The Economic and Functional Impacts of New York's Medical Schools

amsny
The Voice of Medical Education

TECONOMY PARTNERS LLC

About TEConomy Partners, LLC

TEConomy Partners, LLC (TEConomy) is a global leader in research, analysis, and strategy for innovation-driven economic development. Today we're helping nations, states, regions, universities, and industries blueprint their future and translate knowledge into prosperity. TEConomy brings deep firm experience in advanced economic and functional impact analytics, health and life sciences industry studies, and associated public policy to this study.

About the Associated Medical Schools of New York

Representing the collective and collaborative interests of the 17 public and private medical schools in the state, the Associated Medical Schools of New York (AMSNY) was formed to be the voice of medical education in New York State, advancing biomedical research, diversity in medical school and the physician workforce and high quality and cost-efficient care.

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Executive Summary

This report develops and provides a comprehensive examination and quantification of both the economic (or expenditure-based) impacts and the functional (or mission-based) impacts of the combined medical schools in state of New York represented by the Associated Medical Schools of New York (AMSNY). This executive summary contains key highlights of these impacts, including additional details regarding the biomedical research enterprise of these 17 medical schools. The summary of the medical schools' involvement in the emerging COVID-19 pandemic illustrates the unique and multifaceted role these institutions play in New York State.

The Economic Impact of AMSNY Institutional Expenditures

- AMSNY medical schools employ more than 62,000 faculty, researchers and staff across their educational, research, clinical care and administrative functions, earning more than $12 billion in wages and benefits, with total operational expenditures exceeding $19 billion.
- These operations generated more than an additional $15 billion in the New York economy—for a total economic impact of nearly $35 billion.
- For every $1 of output (expenditure) an additional $0.82 was generated throughout the state's economy (multiplier of 1.82).
- From an employment perspective, the multiplier is even greater – reaching 2.35—indicating that for every faculty, researcher, clinical care or administrative employee within the AMSNY member institutions an additional 1.35 jobs are supported within the New York economy.

AMSNY Institutions' Research Performance, Metrics and Impacts

- The combined AMSNY medical schools' level of R&D exceed $3.2 billion in annual research expenditures, growing by 45% from 2010 to 2019, outpacing U.S. growth since 2014.
- New York's medical schools received over $5 billion in research funding from NIH over the 2018-2020 period, receiving more than $500 million from each of four NIH institutes: National Institute of Allergy and Infectious Diseases, National Heart, Lung, and Blood Institute, National Cancer Institute and the National Institute on Aging.
- AMSNY member medical schools are (or were) principal sponsors of or collaborator in 1,468 clinical trials during the 2018-2020 period and provide access for New York's residents to more than 3,500 clinical trials in total during this period.
- Medical research at AMSNY members supports significant additional economic activity in New York State, including an additional 17,000 jobs and $3.4 billion in output within the state's economy in FY 2019.
- The AMSNY member medical schools' total FY 2019 research expenditures also generate and support additional state/local tax revenues (adjusted for the schools' non-profit status) of $298 million, more than five times the state government funded research support in FY 2019.

The Functional, Mission-Based Impacts of New York Medical Schools

The economic impacts associated with the expenditures of medical schools are clearly substantial. These impacts are, however, ancillary to the core mission-based impacts, termed functional impacts. New York's medical schools generate highly diverse benefits for society and the economy which support, serve and enhance New York State across all four broad functional impact categories as defined by TEConomy.

Knowledge Expansion and Innovation

- Critical fundamental research is conducted by faculty and research scientists at New York's schools of medicine. Much of this basic research is made possible through public sector support of science at the federal level (e.g., NIH research grants) and the State.
- New York's medical schools are focused on advancing knowledge and pragmatic health and biomedical technology advancements in the major categories of disease impacting New Yorkers – in cardiovascular diseases, infectious diseases, cancer, chronic respiratory diseases, diabetes, influenza/pneumonia and neurological disease, among others.

Economic Development

- With more than 3,700 medical school faculty and nearly 15,000 research scientists and other research professionals, the AMSNY 17 medical school ecosystem provides an extraordinarily deep resource of specialized knowledge covering clinical and scientific disciplines.
- The discoveries and innovations derived from medical school research translate into advancements in associated business sectors, stimulating the growth of new and existing health science enterprises and the diverse job opportunities they provide.
- More than 200 start-up business have been generated by the AMSNY member medical schools over the last five years.

Educated and Skilled Human Capital

- The educational mission is a central tenet of the AMSNY member medical schools. The 17 AMSNY member medical schools educated more than 11,000 medical students in each of the last three years.
- Respected, independent, and rigorous in the use of the scientific-method, New York's medical schools serve as subject matter experts for government, media, industry and the general public.
- The AMSNY member medical schools have an across-the-board commitment to enhance opportunities among underrepresented and disadvantaged populations. Reflecting this commitment, the medical schools sponsor several "diversity in medicine" programs that have helped AMSNY medical schools reach 21% enrollment by underrepresented student populations for the 2020-2021 school year.

Societal Well-being and Quality of Life

- Through the development of research findings and best practices, medical schools contribute to the development and design of important public health programs. The institutions are the educators of many of the frontline public health workforce in New York and provide for the original and continuing education of primary care physicians who play such a critical role in overall public health and wellness.
- Two highlighted areas, the impacts of the COVID-19 pandemic and the long-term health impacts for 9/11 responders reflect the signature nature and specific focus AMSNY member institutions are able to bring to very specific New York concerns. In both cases, New York's medical schools have directed their special resources, infrastructure, and talent to meet the needs of their fellow New Yorkers. In particular, the medical schools' work to combat infectious disease illustrates the full continuum of research and clinical practice work taking place across the AMSNY member institutions.

A Spectrum of Functional Impacts: AMSNY Medical Schools and COVID-19

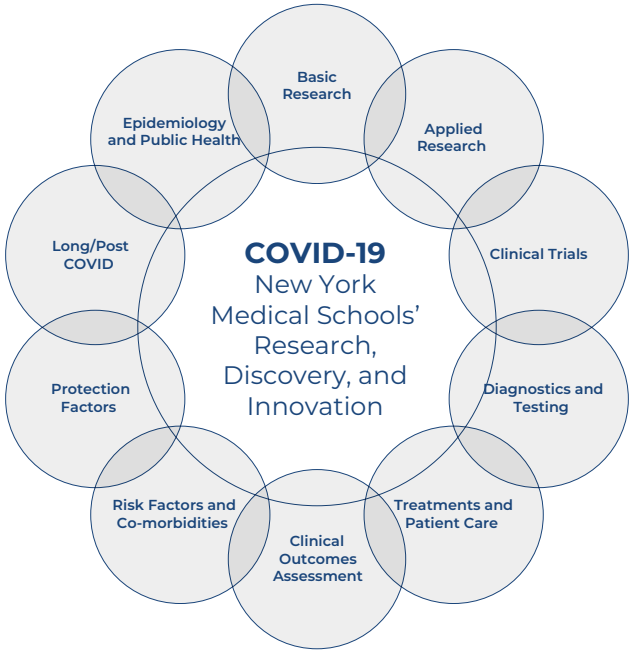
The COVID-19 global pandemic has significantly impacted the lives of us all. As a densely populated and highly connected global hub, New York State, and especially New York City, was hit hard and early by the pandemic.

As the pandemic hit, AMSNY member institutions reacted rapidly, pivoting much of their deep research expertise and signature research infrastructure to address the crisis and combat the disease. Contributions by AMSNY member institutions via research and innovations have contributed greatly to global and national advancements against the pandemic and been crucial in state and local scientific and clinical response to COVID-19. It is important to note that these contributions have been made and sustained while the pandemic itself impacted the operations of the AMSNY research community. The pivoting of resources and people to address the pandemic by AMSNY members represents a humanitarian commitment of New York's medical schools to preserving life and to protecting society and the economy in the face of an unprecedented threat.

Rather than seek to highlight each and every undertaking of the AMSNY member institutions in combatting the pandemic, Figure ES-1 provides classification of ten core domains of research and innovation activity undertaken, and highlights many of the areas of research and innovation activity that have been directed across these domains by New York medical schools.

AMSNY member institutions have been engaged across an extremely broad spectrum of research, discovery, and innovation activities, from basic and applied research on the virus and its disease-causing etiology, through to the development and clinical trials of drugs and vaccines to combat the disease. All of this while taking an active role in the care and treatment of New York's citizens.

Figure ES-1. AMSNY Member Institutions' Research, Discovery and Innovation Activity Domains in Combatting COVID-19



Source: TEConomy Partners, LLC.

The medical schools have been on the front lines in supporting the accurate diagnosis of infections and in tracking and predicting disease spread. Research teams have provided deep insight into best practice treatments of COVID-19 patients and elucidated factors associated with both risk and protection related to the disease and its clinical progression. It is anticipated that research on COVID-19 and its impacts will be sustained into the future, not only because the disease remains with us, but also to address future pandemic preparedness and to understand the long-term clinical impacts of the disease on recovering patients.

In addition to these COVID-19 related research and innovation activities, AMSNY member institutions actively engaged and collaborated in many other ways during the pandemic, including for example:

- Standing up special field hospitals and modifying existing emergency room, critical care and other clinical environments to address the unique triage and treatment requirements of a fast-moving infectious disease.
- Conducting clinician education programs and webinar events to transfer current knowledge and promote best practices in COVID-19 prevention, diagnosis and treatment.
- Working to support the mental health and mitigate stress across frontline clinical and essential workers.
- Rapidly scaling existing telemedicine platforms and adopting new virtual healthcare technologies to provide effective and uninterrupted remote care.
- Providing counseling and support for patients recovering from COVID-19 or experiencing long-term symptoms.
- Graduating fourth-year medical students as early as possible to address physician shortages and facilitating volunteer efforts by health science student populations in support of COVID-19 clinical actions.
- Working collaboratively to secure personal protective equipment and supplies for the frontline healthcare workforce.

The COVID-19 pandemic was experienced particularly acutely in New York and AMSNY member institutions stepped forward to address the challenge and devoted their considerable resources, expertise and infrastructure to the needs of the moment. Were it not for these efforts, the pandemic's negative effects across the state of New York would have been significantly magnified.

Introduction

Across the nation, a collective group of higher education institutions stands at the forefront of advancing health sciences. These are the nation's 192 colleges or schools of medicine,[1] institutions that train physicians and healthcare professionals, educate life scientists and clinical researchers, perform fundamental and applied research to advance life science knowledge and innovate and test new products and practices that improve clinical healthcare and power life science industries. These institutions are also critically important talent magnets, with the United States' world-class medical colleges attracting the best and brightest students from across the globe to train and work within a system that is uniquely well-resourced and on the frontiers of advanced healthcare practice and technology.

Performing both higher education and research, America's medical colleges are on the front lines, not just in advancing healthcare as a clinical practice, but also in advancing local, state and national economies. They are key to advancements in two out of the three forces driving our economic progress (innovation and talent) – providing both technological and scientific advancement through research and educating the talent needed to innovate and implement biomedical innovations.

New York State is an especially important contributor to medical education and research. Home to 17 public and private medical schools (see sidebar), New York is quantitatively specialized.[2] While the state contains

1 Including 155 MD granting institutions (allopathic medical colleges) and 37 DO granting institutions (osteopathic medical colleges) as of 2021.

2 The NYU Long Island School of Medicine's inaugural class began in August of 2019, and hence, was limited in information availability for this effort.

The Missions of Medical Schools

Medical schools, as either standalone or incorporated parts of larger post-secondary institutions, are established with a mission to teach medicine and award professional degrees, primarily either a Doctor of Medicine (M.D.) degree or a Doctor of Osteopathic Medicine (D.O.) degree. Within the AMSNY member institutions, 15 medical schools grant M.D. degrees (allopathic) and 2 grant D.O. degrees (osteopathic). Institutions may additionally grant additional bachelor's, master's or other doctoral level degrees. A core component of medical education is clinical practice, or direct, hands-on learning experiences. These activities are carried out and performed at hospitals and other care settings that are affiliated with the medical school for educational purposes and/or within integrated academic medical centers.

A second mission involves the delivery of clinical care. Different medical schools function in this clinical space differently—ranging from faculty practice groups, to affiliations with external teaching hospitals, to integration in the full operations of an academic medical center. An important characteristic of this economic impact study is that it captures only the economic activities of individuals directly employed by the medical schools. The economic activities of external employees involved in patient care employed by a particular hospital or medical center are not captured within the economic impact metrics developed in this report.

A third and equally important mission that is often highly integrated with education and clinical care is biomedical research. Through both faculty and staff researchers, medical schools perform a broad spectrum of research activities including both basic/pre-clinical science and clinical science research. In many instances an important component of medical school research is the development and performance of clinical trials, a research study involving human subjects to evaluate the effects of specific interventions on health-related biomedical or behavioral outcomes.

Finally, a fourth mission is the medical schools' role in and performance of community service activities. These activities, often integrated across the other three missions, provide medical students and faculty opportunities to directly engage communities of care whether it be a neighborhood, an ethnic community, or even a specific medical condition. The common thread of community care is the outreach into the health care needs of the surrounding community. While it is difficult to measure the economic impacts of these activities, the importance of them to the community, the medical school and the medical students cannot be overstated.

Medical Schools in New York State

- Albany Medical College
- Albert Einstein College of Medicine
- CUNY School of Medicine
- Columbia University Vagelos College of Physicians and Surgeons
- Icahn School of Medicine at Mount Sinai
- Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, SUNY
- New York Institute of Technology College of Osteopathic Medicine
- New York Medical College
- New York University Grossman School of Medicine
- New York University Long Island School of Medicine
- Norton College of Medicine at SUNY Upstate Medical University
- Renaissance School of Medicine at Stony Brook University
- SUNY Downstate Medical Center
- Touro College of Osteopathic Medicine
- University of Rochester School of Medicine and Dentistry
- Weill Cornell Medicine
- Zucker School of Medicine at Hofstra/Northwell

Representing the collective and collaborative interests of these 17 public and private medical schools, the Associated Medical Schools of New York (AMSNY) was formed to be the voice of medical education in New York State, fostering and promoting biomedical research, diversity in medical school and the physician workforce and high quality and cost-efficient care.

