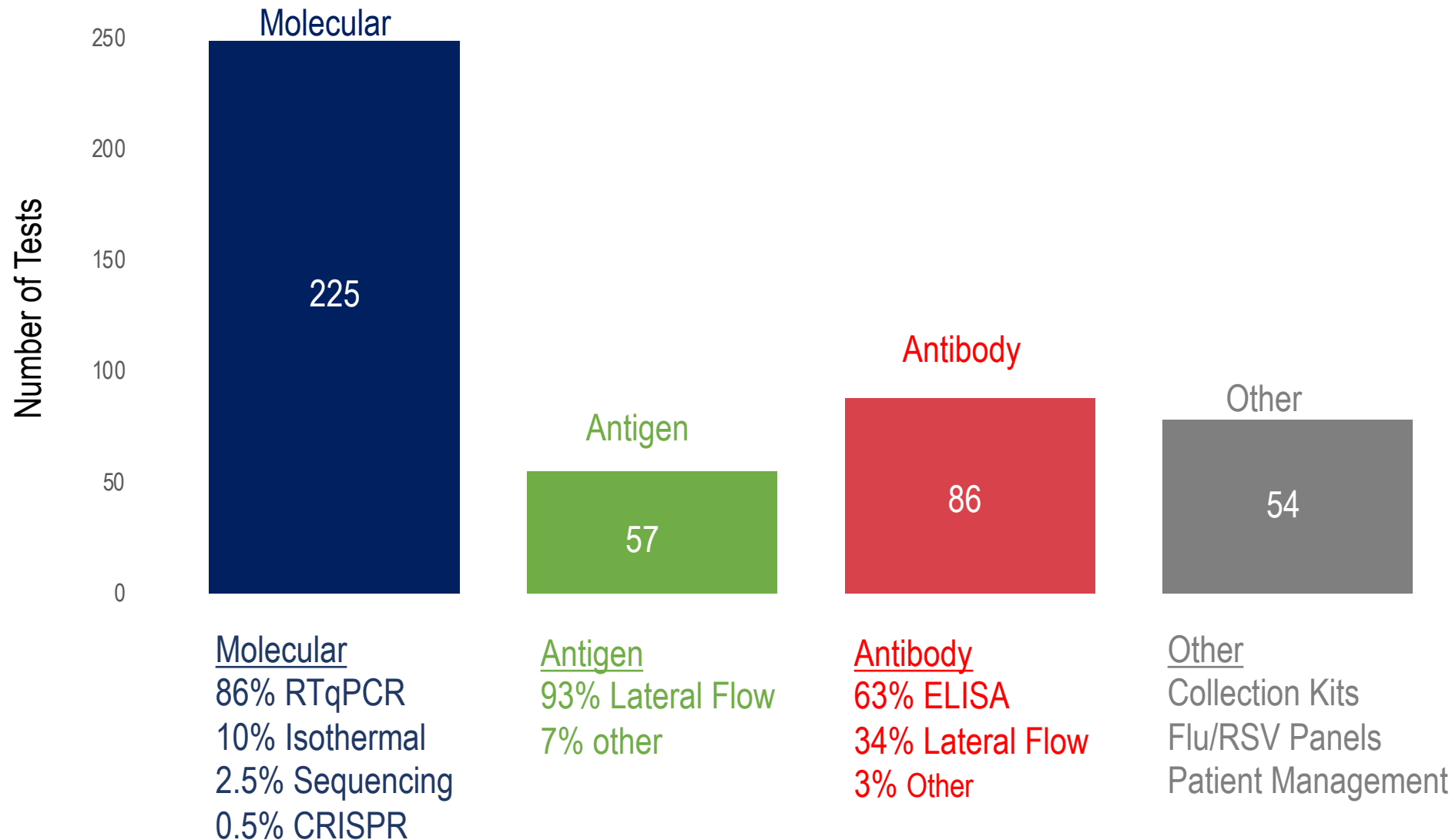
EUA Issuances Annually through 2022



OBSERVATION

The COVID Dx portfolio is now more stable - EUA authorizations have steadily declined over the 3 years. PCR was the urgent need in 2020, together with unfulfilled expectations for Antibody testing. For the past 18 months the focus has been on under-served DTC/OTC Antigen Dx

US FDA Emergency Use Authorizations

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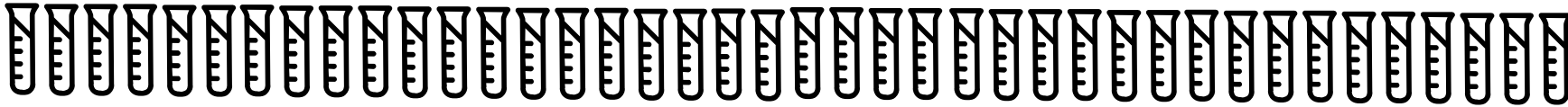
Pandemic Total
through 12/31/22

Profile of US FDA EUAs

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Sample Type Collected¹

SWAB



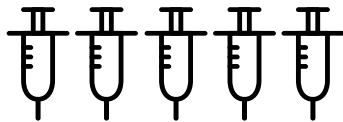
336

SALIVA



44

VENOUS BLOOD



67

FINGERTIP BLOOD



11

BREATH



1

Lab Authorized to
Analyze Sample

CLIA LAB
High
Complexity

CLIA LAB
Moderate
Complexity

CLIA
Waived /
P of Care

Self Test /
No Lab

1. Only a single Swab type per test counted here, in least to most invasive priority order: Saliva; ANS; lastly NPS/OPS.
All PCR tests are sensitive enough to work with nearly all of these swab types: later authorizations specify ANS in addition to other swab methods.