5.9% of the U.S. population,[3] its 17 medical schools account for 8.9% of the 192 U.S. medical schools. At its most basic level New York provides an outsized role in this critically important activity space as would be anticipated given its population size.

The remainder of this study will quantify and describe how New York's medical schools outperform even this basic metric.

A History of Impacts and Contributions

New York is the home to the oldest hospital in the United States, with NYC Health+Hospitals' Bellevue founded as a six-bed infirmary within the New York Alms House in 1736. New York City is also home to one of the first three colleges of medicine established in the U.S., with Columbia's college of medicine established in 1767 (then part of King's College). From their earliest beginnings in colonial times, through to their current highly specialized concentration in New York, medical colleges have been a signature feature for the state. Not surprisingly, New York's medical colleges have made many notable contributions to science and the practice of medicine. They have collectively produced through both education and research 24 Nobel laureates, and there is a distinguished list of "firsts" in terms of medical discoveries and innovations stemming from the institutions (see sidebar for some examples).

It is important to recognize the societal influence and positive impacts generated by New York's medical schools. Not only because these institutions continue to provide and advance critically important training for key professions necessary for the functioning of our society, but also because they continue to be front-and-center in making new discoveries, advancing the frontiers of science and knowledge, and having an oversized influence on our innovation-driven economy.

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3 Source: U.S. Census Bureau latest population statistics (July 1, 2019).

Some Examples of Breakthrough Discoveries and Innovations from New York's Colleges of Medicine

Some examples of innovations developed by scientists at New York's medical schools include the first successful pediatric heart transplant (Columbia University), the first widely used vaccine for bacterial pneumonia (SUNY Downstate Health Sciences University), the most commonly prescribed drug for the treatment of multiple sclerosis (University at Buffalo) and the human papillomavirus (HPV) vaccine (University of Rochester).

Medical School Research and the Frontiers of Knowledge

Academic research is a significant and important component of the U.S. R&D and innovation ecosystem. Academic institutions are at the forefront in performing fundamental research, the basic inquiry that advances human knowledge and which forms the platform upon which applied and translational discoveries are made. They are also considerable contributors to applied research, advancing innovations and pragmatic practice improvements across disciplines. As noted by the National Science Board (NSB) "the life sciences – primarily biological and biomedical sciences and health sciences—have long accounted for the bulk of academic R&D...more than half of the total."[4]

Within the academic R&D space in the United States, schools of medicine are a particularly influential component of the ecosystem. As noted by the NSB, "*These institutions, around half of which are also doctoral universities with highest research activity, performed...70% of the total. Roughly half of these expenditures were associated with the medical schools themselves, whereas the other half were associated with other parts of these same institutions. Institutions with medical schools received...nearly three-quarters of all federal funding for academic R&D.*"[5]

Medical schools are not static institutions; rather, they are constantly investing and evolving to keep pace with and lead new fields of science, advanced biomedical technologies, new practice advancements and associated education and training. Their work educates and trains new healthcare and scientific professionals and is also central to providing the ongoing upskilling and continuing education of those already in practice. New York's medical schools are a key bloc within this ecosystem. Through research, publishing, seminars, events and formal and informal education programs, New York's medical schools are pushing research boundaries and ensuring that New York's biomedical workforce is on the frontier of advanced healthcare and scientific practice.

A Time of Change

The AMSNY member schools are on the forefront of new advancements in biological fields such as genomics, gene editing, stem cell biology, regenerative medicine, synthetic biology and others that bring opportunities and challenges to biomedical research and education. Similarly, the convergence of digital sciences and advanced analytics

Defining R&D

For the purposes of this study "research and development" or R&D is defined using the definition adopted by the National Science Foundation (NSF) and others as: "creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of people, culture, and society—and to devise new applications using available knowledge."

COVID-19

The COVID-19 pandemic has highlighted that our healthcare and life science professionals and institutions are absolutely essential not only in terms of our physical, but also our economic health. The resiliency of our society and economy has been aggressively tested by COVID-19, and without the, frankly, heroic efforts of frontline clinical healthcare personnel, and the intensive R&D work and associated advancements made by the life science research community, we would have experienced a situation orders of magnitude worse than the tragic situation we have encountered.

Early in the pandemic, New York was especially tested by COVID-19. New York City is a leading focal point for international travel for commerce, arts, global policymaking, tourism, and other activities. NYC received over 66 million visitors in 2019 alone. As such, COVID-19 had lots of opportunities to reach the city and circulate, as it did in other internationally influential hubs in the U.S. and around the world. **With the city and state comprising a pivotal early battleground, New York City's and the State of New York's medical and health science expertise was essential in mounting an effective response, and the medical schools across New York (as will be shown herein) were heavily engaged in supporting the fight.**

4 https://ncses.nsf.gov/pubs/nsb20202/academic-r-d-in-the-united-states
5 https://ncses.nsf.gov/pubs/nsb20202/academic-r-d-in-the-united-states

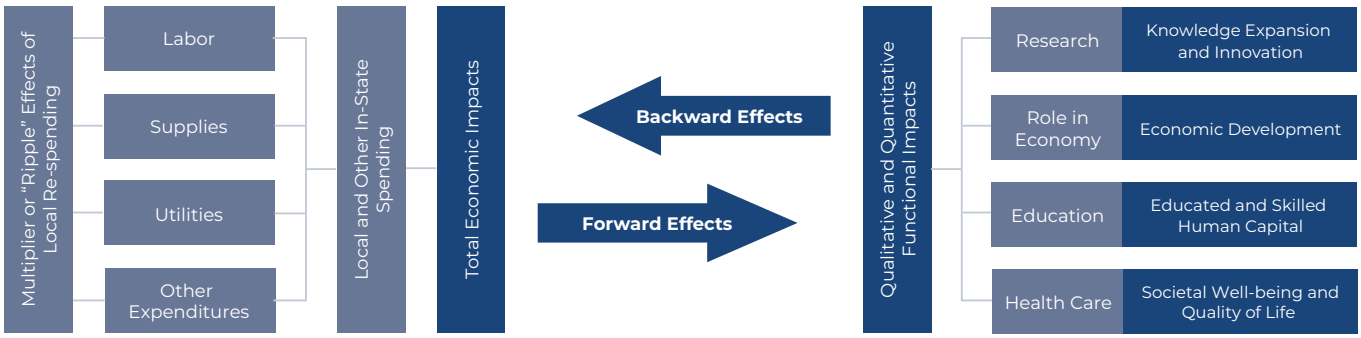
with the health sciences is driving significant gains in areas such as personalized medicine, medical big data (including linking genomics, phenomics, and health outcomes), telemedicine and applications of artificial intelligence within both research and clinical practice, all areas in which New York's medical schools are actively involved.

For New York State to continue to serve and be recognized as a specialized hub for academic medicine and education, and a national leader in biomedical research and innovations, it must support the needs and opportunities of its medical schools, their associated universities and the economic and research ecosystems within which they operate. Across these many areas in which New York's medical schools operate from a leadership position, competition from other universities and states for the best and brightest and for the resources for research and innovation is unrelenting. Additional challenges of demographic changes, an aging population, variable K-12 STEM education performance, health inequities across race and income, and national and state policies regarding healthcare, especially during the pandemic, are dynamic forces and drivers impacting the operations and priorities of New York's medical schools.

About This Study

This study was commissioned by AMSNY and performed by TEConomy Partners, LLC (TEConomy). The impacts of medical schools and their associated facilities may be examined from the perspective of both economic and functional (mission focused) impacts (Figure 1).

Figure 1. Key Forward and Backward Linkage Components of Medical School Impacts



Source: TEConomy Partners, LLC

In terms of economic impacts, a medical school is a significant enterprise in its state and community, generating substantial economic impacts through its budgetary expenditures and the expenditures of its personnel. The economic impacts of these expenditures are measured using input-output (I-O) analysis, which evaluates both direct expenditures, and the follow-on multiplier effects, to illustrate medical school impact on several economic metrics, including state and local economic output, value-added (contribution to GDP), employment, labor income and government revenues. I-O analysis is used herein to measure the expenditure impacts of New York's medical schools collectively on the state. It should be noted that this analysis does not measure economic considerations around specific health outcomes.

The economic (expenditure) impact data used herein are for the institutions 2018-2019 academic year (2019 fiscal year). This study was initiated with data collection efforts beginning in late 2019. As the pandemic raged, and the important attention of the New York schools were focused on meeting those challenges, AMSNY and TEConomy put the project on hold. Final data collection was resumed in early 2021. In order to supplement these FY 2019 economic impact results and begin to capture some of the economic and research effects stemming from COVID-19 actions various aspects of research and education data are presented in a combined 2018-2020 period.

Schools of medicine do not exist to provide an economic stimulus effect through their expenditures (although it is a significant positive economic outcome of their operations). Rather, these institutions exist to perform specific mission-driven functions that benefit society. These "functional impacts" represent the positive impacts generated by the core day-to-day activities of New York's medical schools – the provision of advanced medical and health sciences education and the performance of research and associated innovation (fundamental, applied, and translational). The nature of these functional impacts are also examined and highlighted in this report.

The Economic Impact of AMSNY Institutional Expenditures

Background

As discussed, the 17 medical schools represented by AMSNY are major economic engines for New York State and the regions and communities in which each medical school operates. Businesses and individuals across the service, retail, wholesale, transportation, manufacturing and other sectors benefit from the medical schools' direct expenditures and the spending of their faculty, researchers, staff, students and visitors. In addition, many of these expenditures are then recirculated within each impacted economy as recipients of the first round of income respend a portion of this income with other businesses and individuals within the subject economy. This process of respending is termed the ***multiplier effect*** and its effect across different economic variables is the basis upon which economic impact modeling is developed.

Economic Impact Modeling Overview

Input-output analysis continues to be the generally accepted standard in higher education and institutional economic impact measurement. Using the IMPLAN regional input-output (I-O) analysis system, the TEConomy project team will measure various impact measures that reflect and quantify the interrelationships and impacts of spending by one sector of the economy (e.g., education) on all other sectors, consumers and government.

The impacts are modeled using an approach called "analysis by parts." This type of analysis breaks down the operational characteristics of the sector in question, in this instance the multi-faceted operations of New York's medical schools, and models those impacts in the most representative IMPLAN sector (e.g., medical school research is modeled as scientific R&D not higher education). This approach reflects a more intrinsically accurate model (as the supplier characteristics, and hence downstream (indirect) effects, of these component areas are substantially different) while generating representative, yet conservative,

Types of "Economic" Impacts

The IMPLAN model is used to estimate five types of economic impacts for this analysis:

- **Output**, also known as production, sales or business volume, is the total value of goods and services produced in the economy. For public/nonprofit entities, such as universities, expenditures are often the truest measure of this economic activity.
- **Employment** is the total number of jobs created, including the direct jobs paid for through salary and benefit expenditures and indirect/induced (supported) jobs generated through purchase expenditures.
- **Labor Income** is the total amount of compensation, including salaries, wages, and benefits received by university employees and other workers in the economy.
- **Value Added** is the difference between an industry's total output and the cost of its intermediate inputs; sometimes referred to as the industry's "Contribution to GDP."
- **State/Local Government and Federal Government Tax Revenues** include the estimated revenues to federal and state/local governments from all sources as a result of the impacts estimated. Tax revenues are adjusted for public sector (tax exempt) direct effects (e.g., university expenditures).

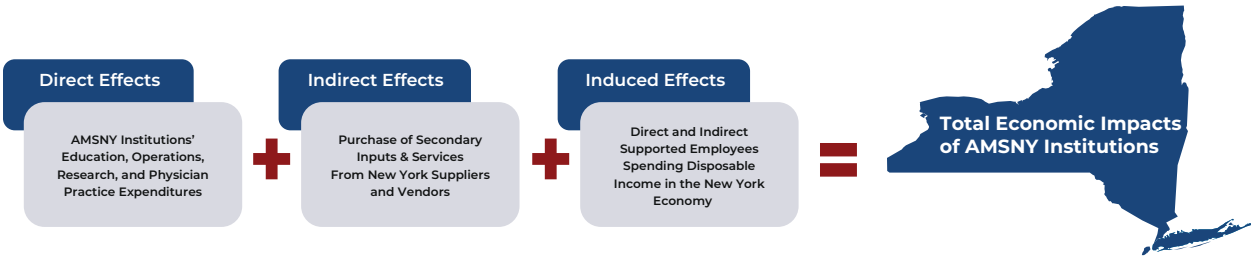
estimates. Three “parts” or component areas are defined by mission-oriented data collection efforts with the AMSNY member medical schools:

- Education
- Research
- Clinical Care (as represented by faculty physicians and faculty practice plans)

Additionally, a fourth expenditure area, that captures the overall leadership and administrative operations of each medical school, is also modeled as Education.

The trade flows built into the IMPLAN input-output (I-O) model permit estimating the impacts of one sector on other sectors. These impact effects consist of three types as depicted in Figure 2.

Figure 2. Depiction of Economic Impact Effects



Source: TEConomy Partners, LLC

In other words, the I-O analysis models the “ripple effect” that originates from the expenditures made by each AMSNY medical school’s operations in the New York economy, flows through suppliers and vendors as additional inputs are purchased, and through faculty, staff and related supplier workers who spend their wages in the economy.

Operational Input Data

Three data metrics are used to drive the economic interactions within the models: ***employment*** (more conservatively, but more precisely, captured as full-time equivalent (FTE) employment, where possible, due, for example, to physicians having part-time research or faculty appointments); ***labor income*** (including salaries, wages and the full cost of benefits) and ***output***. Considering the nonprofit and service mission of the medical schools in conjunction with their research and education functions (that also may receive some levels of operational support through endowments, grants and public support), ***total expenditures*** are used instead of revenues as a truer measure of total direct output.

These three data metrics across the four expenditure areas were reported to AMSNY and TEConomy using a spreadsheet data collection form developed for this effort. Table 1 provides an operational summary of these data for the collective 16 medical schools in full operation in FY 2019.

Table 1. 2019 AMSNY Medical School Operational Summary, by Component Area

Component Area	Total Expenditures ($B)	Total Number Faculty, Researchers, and Staff	Total Wages & Benefits ($B)
Educational	$1.254	3,774	$0.575
Research	$3.172	14,896	$1.813
Clinical Care (Med School-Based)	$13.475	35,664	$8.621
Other Leadership/Admin	$1.183	8,049	$1.206
Total	$19.084	62,382	$12.215

Source: TEConomy analysis of AMSNY Medical School FY 2019 Operations Dataset. Includes data from the 16 AMSNY institutions fully operational in FY2019.

AMSNY Medical Schools' Operational Impacts

Based upon these operational inputs representing New York State's public and private medical schools, the economic impact analysis was completed. Combined, **the AMSNY medical schools' operations of $19.1 billion generated an additional $15.6 billion in the New York economy—for a total economic impact of $34.7 billion** (Table 2). For every $1 of output (expenditure) an additional $0.82 was generated throughout the state's economy (multiplier of 1.82). From an employment perspective, the multiplier is even greater reaching 2.35—indicating that **for every faculty, researcher, clinical care, or administrative employee within the AMSNY member institutions an additional 1.35 jobs are supported within the New York economy.**

Table 2. Total Impacts of New York's Medical Schools, FY 2019

Impact Type	Employment	Labor Income ($B)	Value Added ($B)	Output ($B)	State/ Local Tax Revenues ($B)	Federal Tax Revenues ($B)
Direct Effect	62,382	$12.215	$14.751	$19.084	$0.506	$2.209
Indirect Effect	32,830	$2.878	$4.306	$6.746	$0.346	$0.540
Induced Effect	51,437	$3.283	$5.774	$8.877	$0.674	$0.682
Total Impacts	**146,649**	**$18.375**	**$24.831**	**$34.707**	**$1.525**	**$3.431**
Multiplier	*2.35*	*1.50*	*1.68*	*1.82*		

Sources: TEConomy analysis of AMSNY Medical School FY 2019 Operations Dataset (16 Institutions); IMPLAN Regional and State of New York Impact Models.

These jobs include more than 32,000 New York jobs in industries and firms that supply these medical schools and more than 51,000 jobs that are supported by AMSNY institution employees and supplier employees spending their incomes within the New York economy.

While the overall labor income of these medical school employees is expected to be significant, the operational data shows this compensation (including wages and benefits) to average more than $195,000 per employee. Importantly, from a statewide perspective these operations also generate significant compensation within both the indirect, supplier-based employment (more than $87,000 per year) and the induced, personal spending-based employment (more than $63,000 per year).

New York's Medical Schools Role in the State's Health Care and Biomedical Industry and Overall Economy

To better demonstrate the significance and role that New York's public and private medical schools play in the state's health care and biomedical industry, an overall industry economic impact analysis was also developed for this study. This analysis includes the entire private sector industry (e.g., biopharmaceutical companies, medical device companies, biotech companies) and well as private and public health care (e.g., doctors, hospitals (including VA hospitals), urgent care facilities and outpatient surgery centers, medical laboratories, etc.). These firms and institutions, in conjunction with the AMSNY members, combine to employ more than 869,000 New Yorkers across the state (Table 3). Through the economic impact analysis, it is estimated that the State of New York's health care and biomedical industry supports more than 1.66 million New York jobs (total employment impact). From a value added or contribution to Gross State Product perspective, the industry supports nearly $217 billion or approximately 12% of the New York's GSP.

Table 3. Total Impacts of New York's Health Care and Biomedical Industry (Including AMSNY Institutions), 2019

Impact Type	Employment	Labor Income ($B)	Value Added ($B)	Output ($B)	State/ Local Tax Revenues ($B)	Federal Tax Revenues ($B)
Direct Effect	869,172	$91.931	$120.379	$208.718	$6.454	$18.037
Indirect Effect	376,804	$32.736	$49.056	$78.179	$4.357	$6.508
Induced Effect	415,342	$25.111	$47.463	$72.137	$6.024	$5.482
Total Impacts	**1,661,318**	**$149.777**	**$216.898**	**$359.034**	**$16.835**	**$30.027**
Multiplier	*1.91*	*1.63*	*1.80*	*1.72*		

Sources: TEConomy analysis of U.S. Bureau of Labor Statistics Census of Employment and Wages State of New York data for 2019; AMSNY Medical School FY 2019 Operations Dataset (16 Institutions); IMPLAN Regional and State of New York Impact Models.

With this broad "industry" perspective, it is possible to better understand the public and private medical schools' roles in the state economy. Table 4 shows, for both the direct and total impact results, the shares of the total industry impacts that are represented by the AMSNY institutional operations and impacts. Across the board, the AMSNY medical schools' share of industry impacts is larger than simply their direct employment share of 7.2%. The AMSNY members account for 8.8% of the industry's total supported employment. The medical schools also account for 12.3% of the industry's direct contribution to New York's GSP, declining slightly in terms of its share of total value-added impacts.

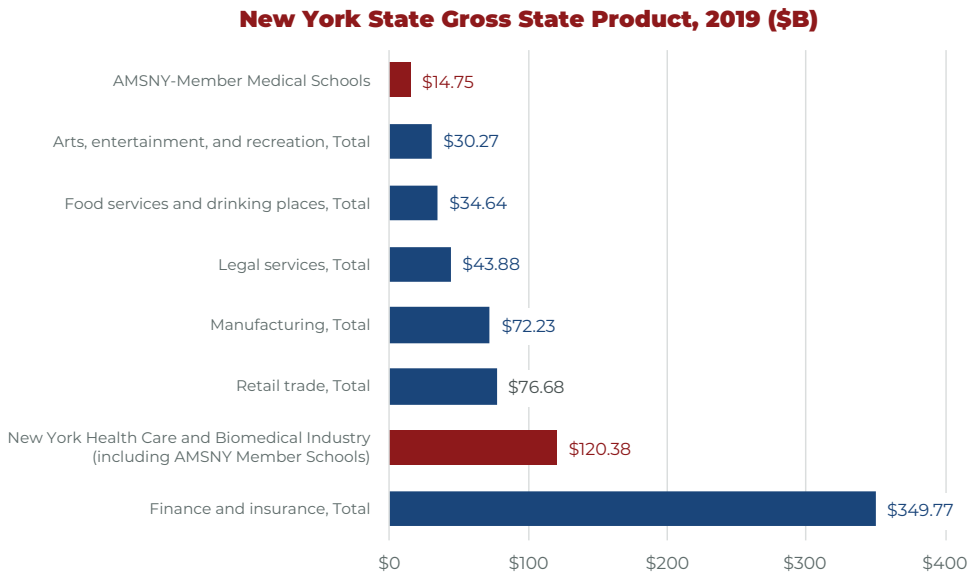
Table 4. AMSNY Institutions' Share of New York State's Total Health Care and Biomedical Industry Impacts, 2019

Impact Type	Employment	Labor Income	Value Added	Output	State/ Local Tax Revenues	Federal Tax Revenues
Direct Effect	7.2%	13.3%	12.3%	9.1%	7.8%	12.2%
Total Impacts	8.8%	12.3%	11.4%	9.7%	9.1%	11.4%

Sources: TEConomy analysis.

Further comparisons are possible to gauge the relative size of both the AMSNY medical schools' and the overall health care and biomedical industries' contributions to New York's Gross State Product. Figure 3 shows both the AMSNY institutions' direct contribution to GSP (direct value added effect) and the state's overall health care and biomedical industry direct contribution to GSP in relation to other significant components of the state's economy. The figure shows that the impacts stemming from the AMSNY medical schools are an important piece of the overall industry, which is, in turn, a major economic engine of the overall New York State economy.

Figure 3. Relative Comparisons to Other Sectors of the New York State Economy



Sources: TEConomy economic impact analysis and analysis of Bureau of Economic Analysis (BEA) State of New York Gross State Product data for 2019.

Summary

On an annual basis, the economic significance of the New York medical schools cannot be overstated. The 16 AMSNY member institutions fully operational in 2019 represent more than 62,000 employees, earning more than $12 billion in wages and benefits and generating over $19 billion in revenues. With the addition of NYU Long Island, which launched in mid-2019, this role and significance is now even greater.

The economic activities stemming from the medical schools' operations have a wide-ranging impact on the state's economy including:

- Total employment impacts of nearly 147,000 jobs reflected in a 2.35 employment multiplier.
- Generating and supporting more than $18 billion in total wages and benefits in the state.
- Supporting nearly $35 billion in total economic impact in New York State.
- Driving innovation within the state's health care and biomedical ecosystems.

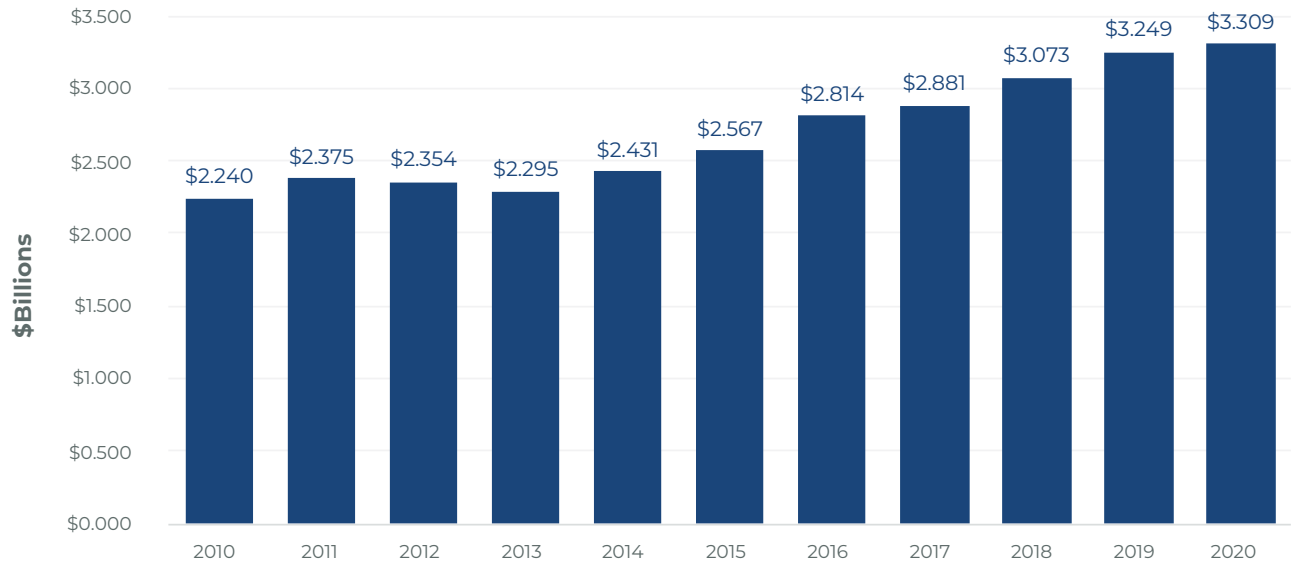
AMSNY Institutions' Research Performance, Metrics and Impacts

As part of the overall assessment of the economic and functional impacts of the AMSNY medical schools, it is important to recognize the breadth and depth of the institutions' research activities and their role relative to the institutions' total economic impacts.

Research Funding Performance and Metrics

At the highest level, the National Science Foundation's Higher Education R&D Survey provides a multi-year view of the AMSNY medical schools' level of R&D (as captured by total R&D expenditures, Figure 4). Combined, the medical schools exceed $3.3 billion in annual research expenditures, growing by 48% from 2010 to 2020.

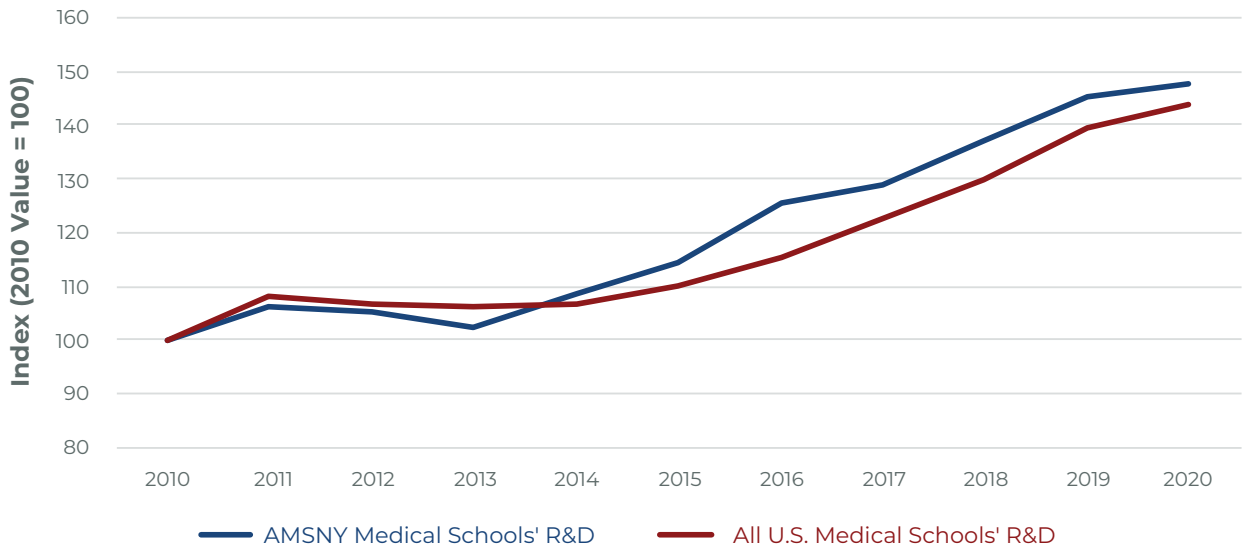
Figure 4. AMSNY Medical Schools' Annual R&D Expenditures, 2010-2020



Source: National Science Foundation/National Center for Science and Engineering Statistics Higher Education R&D (HERD) Survey, 2010 – 2020, Medical School R&D Expenditures data.

It is important to note that overall U.S. medical school funding also increased during this period. However, since 2014 the combined New York public and private medical schools have outpaced overall U.S. medical school research expenditures (Figure 5).