30 EUAs for OTC Self Tests



MOLECULAR TESTS (4)

- Aptitude Metrix COVID-19
- Cue OTC
- Detect At-Home
- Lucira CHECK-IT

ANTIGEN TESTS (26)

- Abbott BinaxNOW Card 2 Home
- Abbott BinaxNOW Ag Self
- Access Bio CareStart Home
- ACON Flowflex
- Advin Test @ Home*
- ANP Technologies NIDS*
- Azure Biotech Fastep*
- BD Veritor At-Home
- Beijing Hotgen*
- Celltrion At Home
- CorDxm Ag Test*
- CTK Biotech ImmuView*
- Ellume COVID-19 Home
- Genabio Rapid Self-Test
- iHealth COVID-19 Home
- InBios Int'l Detect Self
- MaximBio ClearDetect
- Oceanit ASSURE-100*
- OraSure IntelliSwab Rapid
- OSANG OHC Self-Test
- PHASE INDICAID At-Home
- Quidel QuickVue At-Home
- Roche / SDBiosensor At-Home
- Siemens CLINITEST
- Watmind SpeedySwab
- Xiamen Boson Rapid Ag Card*

30 EUAs for Respiratory Panels (Flu, RSV, etc.)



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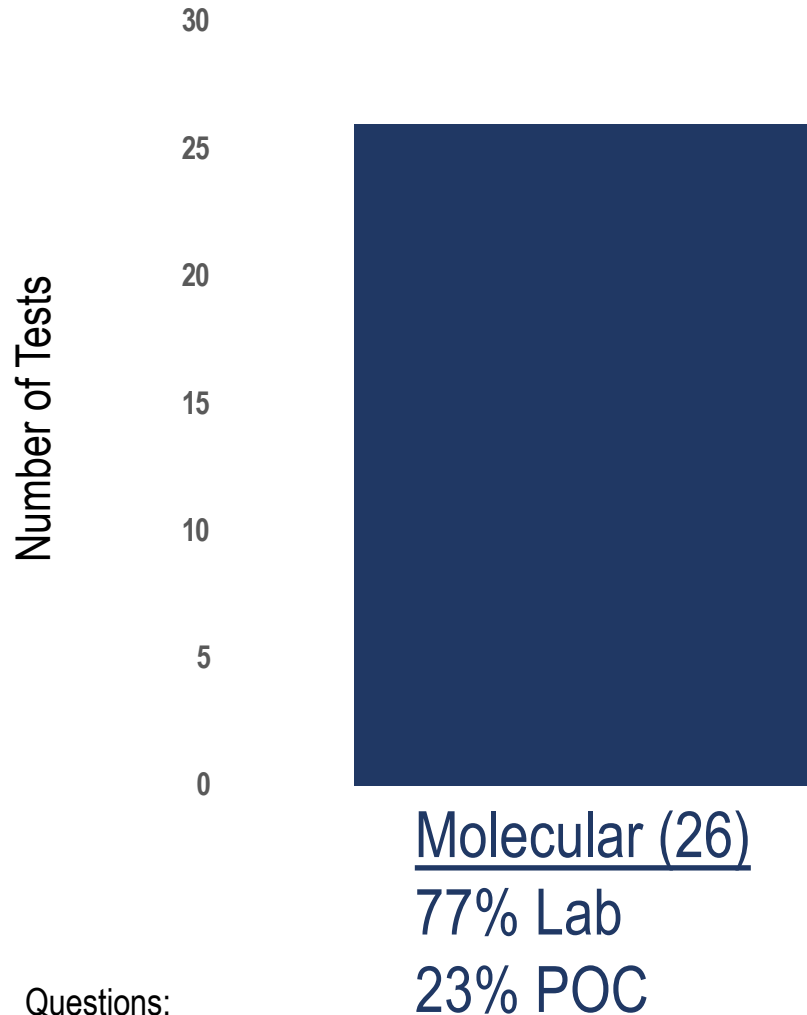
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OBSERVATION

The future of infectious disease testing will be multiplex testing – COVID + Flu A/B + potentially RSV. 2023 and beyond will see many more respiratory panels receiving EUAs and 510ks for full clearance.

Questions:
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sarah.igoe@asu.edu

Pandemic Total
through 12/31/22

CE-IVD Certified Tests (Mostly Europe)



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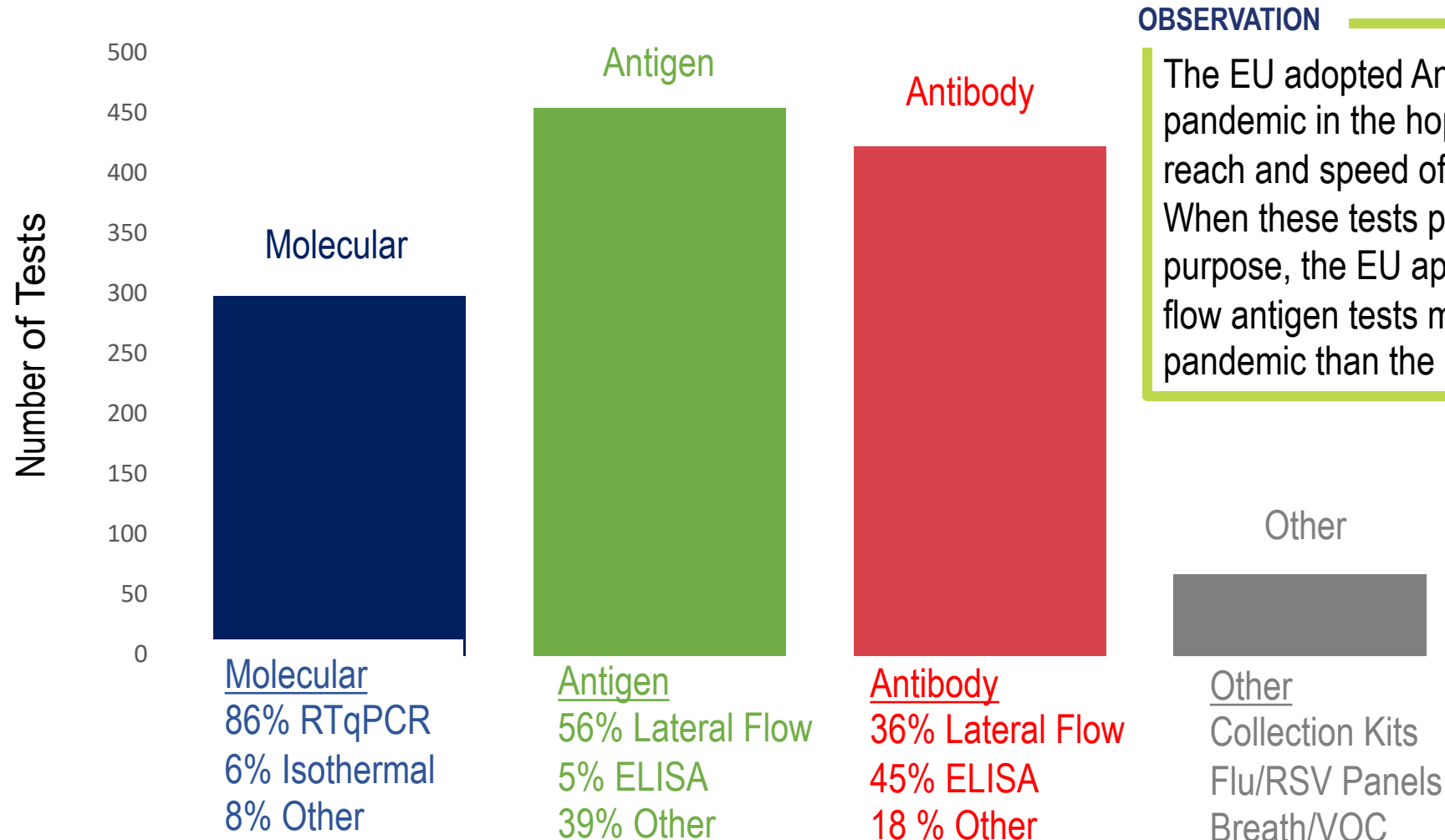
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OBSERVATION