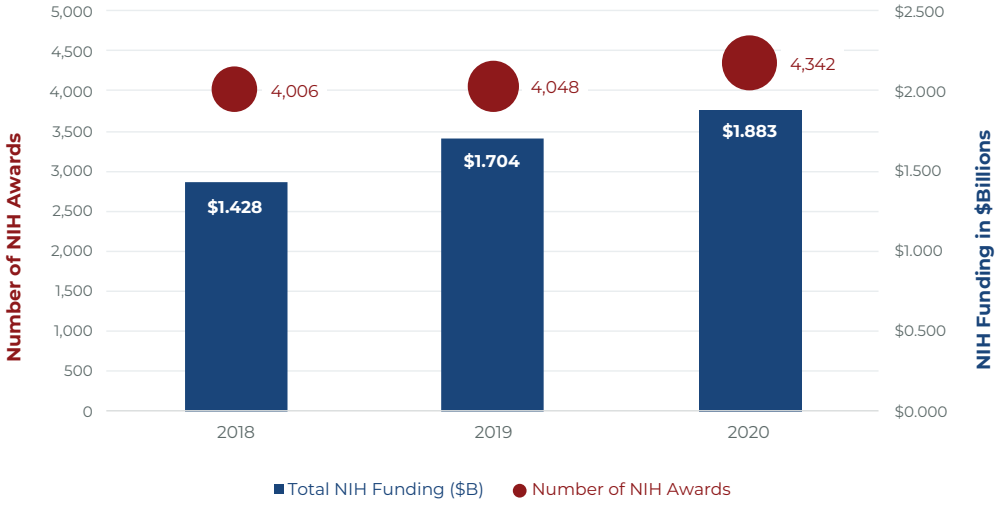
Figure 5. AMSNY Medical Schools' Outpacing U.S. Medical Schools in Research, 2010-2020



Source: National Science Foundation/National Center for Science and Engineering Statistics Higher Education R&D (HERD) Survey, 2010 – 2020, Medical School R&D Expenditures data.

A key component of medical school research, and U.S. academic research in general, is the support from the federal government via research grants and funding from the National Institutes of Health (NIH). Recent performance in securing NIH funding is a driving factor in the AMSNY member schools' increase in overall research levels. New York's medical schools increased their NIH funding by 19% from 2018 (in part reflected in Figure 4 above). From 2019-2020 the medical schools further increased their NIH funding by an additional 10%. Combined this reflects an increase of nearly one-third in a three-year period, reaching $1.883 billion in 2020 (Figure 6).

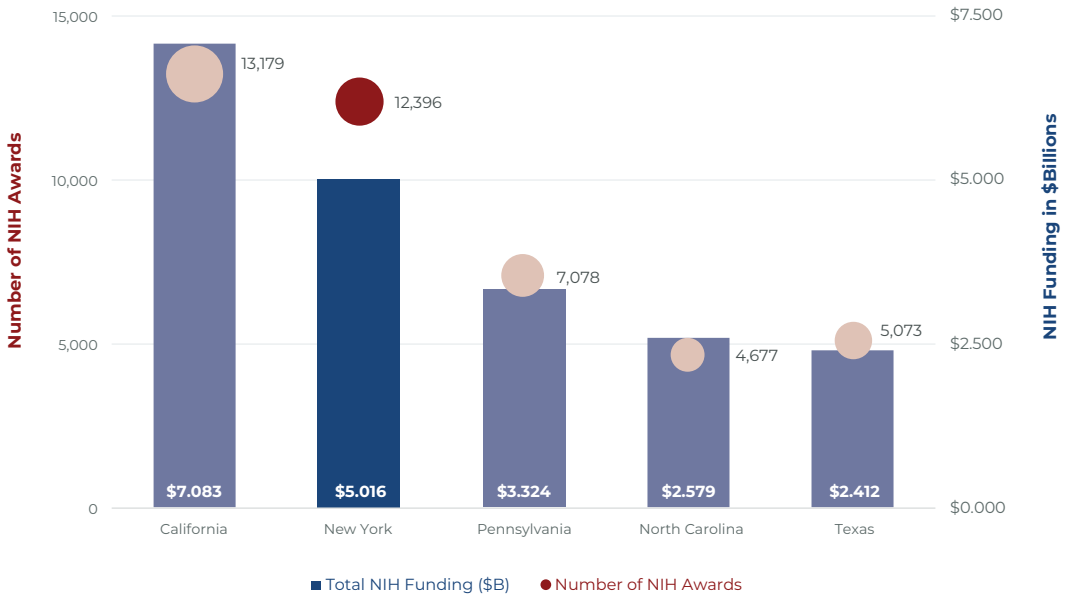
Figure 6. Recent Performance in NIH Awards and Funding Across AMSNY Medical Schools, 2018-2020



Source: National Institutes of Health, RePORT database. TEConomy mapped, to the extent possible, specific awards to medical school and medical school departments and faculty.

This level of NIH funding performance places New York and the AMSNY member medical schools second in the nation, behind only California in terms of total NIH awards and total NIH funding over the 2018-2020 period (Figure 7).

Figure 7. AMSNY Medical Schools Compared to Other Top Five States' Schools of Medicine and Osteopathic Medicine, 2018-2020 Combined



Source: National Institutes of Health, RePORT database data for Schools of Medicine and Schools of Osteopathic Medicine and TEConomy analysis for AMSNY members' data.

These awards also provide a valuable perspective into key research areas across the AMSNY medical school. Figure 8 shows that the National Institute of Allergy and Infectious Diseases (NIAID) was the largest funding institute over the 2018-2020 period, in part due to supplemental research funding related to COVID-19 in 2020. The National Heart, Lung, and Blood Institute (NHLBI) was the second largest funding institute, reflecting a strong heart and cardiovascular research emphasis among many of the AMSNY institutions.

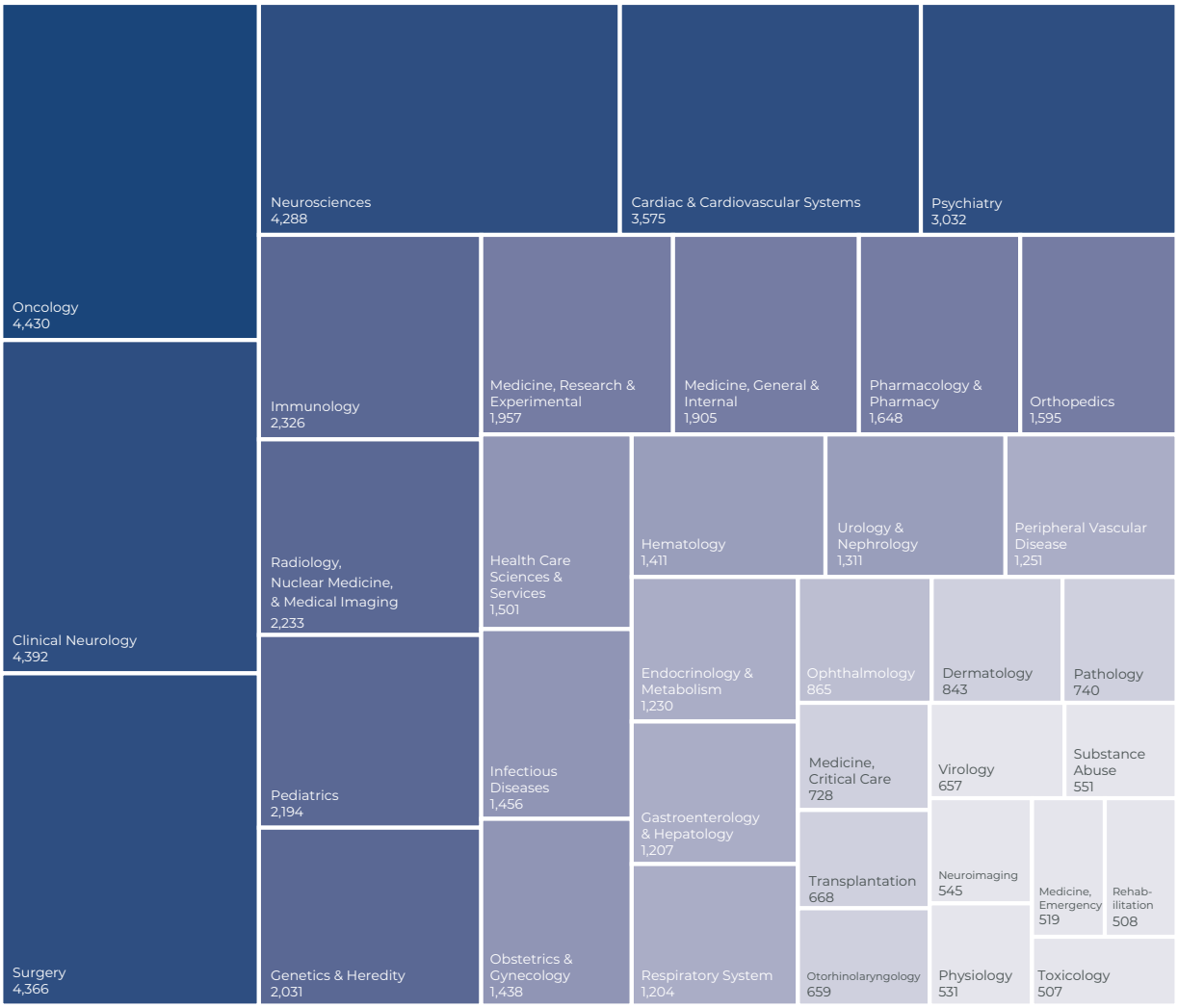
Figure 8. Recent Performance in NIH Awards and Funding Across AMSNY Medical Schools, 2018-2020

Source: TEConomy analysis of the National Institutes of Health, RePORTER database. TEConomy mapped, to the extent possible, specific awards to New York's medical school, medical school departments and medical school faculty/researchers. Awards to broader host university researchers, if any, are not included in these metrics.

Research Publication Performance and Metrics

To provide further insights into the areas of research and educational strength among the AMSNY medical schools, an examination of peer-reviewed journal articles in key clinical research and clinical practice areas was developed for the 2018-2020 period. Over this period, more than 54,000 research articles are captured in the Web of Science database. From this publication-based vantage point, the AMSNY medical schools' significant research activities in Oncology become even more apparent, with 4,430 research articles (accounting for 8% of the analysis records; Figure 9). The research and educational strengths of Clinical Neurology are also demonstrated, accounting for 8% of analysis records.

Figure 9. AMSNY Medical School Authored/Co-Authored Research Articles: 2018-2020, by Key Clinical Fields



Source: TEConomy analysis of Clarivate Analytics' Web of Science database, capturing fields with 500 or more publications. Analysis only used the Web of Science "Articles" document type. Search queries were designed, to the extent possible, to exclude non-medical school components of larger host universities.

Clinical Trials Performance and Metrics

A key requirement and component of the medical schools' applied research is the translation of this research into viable medicines, therapies and protocols through the process of clinical trials. Data were gathered from ClinicalTrials.gov, the public repository for publicly and privately funded clinical studies, including clinical trials, which is managed under the auspices of the U.S. National Library of Medicine (part of NIH).

AMSNY medical schools are (or were) principal sponsors of, or collaborators in, 1,468 clinical trials (interventional studies only) active at some point during the 2018-2020 period (with many still active). These are research studies where AMSNY medical schools' faculty, physicians and researchers are significantly involved in the study design and overall research. The number of clinical trials where an AMSNY institution provided a patient engagement/data collection location exceeded 3,500 trial sites over the same period.

Of the 1,468 clinical trials, all involved funding from AMSNY member institutions or other key New York-based health research organizations such as Memorial Sloan Kettering Cancer Center. Fully 988 clinical trials had no additional outside funding. Among other collaborators and co-funders of the remaining 480 clinical trials, various NIH Institutes provided funding to 284 trials (19% of the total number of trials) often in the context of NIH research awards. Industry collaborators and sponsors (e.g., Pfizer, Eli Lilly, Medtronic, etc.) provided funding to 263 (18%). Other departments and agencies of the federal government (e.g., Department of Defense; Agency for Healthcare Research and Quality; Veterans Affairs) provided funding for 30 (2%) of the trials.

The distribution of these clinical trials, similar to research grants and publications, provides insights into key areas of AMSNY institutions' research focus areas (Table 5). Strengths are seen in a number of specific cancer areas, mental health, diabetes, neurological disorders and infectious disease.

Table 5. AMSNY Member Institution Sponsored Clinical Trials by Condition, 2018-2020 (15 or more trials)

Condition	Number of AMSNY Member Institution Sponsored Clinical Trials
Breast Cancer	51
Depression	47
Diabetes	43
Obesity	31
Anxiety	26
Prostate Cancer	25
Stroke	22
Parkinson's Disease	22
Attention Deficit Hyperactivity Disorder (ADHD)	22
Asthma	21
Pain	20
HIV (Human Immunodeficiency Virus)	20
Uterine Cancer	19
Hypertension	19
Multiple Myeloma	18
Post-Traumatic Stress Disorder (PTSD)	17

Condition	Number of AMSNY Member Institution Sponsored Clinical Trials
Multiple Sclerosis	16
Heart Failure	16
Chronic Kidney Diseases	15
Alzheimer's Disease	15
Total, All AMSNY Member Institution Sponsored Trials	**1,468**

Source: TEConomy analysis of data from ClinicalTrials.gov – AMSNY Institutions. Data includes all Interventional Trials (specific Clinical Trials) that were active at some point during the 2018-2020 period. Individual trials may fall into more than one Condition Type.

The ClinicalTrials.gov data records also provide information regarding the type of intervention the clinical trial is examining. A significant share (46%) of the AMSNY medical schools' clinical trials involve drug studies (Table 6). The second largest intervention type, behavioral, accounts for 23% of the trials, and reflects research to determine if certain behavior changes can lead to improved condition.

Table 6. AMSNY Member Institution Sponsored Clinical Trials by Intervention Type, 2018-2020.

Intervention Type	Number of AMSNY Institution Sponsored Clinical Trials (2018-2020)
Drug	674
Behavioral	351
Device	200
Procedure	123
Radiation	42
Biological	40
Dietary Supplement	26
Diagnostic Test	20
All Other Interventions	296
Total, All AMSNY Member Institution Sponsored Trials	**1,468**

Source: TEConomy analysis of data from ClinicalTrials.gov – AMSNY Institutions. Clinical Trials include all Interventional Trials that were active at some point during the 2018-2020 period. Specific Trials may include more than one Intervention Type.

Though principally among the drug-related trials, the advancement of research from safety-related to efficacy-related studies is captured through the "phases" of clinical trials (Table 7). This metric continually shifts, as clinical research begins on new medicines and other medicines either continue to the next phase or research is discontinued. Over the 2018-2020 period, AMSNY medical schools were involved in 263 Phase 2 trials (within an additional 97 trials in multi-phase trials with Phase 2 goals), indicating substantial research engaged in whether these drugs can perform as expected across a population of patients.

Table 7. AMSNY Member Institution Sponsored Clinical Trials by Trial Phase, 2018-2020.

Clinical Trial Phase(s)	Number of AMSNY Institution Sponsored Clinical Trials (2018-2020)
Early Phase 1	36
Phase 1	90
Phase 1|Phase 2	72
Phase 2	263
Phase 2|Phase 3	25
Phase 3	45
Phase 4	159
Not Applicable	778
Total	**1,468**

Source: TEConomy analysis of data from ClinicalTrials.gov – AMSNY Institutions. Clinical Trials include all Interventional Trials that were active at some point during the 2018-2020 period. Note: Not Applicable is used to describe trials without FDA-defined phases, including trials of devices or behavioral interventions.

Economic Importance of Research

Given the importance of the research enterprise within the AMSNY institutions, a research-specific economic impact assessment was performed. For the FY 2019 operations dataset the AMNSY medical schools reported a total of $3.172 billion in research expenditures (Table 8). Fully 60% ($1.907 billion) of these funds were received from the federal government (e.g., from the National Institutes of Health), indicating both a significant amount of high-quality research and a significant amount of economic activity brought into the state from outside. Another significant source of funding among the New York medical schools are foundations and other nonprofit organizations, such as patient advocacy organizations and voluntary health associations. More than $620 million in research expenditures were funded by these organizations. Among the sources of funding for the medical schools' research, nearly 10% is institutionally funded via endowments or through research support gifts to the institutions. Industry funded research through grants or specific research contracts account for more than $280 million in FY 2019 funding. The smallest amount of research funding flowing to the AMSNY medical schools comes from state government grants and support, reaching nearly $55 million in FY 2019, but accounting for less than 2% of total research funding. However, it should be recognized that in many instances state government support provides a critical catalytic effect whereby the medical schools can leverage state investments many times over from other support sources. It should also be noted that significant state government support is provided for the educational missions of these medical schools.

Table 8. Source of Funding for AMSNY Institutions Research and Development Efforts, FY 2019

Source of Research Funds	FY 2019 Research Expenditures, by Source	Share of FY 2019 Total Research Funding
Federal Government Grants/Support	$1,906,957,655	60.1%
Foundation or Other Non-Profit Grants/Support	$620,292,144	19.6%
Restricted/Unrestricted Gifts and Endowment Funds	$309,643,465	9.8%
Industry Grants/Support/Contracts	$280,359,909	8.8%
State Government Grants/Support	$54,861,642	1.7%
Total	**$3,172,114,815**	

Source: TEConomy analysis of AMSNY Medical School FY 2019 Operations Dataset. Includes data from the 16 AMSNY institutions fully operational in FY2019.

State Government Grants/Support in FY2019 includes but is not limited to, the New York State Stem Cell Science program (NYSTEM), New York Fund for Innovation in Research and Scientific Talent (NYFIRST), the Spinal Cord Injury Research Program (SCIRP), the Empire Clinical Research Investigator Program (ECRIP)).

Using the operational data for the AMSNY medical schools' research activities, as provided in Table 1, a research-specific economic impact model was developed to provide insights into the specific economic impacts of the AMSNY members' research expenditures (Table 9). **From both an employment and output perspective, AMSNY member medical research supports significant economic activity in New York State, with both metrics yielding multipliers above 2.00. Total research expenditures also generate from direct, indirect and induced effects state/local tax revenues (adjusted for the schools' nonprofit status) of $298 million, more than five times the state government funded research support in FY 2019.**

Table 9. Total Impacts of AMSNY Institutions Research and Development Expenditures, FY 2019

Impact Type	Employment	Labor Income ($B)	Value Added ($B)	Output ($B)	State/ Local Tax Revenues ($B)	Federal Tax Revenues ($B)
Direct Effect	14,896	$1.813	$2.265	$3.172	$0.080	$0.344
Indirect Effect	8,567	$0.787	$1.144	$1.859	$0.091	$0.154
Induced Effect	8,607	$0.516	$0.986	$1.497	$0.127	$0.114
Total Impacts	**32,070**	**$3.116**	**$4.395**	**$6.527**	**$0.298**	**$0.611**
Multiplier	*2.15*	*1.72*	*1.94*	*2.06*		

Sources: TEConomy analysis of U.S. Bureau of Labor Statistics Census of Employment and Wages State of New York data for 2019; AMSNY Medical School FY 2019 Operations Dataset (16 Institutions); IMPLAN Regional and State of New York Impact Models.

Summary

To recognize the magnitude, diversity and effects on the New York State economy, a specific examination of the research funding and expenditures of AMSNY medical schools was developed. Key findings include:

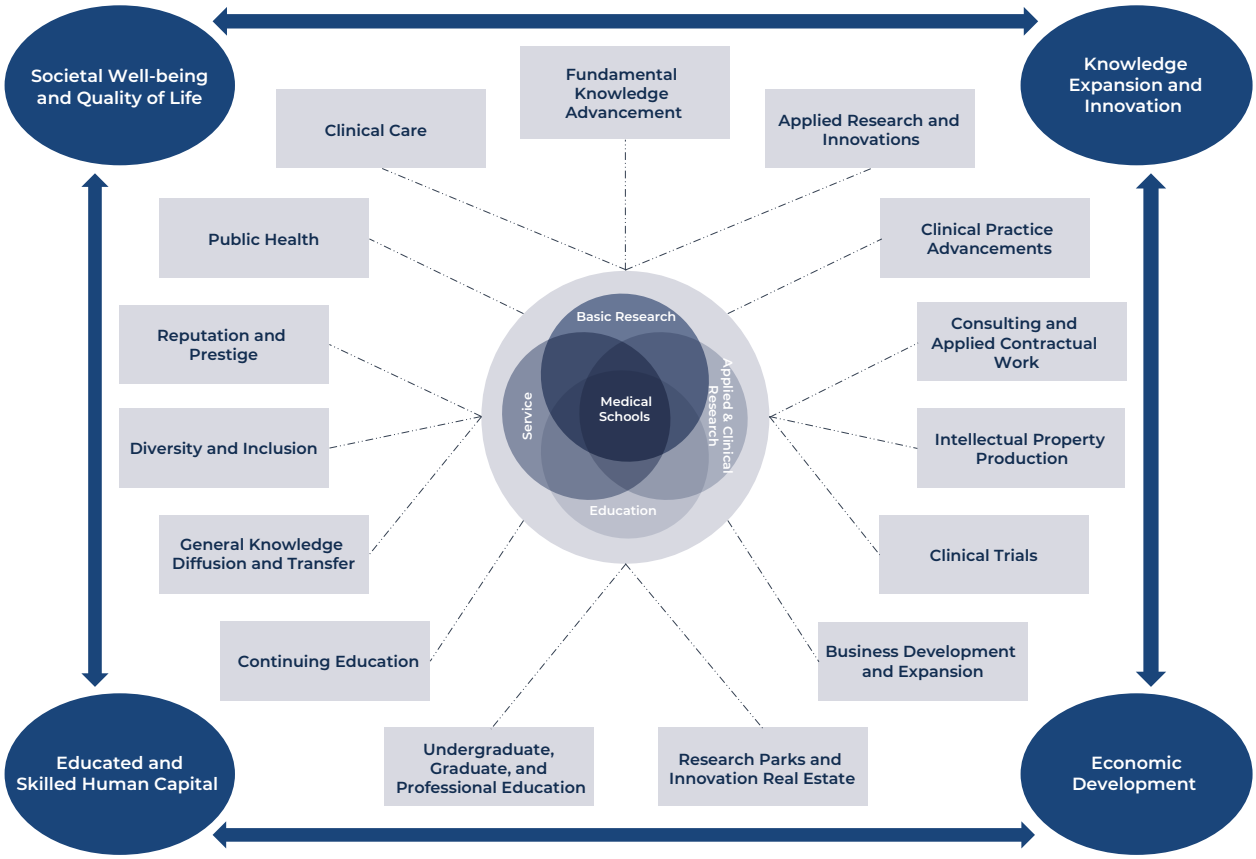
- Combined, the New York medical schools exceed $3.3 billion in annual research expenditures, growing by 48% from 2010 to 2020.
- Since 2014, the combined New York public and private medicals have outpaced overall U.S. medical school research expenditures.
- New York's medical schools received more than $5 billion in research funding from NIH over the 2018-2020 period, with more than $500 million from each of four NIH institutes: National Institute of Allergy and Infectious Diseases, National Heart, Lung, and Blood Institute, National Cancer Institute, and the National Institute on Aging.
- The research strengths and diversity of the AMSNY members is demonstrated in more than 54,000 research publications over the 2018-2020 period. Key fields with 3,500 or more publications include: Oncology, Clinical Neurology, Surgery, Neurosciences and Cardiac and Cardiovascular Systems.
- AMSNY member medical schools are (or were) principal sponsors of, or collaborators in, 1,468 clinical trials during the 2018-2020 period and provide access for New York's residents to over 3,500 clinical trials in total during this period.
- From both an employment and output perspective, AMSNY member medical research supports significant additional economic activity in New York State including an additional 17,000 jobs and $3.4 billion in output within the state's economy.
- The AMSNY member medical schools' total research expenditures also generate and support additional state/local tax revenues (adjusted for the schools' non-profit status) of $298 million, more than five times the state government funded research support in FY 2019.

The Functional, Mission-Based Impacts of New York Medical Schools

The economic impacts associated with the expenditures of medical schools as highlighted in the previous chapter are clearly substantial. These impacts are, however, ancillary to the core mission-based impacts, termed functional impacts, that are the reason for the development and operation of colleges of medicine. Functional impacts are central to the medical schools, representing the impacts generated by their core missions of higher education and research.

When all the activities undertaken by medical schools are considered, it is apparent that these important institutions generate highly diverse benefits for the economy and society. Figure 10 categorizes key functional impact areas that emanate from the core mission areas of New York's medical schools in performing research (including basic, applied, translational and clinical research), higher education, outreach and service work. Fifteen individual functional impact categories can be seen to attach to these core mission activities.

Figure 10. The Functional Impact Domains of Medical Schools



Source: TEConomy Partners, LLC.

These diverse functional impact categories lead to four core domains of benefits for the economy, for society, and for individuals:

1. **Knowledge Expansion and Innovation –** Whereby basic, applied, translational and clinical research leads to discoveries that expand human knowledge, empower biomedical and health science innovations and generate clinical practice advancements.

2. **Economic Development –** Innovation is at the heart of the American economy, with technology powering advanced industries that stimulate and expand the economy. The discoveries and innovations derived from medical school research translate into advancements in associated business sectors, stimulating the growth of new and existing health science enterprises and the diverse job opportunities they provide.

3. **Educated and Skilled Human Capital –** By providing education and professional training for physicians, nurses, allied health professionals, researchers and scientists, medical colleges play an essential role in assuring our economy and society has the human capital resources necessary to meet critical clinical, scientific, and health science industry functions across society.

4. **Societal Well-being and Quality-of-Life –** The functional activities of medical schools create a range of additional benefits for society and individuals. Clinical faculty are on the frontiers of clinical practice in their respective medical specialties (providing clear benefits for their patients). New York's medical schools are embedded in their communities, engaged in advancing social wellbeing, providing diverse job opportunities and imparting prestige to the communities hosting their operations.

Each of these activities may vary in importance or weight depending upon the perspective of the audience, and no attempt is made herein to rank impact areas. Rather, a description of each functional impact activity area is provided (starting from the top of the diagram and proceeding in a clockwise direction) and context is provided regarding the generation benefits in each area for New York. Summary examples are provided of the multi-faceted impacts being generated by the 17 medical schools.

Knowledge Expansion and Innovation

Fundamental Knowledge Advancement

Medical colleges are particularly important drivers of research that advances understanding of the fundamental processes that govern human biology and human health. Fundamental (also called "basic") research describes research that is exploratory in nature and curiosity driven, seeking to advance the boundaries of knowledge without having a specific practical application in mind. Basic research is critically important because it forms the base of scientific theories and knowledge, which will support later discoveries, often highly practical applied discoveries. For example, basic science research elucidates the biological structures (cells, viruses, proteins, neurons, DNA, etc.) and therefore, the foundation upon which practical discoveries may then be made. Pharmaceuticals and vaccines are the result of fundamental knowledge of chemistry, molecular and cellular structures, cell signaling pathways, the physical properties of tissue and fluids and a host of other prior discoveries. **Every pragmatic technology and lifesaving product in medicine is built upon the previous work of basic scientific inquiry.** As a very current example, the COVID-19 mRNA vaccines of Moderna and Pfizer may look like nearly instantaneous developments, but they were actually the products of decades of preceding basic research in areas such as genetics and human genomics. Much of that preceding research was undertaken without a direct line-of-sight to a specific vaccine application. Without that prior work, however, we would not have been able to deploy such highly effective vaccines on such a short timeline.

A key aspect of basic research is that it focuses on fundamental science without an immediate line-of-sight to any market or commercial application. As a result, industry very seldom, if ever, engages in it; rather, **it requires the public sector**, and to a lesser degree philanthropy, to fund core scientific advancements. **The critical fundamental research conducted by faculty and research scientists at New York's schools of medicine is made possible primarily through public sector support of science.** Without that support, largely (but not exclusively) channeled in the U.S. through the National Institutes of Health and the National Science Foundation and supplemented with state funding, the research ecosystem that powers discoveries and downstream applied innovations would be greatly diminished.[6] Among the many basic science discoveries made at AMSNY member medical schools, include:

- **Nonsense-mediated mRNA decay** – Lynne E. Maquat, PhD discovered nonsense-mediated mRNA decay, also called NMD, and has been central in advancing ongoing study of its properties at the University of Rochester School of Medicine and Dentistry. NMD has since been found to be central in ensuring the production of normal, healthy proteins. It is a prime example of a basic research discovery serving as a springboard to new therapeutic approaches across a broad variety of diseases.