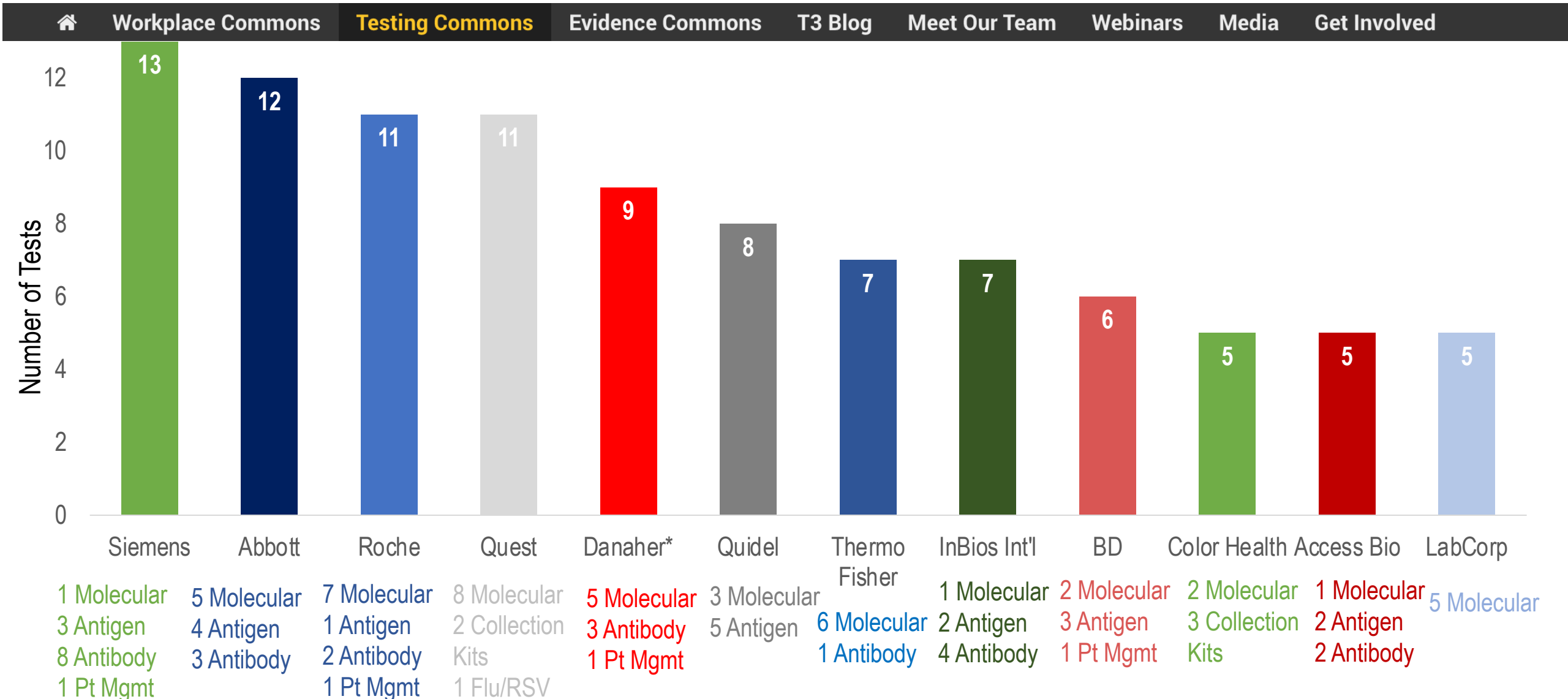
The EU adopted Antibody tests early in the pandemic in the hope of expanding the reach and speed of COVID diagnosis. When these tests proved ineffective for this purpose, the EU approved many lateral flow antigen tests much earlier in the pandemic than the FDA.

Questions:

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sarah.igoe@asu.edu

Pandemic Total
through 12/31/22

Companies with the Largest Number of EUAs



*Cepheid + Beckman Coulter

Pandemic Total
through 12/31/22

FDA Revoked EUAs & Other Safety Communications



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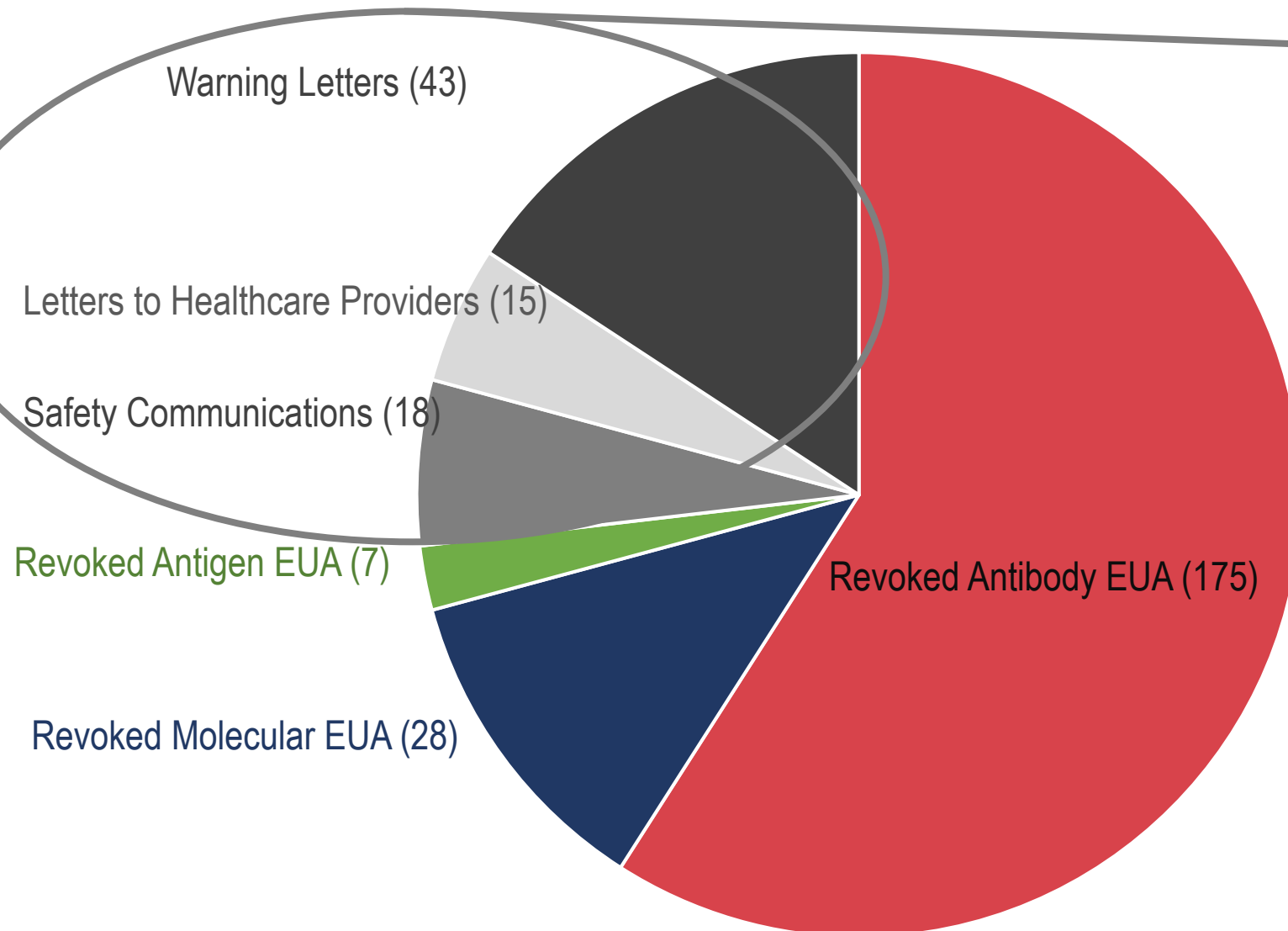
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- **Warning Letters:** FDA identifies significant violations of regulations and notifies manufacturer
- **Safety Communications:** FDA posts Medical Device Safety Communications to describe FDA's analysis of a current issue and provide specific regulatory approaches and clinical recommendations for patient management.
- **Letters to Healthcare Providers:** FDA posts the letters it sends to health care providers about safety concerns with medical devices used in health care facilities.

Pandemic Total
through 12/31/22

FDA Revoked EUAs & Other Safety Communications

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Warning Letters (43)

- Blue Willow Biologics
- Invisi Smart Technologies
- Jordan's Crossing Herbal Connections
- Kaleido Biosciences, Inc.
- Mahita, LLC dba PushMyCart
- Rxmedcart.com
- Shanghai Dasheng
- Varigard, LLC
- Amcyte Pharma, Inc.
- Genesis Partnership Co SA
- CES LLC
- Frozen Wheels, LLC
- Avila Herbals, LLC
- Glenn Burkett Naples Corporation
- Pharmacy2Home/LandiCom Holding
- Extrapharmacy.ru
- Rxshopmd.com
- CytoDyn, Inc
- My Natural Treatment
- Lusys Laboratories, Inc
- Bea Lydecker's Naturals, Inc.
- Viraldine, LLC
- Soda Pharm
- Ivermectin24h.com
- Iotech International LLC
- Applied Biological Laboratories,
- Iodine Products I
- Agropharma Laboratories, Inc.
- Heaven's Organic LLC
- UPSY LLC
- Nature's Highway
- Functional Remedies, LLC D/B/A Synchronicity Hemp Oil
- CBD Social
- Heaven's Organic LLC
- UPSY LLC
- Sensory Cloud, Inc
- CoFixRx, LLC
- Santhigram Kerala Ayurvedic US.
- Haniel Concepts, Inc. DBA Free State Oils, LLC
- FluxxLab, LLC
- W.H.P.M, Inc.
- H2 Beverages, Inc.
- Bespoke Apothecary, LLC
- Lakpura LLC
- Empowered Diagnostics LLC
- Alternative Health Distribution LLC

Letters to Healthcare Providers (15)

- Antibody Testing (2)
- Transport Media
- Self Testing / Nasal Swabs
- Rapid Antigen Tests
- Variants
- BD Max
- ThermoFisher
- Roche

OBSERVATION

The FDA has been aggressive to communicate safety concerns, with a consistent focus on the risks of antibody testing, and more recently the importance of serial DTC / OTC antigen tests.

Safety Communications (18)

GENERAL:

- Antibody Testing
- Veterinary Ivermectin
- Home Test Use & Storage
- Home Test False Negatives

TEST-SPECIFIC:

- Abbott
- Curative
- Ellume
- Innova
- Leccurate
- Lepu Medical
- Quidel
- LuSys Labs
- Empowered Diagnostics
- E25Bio
- Celltrion DiaTrust
- SD Biosensor
- STANDARD Q
- ACON Flowflex
- Skippack Medical Labs

Pandemic Total
through 12/31/22

EUAs for Management of COVID-19 Patients

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IVDs for Management of COVID-19 Patients (4)

- Roche Diagnostics Elecsys IL-6 EUA: June 2020
- Beckman Coulter, Inc. Access IL-6 EUA: October 2020
- Siemens Healthcare Diagnostics Inc. ADVIA Centaur IL6 Assay EUA: December 2020
- BD Vacutainer Plus Citrate Plasma Tubes (UK Manufacturing Site) EUA: August 2021

OBSERVATION

Despite initial excitement about IL6 for prognosis of COVID pathogenicity, and to support use of IL6 therapies, clinical utility was found to be limited and these tests have not met expectations.