- **Hyaluronidase characterization** – Hyaluronidases, previously a family of neglected enzymes, have been intensively studied and characterized through fundamental techniques and analysis developed by Robert Stern, MD, at the Touro College of Osteopathic Medicine. Again, this fundamental research is leading to applied discovery, with findings indicating that these enzymes have major impacts in embryology, cancer progression, stem cell biology, disease diagnostics, wound healing, tissue repair and regeneration.

- **Memories and protein kinase M zeta** – An enzyme molecule, protein kinase M zeta (PKM zeta), has been determined through research by Todd Sacktor, MD, and colleagues at SUNY Downstate to be a fundamental pathway for storing multiple forms of memory through a process of strengthening synaptic connections between neurons.

- **Synaptic pruning and autism** – David Sulzer, MD, and Guomei Tang PhD, at Columbia University College of Physicians & Surgeons discovered a relationship between synaptic pruning and autism, and that the brain cells of

6 See previous section for details about the depth and breadth of AMNSY medical schools research activities.

children with autism spectrum disorder lack a degradation pathway called autophagy. These fundamental discoveries are now being applied to identifying potential new treatments for autism.

The above examples illustrate how curiosity driven basic inquiry may lead either the original researchers, or others building upon their published research, to advance new scientific knowledge towards applications in human health – leading to the next category of impacts in "applied research and innovation."

Applied Research and Innovation

Medical colleges are home to intensive applied research – **research that is focused on finding practical solutions to health challenges and innovating technologies that improve the practice and outcomes of healthcare.** This applied research takes many forms and includes work as diverse as the discovery of new pharmaceutical molecules, design of novel medical devices, improvements in clinical practices, engineering of innovative new biocompatible materials, development of bioinformatics software algorithms, design of medical education technologies and researching approaches for improving public health (to name just a few areas of study). Applied research deals with solving practical problems and typically employs empirical methodologies.

Applied research, and associated innovations, at New York's medical schools bring very wide-ranging benefits to New York. There are many examples of applied and translational research inquiry pursued by New York's medical schools yielding pioneering research discoveries and innovations. Many of these leading-edge discoveries have had important implications for the advancement of science and the practice of human medicine (see Appendix A. for recent applied research examples).

Researchers across New York's medical schools are focused on advancing knowledge and pragmatic health and biomedical technology advancements in the major categories of disease impacting New Yorkers – including cardiovascular disease, infectious diseases, cancer, chronic respiratory diseases, diabetes, influenza/pneumonia and neurological disease.[7] Ongoing research is being applied across the human lifespan, from applied and translational research in pediatrics impacting maternal and newborn health, all the way through to studies focused on mechanisms of aging and age-related health disorders.

Significant perspective can be gained by looking at the high impact work taking place in New York across many of the most significant areas of chronic disease that impose severe burdens on society and individuals in the state. A series of disease-area specific summaries are provided that serve to provide an overview of key research areas affecting New Yorkers in which AMSNY member institutions are performing significant research:

- Heart health and cardiovascular disease
- Neurological diseases and disorders
- Cancer

7 Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999-2020 released in 2021. Data are from the Multiple Cause of Death Files, 1999-2020, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/ucd-icd10.html on Jan 19, 2022 3:12:21 PM

For many of the text boxes that follow, Appendix A provides examples of current research activities across the AMSNY member institutions. Within the digital PDF, a link is embedded in these text box titles to Appendix A where the specific examples of AMSNY member research are discussed. A link is also embedded within the Appendix A section title to return the reader to the text box in the main report.

Research Focus: Heart Health and Cardiovascular Disease

Description:

Cardiovascular disease (CVD) comprises a group of disorders that effect the heart (cardio) and blood vessels (vascular). CVD presents as a range of disorders that may impact the heart itself including, congenital heart defects, weak heart muscle (cardiomyopathy), valve defects and infection of the endocardium (endocarditis). CVD also presents in blood vessels (atherosclerotic or ischemic heart disease), effecting the supply of blood to and from the heart. The narrowing or blockage of blood vessels can lead to a heart attack, chest pain (angina) or stroke. Arteriosclerosis refers to the process of hardening and thickening of the walls of arteries that occurs through aging and the build-up of cholesterol plaque.

Challenges:

Heart and vascular disease is the leading cause of death in New York and in United States. The CDC reports that approximately 870,000 Americans died from major cardiovascular diseases in 2019, including more than 54,000 New Yorkers. At this level, CVD accounts for 35% of all New York deaths (equivalent to more than 1 in every 3 deaths) in 2019. As reported by the New York State Department of Health (NYS DOH), more than 1.2 million people (or 8% of New York's population) report that they have had a hard attack, angina/coronary heart disease or stroke. These figures increase with age with one out of five New Yorkers (20%), aged 65 and older, report having had some type of CVD.

The American Heart Association reports[8] that:

- The average annual direct and indirect cost of CVD in the United States was an estimated $363.4 billion in 2016 to 2017.
- The estimated direct costs of CVD increased from $103.5 billion in 1996 to 1997 to $216.0 billion in 2016 to 2017.
- By event type, hospital inpatient stays accounted for the highest direct cost ($96.2 billion) in 2016 to 2017.

When extrapolated for New York, based on population (5.9% of the U.S. total), the average annual direct and indirect cost of CVD in the state can be estimated to be $21.4 billion.

Recent AMSNY member NIH Funding:

AMSNY institutions received 1,310 annual research awards with total funding of more than $633 million from the National Heart, Lung, and Blood Institute (NHLBI) in the 2018-2020 period.

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8 Virani SS, et al. on behalf of the American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2021 update: a report from the American Heart Association. Circulation. 2021;143:e254–e743. doi: 10.1161/CIR.0000000000000950

Research Focus: Neurological Disorders

Description:

Neurological disorders include diseases of the brain, spinal cord and nerves. Some examples include Alzheimer's disease and other dementias, stroke, traumatic brain injury, Parkinson's disease, epilepsy and migraines.

As our population ages, the incidence and prevalence of neurological disease, especially in key areas such as dementia and stroke, is on the rise. These disorders present significant challenges for those affected, their caregivers, society and the economy. Because many neurological diseases can be progressive, with a patient affected for many years, and because disability caused by these diseases may be severe, impacts are very much seen in the high levels of daily care, supervision and assistance required in service to the patient.

Challenges:

Though many neurological disorders are seen through the lens of impacts on quality of life for both patients and care givers, they are nonetheless a significant cause of death for New Yorkers. Alzheimer's and Parkinson's combined were the cause of death for 5,345 New Yorkers in 2019. Recent data for observed years of life lost (YLLs) by disease area show Alzheimer's disease and stroke in the top 5 causes for New York YLLs (ranked 3rd and 5th respectively). Just in terms of Alzheimer's, there are 410,000 New Yorkers with the disease, and by 2025 this is expected to grow to reach 460,000.[9]

Neurological disorders are the leading cause of disability and the second leading cause of death worldwide.[10] In the U.S. stroke, migraine, and dementias (including Alzheimer's disease) are the top three leading neurological disorders in terms of DALY[11] rate impacts.[12] Estimates place the annual cost of purchased care and informal home care at between $45,806 and $61,525 per patient for a patient with Alzheimer's disease or other forms of dementia.[13] Just Alzheimer's and other dementias alone are estimated to cost over $243 billion in care annually in the U.S., and the burden of this disease group is growing.[14]

Another prevalent example of a neurological disease and its associated economic burden is Parkinson's disease. Research by Wenya Yang, et al.[15] estimated the U.S. prevalence to be approximately one million individuals with diagnosed Parkinson's disease in 2017 with an estimated a total economic burden of $51.9 billion. Based on NY's percentage of the national population this would extrapolate to a cost of circa $3.1 billion annually.

Recent AMSNY member NIH Funding:

AMSNY institutions received 1,293 annual research awards with total funding of nearly $495 million from the NIH National Institute of Neurological Disorders and Stroke (NINDS) over the 2018-2020 period.

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9 Alzheimer's Association. New York State Coalition. "New York Alzheimer's Statistics" Accessed online at: https://www.alz.org/media/Documents/newyork-alzheimers-facts-figures-2021.pdf

10 GBD 2015. Neurological Disorders Collaborator Group. "*Global, regional, and national burden of neurological disorders during 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015.*" Lancet Neurol. 2017;16:877–897.

11 DALY refers to disability-adjusted life year, a measure of overall disease burden expressed as the number of years lost due to ill-health, disability, or early death.

12 GBD 2016 Neurology Collaborators. "*Global, regional, and national burden of neurological disorders, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016.*" Lancet Neurol. 2019 May; 18(5): 459–480.

13 Clifton L. Gooch MD, Etienne Pracht PhD, Amy R. Borenstein PhD. Invited Editorial. "*The burden of neurological disease in the United States: A summary report and call to action.*" Annals of Neurology. First published 15 February 2017.

14 Ibid

15 Wenya Yang, et al. 2020. "*Current and projected future economic burden of Parkinson's disease in the U.S.*" npj Parkinson's Disease volume 6, Article number: 15 (2020)

Research Focus: Cancer

Description:

Cancer is the term used for "diseases in which abnormal cells divide without control and can invade nearby tissues. Cancer cells can also spread to other parts of the body through the blood and lymph systems."[16] Cancer is not a single disease, but rather comprises more than 100 disease types, each with their own causes, epidemiological patterns, treatments, survival rates and risk for reoccurrence.

Challenges:

Cancers of various forms are the second leading cause of death in New York, accounting for more than 33,600 deaths (or 22% of all New York deaths) in 2019. Nationally, cancer is also the second leading cause of death, accounting for 600,000 deaths in 2019. Estimates from recent studies show that each year more than 115,000 New Yorkers are diagnosed with cancer with more than 1 million living New Yorkers having been diagnosed with cancer.[17]

The World Health Organization (WHO) notes that "cancer is the second leading cause of death globally and is responsible for an estimated 9.6 million deaths in 2018… [and that] about 1 in 6 deaths is due to cancer."[18] WHO reports that worldwide the most common forms of cancer are: Lung (2.09 million cases); Breast (2.09 million); Colorectal (1.80 million); Prostate (1.28 million); Skin cancer (non-melanoma) (1.04 million) and Stomach cancer (1.03 million cases). As of 2020, the most common cancers in the United States are breast cancer, lung and bronchus cancer, prostate cancer, colon and rectum cancer and melanoma of the skin.[19]

In the U.S., the American Cancer Society (ACS) notes that at the start of 2019 there were 16.9 million Americans alive with a medical history of cancer.[20] The ACS also reports that an estimated 1,806,590 new U.S. cancer cases will occur in 2020, with an estimated 117,910 cases anticipated to occur in New York.[21]

The individual suffering caused by cancer and the challenges imposed by treatment of the disease are significant for the American's impacted and those who care for them. The economic challenge is also significant, with a total cost in 2020 for U.S. cancer care and medical treatment projected to be $174 billion.[22] Based on NY's population, it can be estimated that the proportionate cost in the state would be $10.3 billion.

Cancer present considerable medical challenges, in part because it is a collection of hundreds of different cancer disease types and also because for any given type of cancer multiple risk factors, environmental and behavioral exposures, and genetic characteristics may be at work.

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16 National Cancer Institute. "NCI Dictionary of Cancer Terms." Accessed online at: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/cancer
17 Snapshot of Cancer in New York
18 World Health Organization. 2018. "Cancer: Key Facts." Accessed online at: https://www.who.int/news-room/fact-sheets/detail/cancer
19 https://www.cancer.gov/about-cancer/understanding/statistics
20 American Cancer Society. "*Cancer Facts and Figures: 2020.*"
21 Ibid
22 National Cancer Institute. "*Cancer Prevalence and Cost of Care Projections*." Accessed online at: https://costprojections.cancer.gov/

Recent AMSNY member NIH Funding:
From 2018-2020, AMSNY institutions received 2,126 research awards with total funding of over $573.4 million from the National Cancer Institute (NCI). Additionally, AMSNY institutions received an additional 443 awards for $145.4 million from other NIH Institutes with some aspects of the project related to cancer research.

It is important to note that because medical schools are unconstrained by the profit-making commercial considerations of private industry, medical schools are free to perform critically important research in many rare diseases, complex conditions, poorly understood conditions and other areas of human health that do not sustain much, if any, research within the biomedical industry.

While individual rare diseases are, by definition, rare, they collectively impact a large global and domestic population. Liu, Zhu, Roberts, and Tong estimate that:

> *Approximately 7,000 rare diseases have been recognized, a substantial number of which are life threatening or chronically debilitating. Around 80% of rare diseases are genetic in origin. A single rare disease affects a small number of the population (defined as <1/15,000 in the US and <1/2,000 in Europe)… Most rare disease patients (50 to 75%) show onset at birth or in childhood. As many as 30% of rare diseases patients die before the age of five years. Furthermore, each rare disease patient has been estimated to cost a total of $5 million throughout their lifespan.*[23]

The Genetic and Rare Diseases Information Center reports that 25-30 million people in the U.S. have a rare disease, and over 350 million people worldwide are afflicted.[24] **Approximately 1 in 10 individuals has a rare disease, so collectively rare diseases have a significant population impact.** Work on these rare diseases is critically important, because this is an area underserved by industrial life science solutions. An example of this is autism spectrum disorder, highlighted in the following case study.

23 Liu, Zhichao, et al. "Toward Clinical Implementation of Next-Generation Sequencing-Based Genetic testing in Rare Diseases: Where Are We?" Trends in Genetics, vol. 35, no. 11, Nov. 2019.

24 National Center for Advancing Translational Sciences, Genetic and Rare Diseases Information Center. "FAQs About Rare Diseases." https://rarediseases.info.nih.gov/diseases/pages/31/faqs-about-rare-diseases. Accessed 12 May 2021

Research Focus: Autism Spectrum Disorder

Description:

Autism spectrum disorder (ASD) is a developmental disability that can cause individuals to communicate, interact, behave and learn in ways that are different from most other people. The learning, thinking and problem-solving abilities of people with ASD can range from gifted to severely challenged.

Previously, conditions such as autistic disorder, pervasive developmental disorder not otherwise specified (PDD-NOS), and Asperger syndrome were diagnosed separately. Now, these conditions are now all called autism spectrum disorder. By the age of 2, and sometimes as early as 18 months, ASD can be detected and a diagnosis by an experienced professional can be considered reliable.

Challenges:

Recent data from the Center for Disease Control (CDC) estimates that in 2017 there were more than 340,000 adults living with an ASD in New York State.[25] Additionally, more than 70,000 children (ages 3 through 17) have been diagnosed with an autism spectrum disorder in New York State.[26]

Nationally, approximately 1 in 54 children has been identified with autism spectrum disorder (ASD) according to estimates from CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network, which translates to roughly 18.5 per 1,000 8-year-olds.[27] CDC estimates that autism is more common in boys: ASD is identified in 1 in 34 boys, compared to 1 in 144 girls.

While autism affects all ethnic and socioeconomic groups, minority groups tend to be diagnosed later and less often. Early intervention is an important part of supporting healthy development and delivering benefits across a child's lifespan. On average, autism costs an estimated $60,000 a year through childhood, with the bulk of the costs in special services and lost wages related to increased demands on one or both parents.[28] These costs also increase with the occurrence of intellectual disability.

According to Autism Speaks, common challenges related to ASD include:[29]

- Difficulty communicating: an estimated 40% of people with autism are nonverbal.
- Intellectual disabilities: Approximately 31% of children with ASD have an intellectual disability (intelligence quotient [IQ] <70) with significant challenges in daily function, 25% are in the borderline range (IQ 71–85),
- Bullying: nearly two-thirds of children with autism between the ages of 6 and 15 have been bullied), and
- Harmful behaviors such as head banging, arm biting, and skin scratching: nearly 28% of 8-year-olds with ASD have self-injurious behaviors).
- Wandering or bolting from safety: nearly half of those with autism wander or bolt from safety).
- Drowning: is a leading cause of death for children with autism and is associated with roughly 90% of deaths related to children wandering or bolting.

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25 https://www.cdc.gov/ncbddd/autism/features/adults-living-with-autism-spectrum-disorder.html
26 Child & Adolescent Health Measurement Initiative, 2019-2020 survey. https://www.childhealthdata.org/browse/survey/results?q=8549&r=34
27 https://www.cdc.gov/ncbddd/autism/addm.html
28 https://www.autismspeaks.org/autism-statistics-asd
29 Ibid.

Recent AMSNY member NIH Funding:
AMSNY member institutions received 107 annual research awards with total funding of $39.8 million from the NIH for research into the causes, effects and treatments of ASD during the 2018-2020 period.

Because of the large burden of diseases and health disorders on individuals and society, New York medical schools demonstrate a significant commitment to formal work and institutional structures designed to translate biomedical and health science discoveries into tangible health care products and improved practices. The process of doing so is furthered by having access to New York's robust base of life science companies, providing an ability for medical school and industry R&D teams to collaborate on advancing innovations forward.

New York's medical schools are particularly intensive participants in the NIH funded Clinical and Translational Science Award (CTSA) program, which is focused on the translation of scientific discoveries at academic medical centers into clinical trials and new patient treatments to benefit patients. It is an important program in terms of building and sustaining medical school and industry collaborations and is supportive of biomedical and health science industry clusters across the nation. There are 62 CTSA's nationally, and New York contains seven (six AMSNY institutions), second only to California's eight (Table 10).[30]

Table 10. Clinical and Translational Science Award (CTSA) Institutions in New York State, FY 2020

CTSA Name	Engaged Institutions
Block Institute for Clinical and Translational Research	Albert Einstein College of Medicine and Montefiore Medical Center
Irving Institute for Clinical and Translational Research	Columbia University
New York University School of Medicine	New York University Grossman School of Medicine, NYU Langone Health
University at Buffalo Clinical and Translational Science Institute	State University of New York at Buffalo
University of Rochester Clinical and Translational Science Institute	University of Rochester, University of Rochester Medical Center
Weill Cornell Medicine Clinical & Translational Science Center	Weill Medical College of Cornell University
The Center for Clinical and Translational Science	The Rockefeller University (Affiliated with, but not an AMSNY member)

Source: NIH CTSA Program Hub

30 https://clic-ctsa.org/ctsa-program-hub-directory%3Ffield_hub_fiscal_year_value%3D2020%26title%3D?field_hub_fiscal_year_value_1=2&title=&field_city_administrative_area=NY

In 2017, the University of Rochester (one of the 12 original CTSAs awardees) and its Clinical and Translational Science Institute and Center for Leading Innovation and Collaboration received a $19 million award from the National Institutes of Health's National Center for Advancing Translational Sciences (NCATS) to coordinate and assist in the further collaboration among the 62 CTSA's across the country.

Through the individual work of researchers at the medical schools, and the formal institutional structures of the CTSA's, the important goal of moving discoveries into pragmatic use to improve New Yorker's health is being advanced.

Clinical Practice Advancements

The practice of clinical medicine is constantly evolving, as new discoveries, innovations and lessons-learned lead to improved methods and technologies applied to the care of patients. Improving clinical practice processes, procedures, and advancing standards of care is part of the research activity undertaken at schools of medicine. Several examples of NY medical school leadership in this regard include:

- The assessment technique for motoric cognitive risk syndrome (developed at Albert Einstein College of Medicine)
- The innovation of the Apgar Score, a technique used to assess the health of newborns (developed at Columbia University Vagelos College of Physicians and Surgeons)

Such advancements serve to improve patient care and clinical outcomes and typically refine the practice of medicine to be more effective and efficient.

It is also the case that research is opening up completely new areas of clinical practice, such as regenerative medicine, and serving to revolutionize the delivery of medicine that is personalized to the specific genotype and phenotype of individuals. In reality, there is a continuum of research; the strict categorization of research into basic, applied, translational and clinical may not adequately reflect the profound changes that will likely result from the convergence of research types and individual fields of study. There is significant promise for both evolutionary and revolutionary change occurring in clinical practice through the advancement of certain fields of research, and New York is on the front lines in advancing these as the examples of work in personalized medicine and regenerative medicine – as highlighted in the following case studies.

Clinical Practice Advancement: Precision Medicine

Description:

Precision medicine is an emerging approach to treating and preventing disease that considers individual variability in genes, environment and lifestyle for each person.[31] In contrast to a one-size-fits-all approach that seeks to treat the average person, precision medicine allows doctors and researchers to predict more accurately which treatment and prevention strategies for a particular disease will work in which groups of people.

Challenges:

While precision medicine has made many strides in recent years, the field remains a nascent growth opportunity with considerable challenges and unknowns.[32] From a technical standpoint, one significant challenge is that collecting and standardizing data from hospitals and clinics remains complicated, and there is a need to effectively design databases that can efficiently store the generated and required large amount of data. Maintaining this data is also expensive, and although the cost of gene sequencing has decreased dramatically, financial limitations remain a challenge in the proliferation of precision medicine more broadly. Lastly, there are also social, ethical, and legal concerns related to an individual's data and their right to privacy and confidentiality with their health information.

Recent AMSNY member NIH Funding:

For the three-year period, 2018-2020, AMSNY member institutions received 421 annual research awards with total funding of $227.3 million from the NIH for research into the tools for and use of precision medicine.

Clinical Practice Advancement: Regenerative Medicine and Stem Cells

Description:

Regenerative medicine refers to medical treatments and research that helps restore/improve the function of organs or tissues that are damaged by disease, aging or trauma.[33] Because stem cells offer a potential source of renewable replacement cells to treat diseases, conditions, and disabilities, they are of frequent use in regenerative medicine and therapies and of great interest to researchers.

One promising use of stem cells to treat disease is cell therapy, which is the replacement of diseased cells with healthy cells. Researchers are investigating the use of adult, fetal and embryonic stem cells as a resource for various, specialized cell types (e.g., nerve cells, muscle cells, blood cells and skin cells) that can be used to treat various diseases.

Conditions that are potential candidate for stem cell therapies involve tissue degeneration, including Parkinson's disease, spinal cord injury, stroke, burns, heart disease, Type 1 diabetes, osteoarthritis, rheumatoid arthritis, muscular dystrophy and liver diseases. Other uses of stem cells include retinal regeneration, with stem cells isolated from the eyes helping lead to possible cures and treatments for weakened, damaged or diseased eyes. Bone marrow transplantation, which involves the transfer of blood stem cells, is a well-established treatment for blood cancers and other blood disorders.

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31 https://medlineplus.gov/genetics/understanding/precisionmedicine/definition/
32 https://medlineplus.gov/genetics/understanding/precisionmedicine/challenges/
33 https://www.unmc.edu/stemcells/educational-resources/faqs.html

Challenges:

Twenty years ago, a medical research revolution was born when scientists discovered how to harvest stem cells. Since then, researchers across New York have made huge advances in finding treatments and cures. Stem cells' ability to self-renew and their capacity for differentiation offers considerable potential for the generation of tissues with minimal risk of rejection and side effects. Despite this great promise, this field of research is also associated with challenges.

First, there are challenges in the use of embryonic stem cells are how to reduce contamination, and how to prevent cancer risk. Another primary challenge for researchers is the need to understand the mechanisms by which stem cells function in the injured microenvironment using animal models, and then to translate the results of these studies to humans.[34] From here, other challenges include how to identify and isolate stem cells from tissue, and then induce their differentiation into the desired cell types. Researchers must also learn how to control and regulate the process to successfully trigger differentiation into the desired cell type after the stem cells have been isolated.

Immunological rejection is a major barrier to successful stem cell transplantation, as a person's immune system may occasionally recognize transplanted cells as foreign bodies, which can trigger an immune reaction that results in the rejection of the transplanted cells.[35] For this reason, recipients of stem cell transplants typically take strong immunosuppressive drugs to reduce the chances of rejection.

Ultimately, stem cell research contributes to a fundamental understanding of how organisms develop and grow over the course of a lifetime, fundamental knowledge that is needed to gain a better understanding of the diseases and injuries that impact the human condition. And are maintained throughout adult life. This is knowledge that is required to work out what goes wrong during disease and injury and ultimately how these conditions might be treated. As a range of human tissue-specific and embryonic stem cell lines are developed, researchers will have new tools and approaches to modeling disease, testing drugs and developing more effective therapies.

Recent AMSNY member NIH Funding:

AMSNY member institutions received 1,033 annual research awards with total funding of $371.1 million from the NIH for research that examined the potential of regenerative medicine and stem cells for treatments over the 2018-2020 period.

Researchers at AMSNY institutions were also frequent recipients of funds from NYSTEM (New York Stem Cell Science). However, no awards were made in 2019 and since then the program has been first on hiatus and now officially cancelled with the FY2022 budget.

34 Ibid.
35 Ibid.

Economic Development

Consulting and Applied Contractual Work

Medical school faculty and scientists may choose to make their specialized expertise available to external organizations, providing consulting or performing applied contractual work for government and private-sector organizations who need to utilize the faculty or researchers' specialized knowledge in a given area. There are more than 3,700 medical school faculty and nearly 15,000 research scientists and other research professionals in the 17-medical school ecosystem in New York State, providing an extraordinarily deep resource of specialized knowledge covering clinical and scientific disciplines.

The base of faculty, research personnel and clinical personnel at AMSNY member medical schools provides a resource that industry may access and represents a source of knowledge transfer between the medical schools and New York's industry. By having this resource in the state, industry, and other stakeholders in human health and medicine, are able to access specialized knowledge and services that they may need only periodically or which they cannot afford to employ on their own (especially in the case of smaller entrepreneurial ventures).

Intellectual Property Production

Applied research at New York State's medical schools can result in the development of innovations, technologies, creative works or other "works of the mind" that not only advance health science but may also have tangible market value. Intellectual property (IP) law grants the medical colleges/inventors exclusive rights to the use of their invention for a multi-year period. Faculty at New York medical schools will file "invention disclosures" with their institution when they produce innovations with potential commercial value. The larger institutions have significant technology transfer and licensing offices which professionally evaluate each disclosure for potential commercial value and decide whether to pursue the process of filing for patent or other formal IP protection.

IP generation benefits institutions and the research teams by providing the potential for financial returns via licensing innovations to commercial enterprises. IP production in academia also provides industry with access to novel innovations that may improve their current products or processes or form the basis for further investigation and value-adding clinical development activities.

Data provided by 10 AMSNY member medical schools (Table 11) point to IP generation being significant within the state's medical school ecosystem.

Table 11. Intellectual Property Generation Across a Sample of AMSNY member Medical Schools (n=10)

Intellectual Property Metric	FY 2018-2019 Totals	Total, Last Five FY Combined
Number of Disclosures	1,094	4,989
Number of Patent Applications	902	4,346
Number of Issued Patents	420	2,119
Number of Licenses	282	1,281
Total Licensing Income	$119,537,029	$1,461,002,506

Source: AMSNY Member Data Set

Since the above data are from a subset of 10 of the 17 AMSNY member medical schools, they certainly underestimate the total impacts being generated across the IP domain. While incomplete, the picture formed is clearly that of a significant volume of patentable innovations (>2,100 issued patents in the past 5 years) being generated by medical schools in New York State. Further, with more than 1,200 licenses executed over the past five years, it is clear that industry finds significant commercial promise and value in these medical school innovations – working to advance the discoveries forward towards the market and their application to benefit patients.

Clinical Studies and Trials

As Figure 10 illustrates, the research activities of AMSNY member medical schools produce many practical discoveries and innovations that show promise for clinical application. These may be drugs, vaccines, diagnostics, medical devices or other patient-impacting technologies. Each of these will need to be evaluated through clinical studies and clinical trials for efficacy and safety, with trials data evaluated by the U.S. Food and Drug Administration (FDA), before they can move to practical application in the market treating patients.[36] Medical schools, with their skilled research personnel, high-quality infrastructure and associated university hospitals and health systems, provide well-organized testing grounds for clinical products.

Early-stage animal models are typically used to produce efficacy and safety data prior to moving the trial into human subjects for further testing. Patient access provided by hospitals, health systems and affiliated clinical practices help to facilitate trials management and subject recruitment. In addition to conducting trials on innovations made by medical school faculty or personnel, the institutions may also participate in industry trials. The benefits of conducting clinical trials are many: providing revenue from industry trials, providing a pathway to advancing medical school IP towards commercialization and, importantly, **giving New York's patients with challenging health conditions access to new leading-edge treatments, therapies, and medical devices.**

Business Development and Expansion

As noted above, innovations derived through medical school research may be suited to commercialization by private industry. Medical school IP for new inventions may be licensed or sold to a company to pursue commercialization. Those companies may be existing enterprises or new start-up ventures specifically formed to advance the innovation to market. Because New York has a large base of life science companies, there are many opportunities for the innovations of New York's medical schools to be licensed for commercialization in-state.