Individual EUA for Diagnostic Breath Tests for SARS-CoV-2

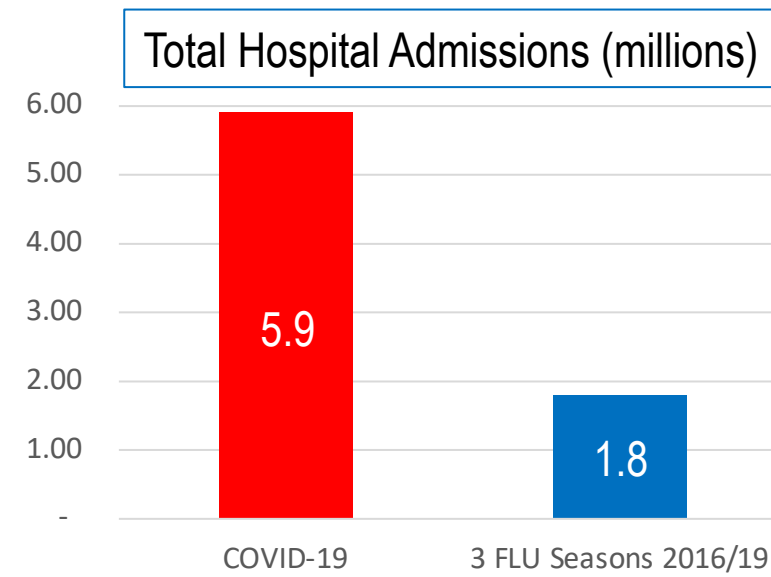
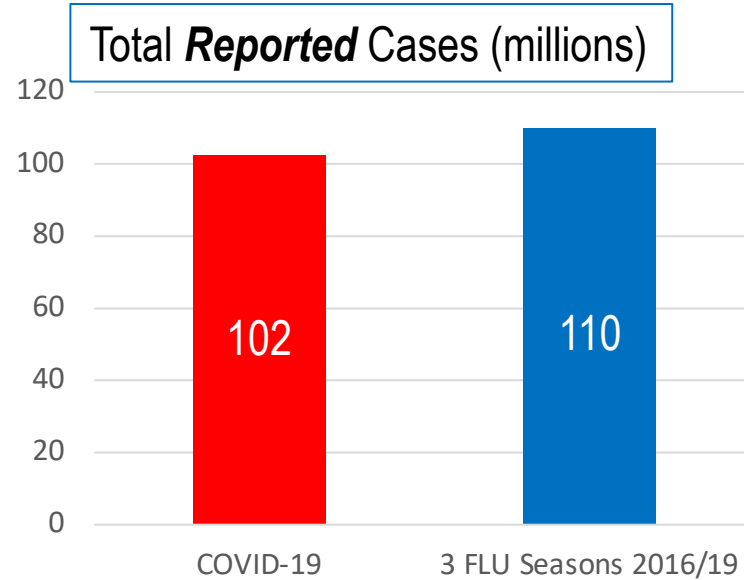
- InspectIR COVID-19 Breathalyzer (April 2022)
 - First COVID diagnostic test using Breath as a Specimen

Individual EUA for Genotyping Tests for SARS-CoV-2

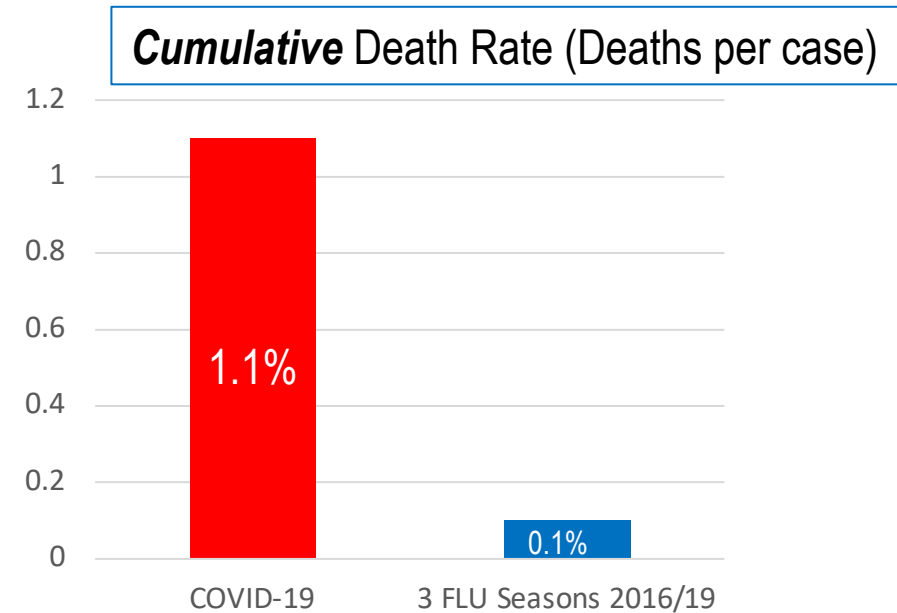
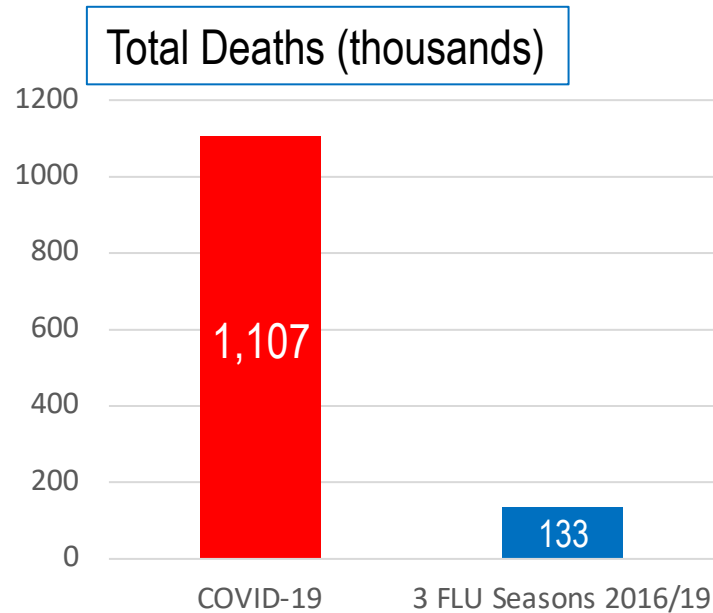
- Labcorp VirSeq SARS-CoV-2 NGS Test (June 2022)
 - New category of COVID EUAs for the identification and differentiation of SARS-CoV-2 phylogenetic assignment of named Global Outbreak (PANGO) lineages



COVID-19 is *not* “Just the Flu” – Versus normal flu seasons



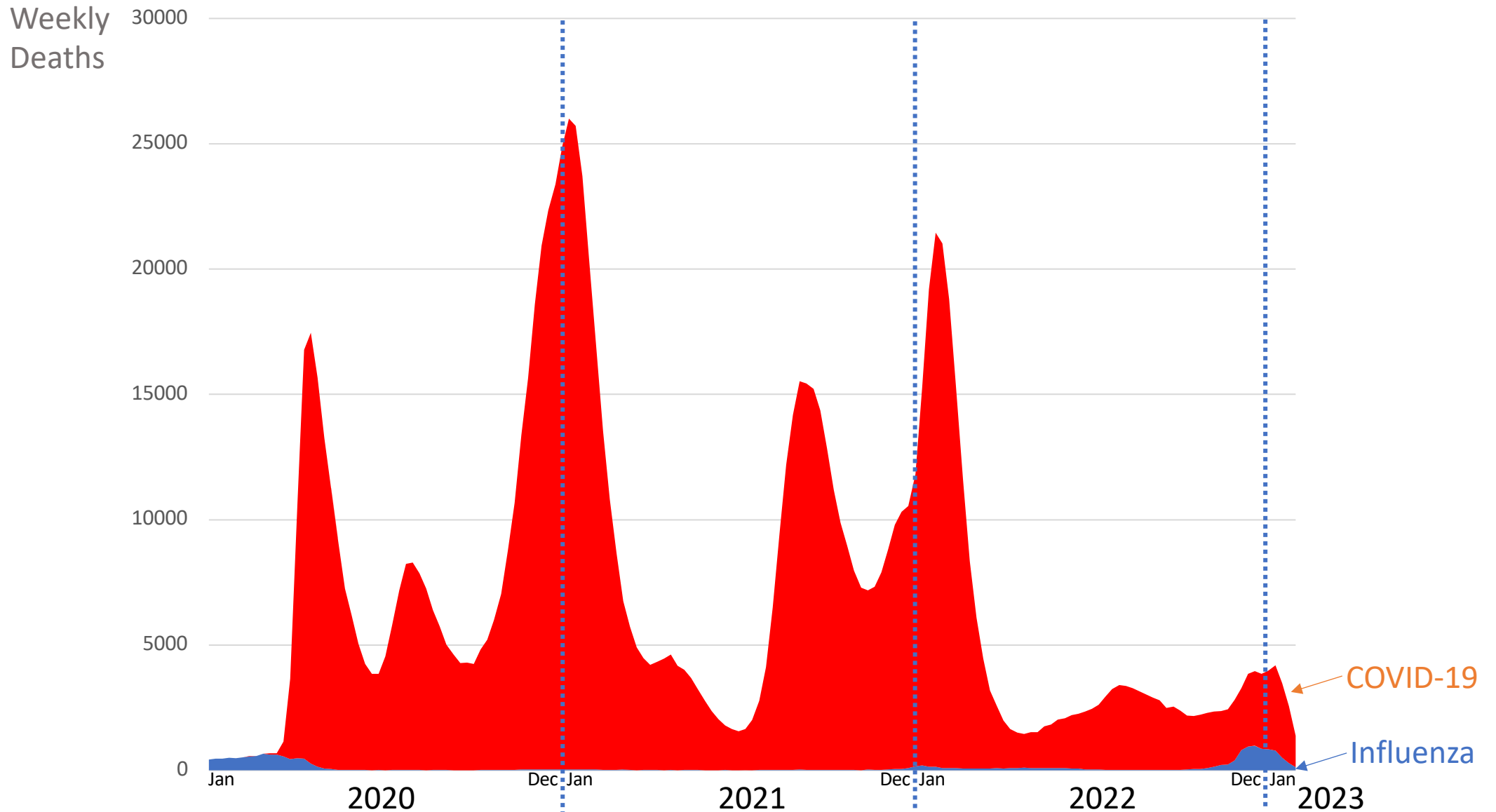
COVID
FLU



Sources:
[CDC COVID data tracker through 2/1/2023](#); [CDC past flu seasons](#)



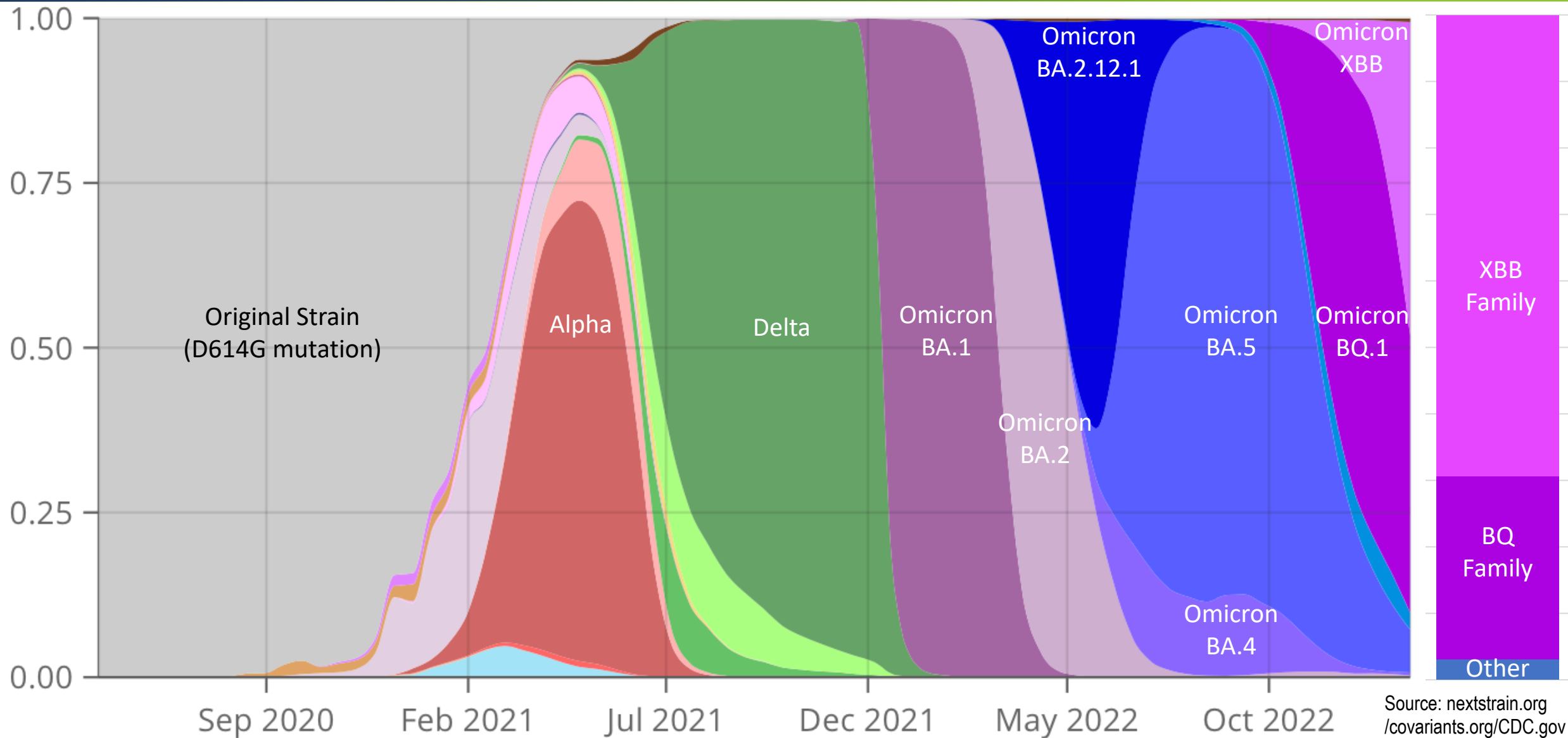
COVID-19 is *not* “Just the Flu” – Deaths in concurrent flu seasons





Variant History of the US: 2020-23

CDC Forecast
Feb 2023





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