Data provided by 10 of the AMSNY member medical schools regarding new business start-ups focused on their innovations provides a base measure of activity (and certainly underestimates total such activity across all 17 medical schools). The data (Table 12) indicate that at least 42 start-up businesses were generated by the medical schools in FY2018-19 alone, and that over a five-year period more than 200 such new businesses were generated. Also notable is the activity of entrepreneurial medical school faculty in applying for and receiving federal SBIR/STTR grants which focus on advancing innovations and technologies with strong commercial potential, with approximately 100 such grants awarded over a five-year period.

36 Note: Data on clinical trials activity across New York's medical schools are covered in detail in the previous chapter.

Table 12. Intellectual Property Generation Across a Sample of NY Medical Schools (n=10)

Intellectual Property Metric	FY 2018-2019 Totals	Total, Last Five FY Combined
Number of New Start-ups Based on Medical School Innovations	42	205
Number of SBIR/STTR grants connected to existing faculty	36	99

Source: AMSNY Member Data Set

Further information and examples of New York State's medical school activities in progressing important innovations, technologies and discoveries towards commercialization by existing or new business ventures is provided in the following case study.

Business Development: Commercialization & Life Science Entrepreneurship

Description:

While academic and medical research is critical to the development of life-saving treatments and cures, bringing these new developments to market is far from an easy task. Commercialization refers to the process of introducing a new products, services or therapies to market, typically those stemming from commercializing novel therapies associated with research discoveries generated at universities, nonprofit research institutes and federal laboratories. New York State is among the nation's leaders in academic research and development in the biosciences, as well as for commercializing this research:[37]

- In 2019, biomedical-related academic R&D expenditures in New York State exceeded $4.5 billion, ranking the second highest in the nation after California and over $1.0 billion more than third-place Texas.
- New York State also ranks third among states in NIH funding ($2.9 billion) and tied for eighth in NIH funding per capita.
- New York State is a leader in bioscience patenting, with more than 7,592 patents disclosed between 2016-2019, trailing only California (32,299) and Massachusetts (13,003).
- New York State ranks third in total bioscience venture capital investments ($6.9B from 2016-2019), and fourth in VC investments per capita ($353 per New Yorker). The state is a leader in venture capital investment across multiple segments/verticals, including biotechnology, drug discovery and delivery, healthcare technology systems, laboratory services, medical supplies and monitoring equipment.

Challenges:

There are many challenges to converting research and development into new products and services. These barriers are especially burdensome in the health and life sciences. Examples of challenges facing New York State in life-sciences commercialization and entrepreneurship include:

- The need for experienced management talent and hands-on mentorship, especially those with management experience in the health and life sciences. This talent is necessary to guide a new company in validating its market opportunity, building a management team, developing an effective investor pitch and scaling up a new business venture.
- The need for financial capital at each stage of the business' development (e.g., early-stage, proof-of-concept and prototype development to Series A and B venture financing).
- Access to new customers and markets as they seek to grow. Proactive university communities may seek ways to network early-stage companies with first customers and early adopters.

37 https://www.bio.org/sites/default/files/2020-06/BIO2020-report.pdf

Examples of AMSNY Members in Action:

- Faculty at **Albany Medical College** are launching a clinical study on precision neuromodulation therapy with **Micro-Leads Medical, Inc.**, a clinical neurostimulation startup developing a high-resolution spinal cord stimulation therapy for treating chronic focal pain without opioids. Backed with a $10 million award for therapy development funding, Micro-Leads will partner with Albany Medical College neuroscientists to further develop its HD64TM implantable therapy system and launch a clinical study in patients.
- Recently, **HiberCell**, a biotechnology company based upon the pioneering tumor dormancy research conducted by the Julio Aguirre-Ghiso Lab at The Tisch Cancer Institute, part of the **Icahn School of Medicine at Mount Sinai**, launched with nearly $61 million in venture funding.
- Faculty at the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are developing the promising cancer drug spinoff **For-Robin**.[38] For-Robin is an antibody immunotherapy company that uses a proprietary technology (monoclonal antibody, JAA-F11 and humanized variants, hJAA-F11) to target all breast and lung cancer cell subtypes including triple negative breast cancer where no targeted therapy currently exists.
- **Quadrant Biosciences Inc.** is developing novel molecular diagnostic solutions and has released the first-ever epigenetic test for autism spectrum disorder (ASD). This test, the Clarifi ASD, was developed in cooperation with **SUNY Update Medical University** and is designed to aid the diagnosis of autism in children 18 months through six years of age.
- Decades of research by Dr. Steven Goldman, MD, PhD at the **University of Rochester School of Medicine and Dentistry**, led to the formation of **Oscine Therapeutics**, a biotechnology company developing cell-based therapies for neurological disorders. In 2019, Oscine Therapeutics received a significant multi-year investment to support the research and development activities. The funding represents the largest-ever investment in a URMC start-up company. The company's experimental transplant therapy for multiple sclerosis and other glial diseases is currently under early FDA review for clinical trials.

38 http://www.buffalo.edu/news/releases/2018/05/004.html

Incubators, Research Parks and Innovation Real Estate

Because they are large-scale performers of practical research, and because there are often important relationships with industry and entrepreneurial ventures, medical schools and their affiliated universities often facilitate medical school-industry partnerships through the development of research parks and other innovation and commercialization-focused real estate developments. A new model for such developments is called an "Innovation District" whereby research institutions and companies co-locate in mixed-use live/work/play environments that are increasingly attractive to the skilled talent that companies and institutions have to attract in a competitive labor market. Research parks and innovation districts are frequently anchored by medical schools and their associated operations – examples around the nation include Mission Bay in San Francisco (anchored by UCSF's medical school), Innovation Quarter in Winston-Salem anchored by Wake Forest's School of Medicine and the Cortex Innovation Community in St. Louis, which has been developed with substantial engagement of the Washington University (St. Louis) School of Medicine. These are just a few national examples of the phenomenon, and there are multiple examples of this specific to New York State:

- At **Albany Medical College**, The Biomedical Acceleration and Commercialization Center (BACC) is providing direct financial assistance to BACC biomedical start-up companies for commercialization needs and access to experts, in part due to economic development grant funding from National Grid.
- **Columbia University Vagelos College of Physicians and Surgeons** has a significant track record in this space having created the Audubon Business and Technology Research Center in the 1990's. Audubon is a six-story facility housing 50,000 square feet of laboratory and office space.
- The **Icahn School of Medicine at Mount Sinai** and Mount Sinai Innovation Partners are leveraging the i3 Asset Accelerator, a new fund that fast-tracks select research discoveries to reach patients sooner and help advance the development of life-saving discoveries.
- The new Buffalo Niagara Medical Campus (BNMC) of the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** is advancing as an innovation district, focusing on mixed-use development and integration with the surrounding community. BNMC is also operating an Innovation Center and a business incubator within the Center of Excellence in Bioinformatics and Life Sciences.
- **New York Medical College's** campus in Valhalla is developing as a mixed-use research site, and the BioInc@NYMC program has formalized biotech business incubator operations with specialized lab facilities and core equipment access. BioInc@NYMC has recently expanded with an additional 9,500 square feet of new offices, conference rooms, shared-space desks and collaborative space. The expansion allows for the incubation of up to 20 additional companies at the forefront of medical innovation.
- SUNY Stony Brook, parent university of the **Renaissance School of Medicine at Stony Brook University** operates the Long Island High Tech Incubator (LIHTI), a full-scale wet-lab incubator. LIHTI is home to a broad range of life science companies, including multiple therapeutics companies.
- **SUNY Downstate Medical University** is developing "Biotech Park" within its medical school location, with two significant developments in terms of the "Tech @ 710" building, providing access to specialized chemistry space and offices, and the Biotechnology Incubator at 760 Parkside Avenue, Brooklyn.
- Researchers at the **Norton College of Medicine at SUNY Upstate Medical University** are active with startup companies, leveraging the resources of the Central New York (CNY) Biotech Accelerator in Syracuse.

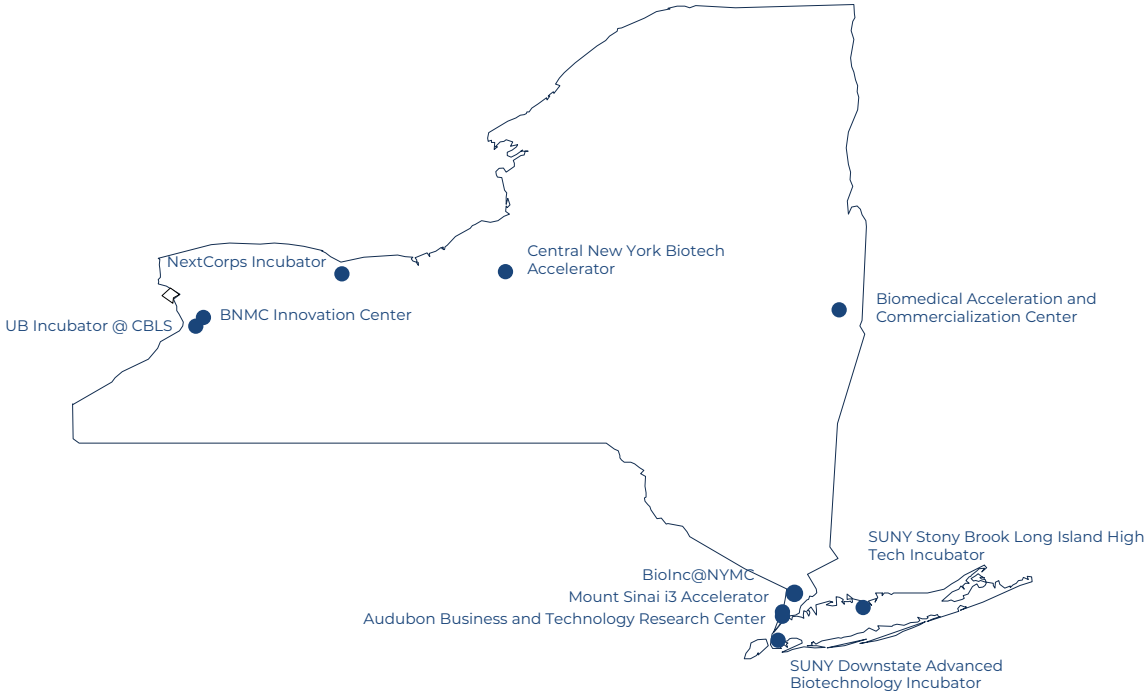
The collective medical schools in New York City have also been a key attractor for the development of the commercial Alexandria Center for Life Science. As Alexandria Real Estate Equities notes:

> *The Alexandria Center is home to a diverse range of high-quality life science entities, including multinational pharmaceutical companies and a number of growth- and early-stage companies. Fostering innovative collaborations among New York's renowned academic and medical institutions, preeminent scientific talent, top-tier investment capital, and a broad and diverse commercial*

life science industry, the Alexandria Center enables the region to capitalize on its talent and speeds the translation of promising new life science discoveries from bench to bedside.[39]

What has emerged is a statewide network of bioscience, biomedical and biotechnology business incubators and innovation centers that exhibit a robust contribution by, and engagement with, New York State's medical schools. Figure 11 shows New York State's current biomedical incubators and accelerators.

Figure 11. Biomedical Incubators and Accelerators Affiliated with AMSNY Medical Schools



39 http://www.alexandrianyc.com/ersp.html

Educated and Skilled Human Capital

Undergraduate, Graduate and Professional Education

Biomedical science and health care are human endeavors, made possible by a well-educated and highly skilled population able to provide clinical care, perform research and advance innovative life science industries. The education and training of high-performance talent for health care, health sciences and biomedical research lies at the very core of every medical school's mission. As "school" implies each of the 17 institutions covered in this report is an education provider – institutions of higher education with a purposeful mission of providing for-credit educating and training of:

- Physicians
- Nurses
- Allied health professionals
- Biomedical and life science researchers

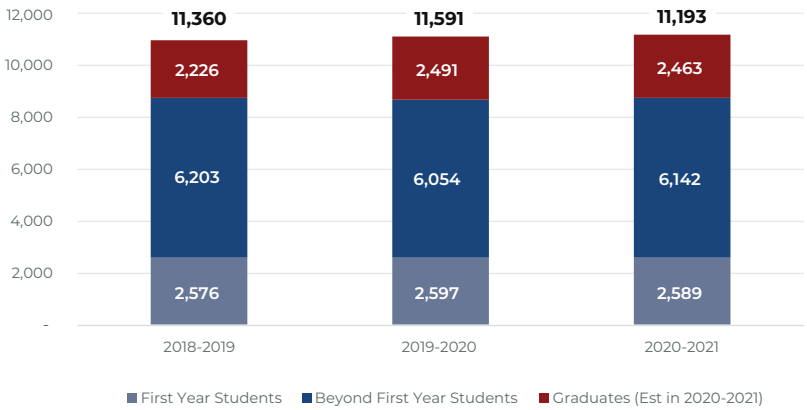
Education across the medical schools covers engagement in undergraduate education in various health and health-related disciplines, together with education for graduate degrees (e.g., Masters and PhD) and professional practice degrees (e.g., MD, DO). Additionally, the medical schools are centers for post-graduate degrees and postdoctoral fellows in multiple specialized fields.

These are also institutions of continuing education, working to ensure that New York's many thousands of health care professionals are kept current in their training and up to date on latest science, technology and practice advancements.

Education of undergraduate, Master's, PhD, medical and professional degree students provides a constant annual flow of talent available to employers. Higher education brings both private returns to the student (in terms of skills, capabilities, and enhanced job and income prospects) and social returns in areas such as enhanced labor productivity, increased innovation capability and reduced social costs generally found to be associated with higher education (such as reduced levels of crime and improved health). In a knowledge-based economy, it is clear that human capital becomes the most valuable form of capital – and medical schools are important contributors to production of this crucial capital asset.

To this end, the 17 AMSNY member medical schools accounted for more than 11,000 medical students in each of the last three years (Figure 12). These levels of enrollments have increased as both the NYU Long Island medical school began accepting students (starting in the 2019-2020 school year) as well as a general trend (the COVID-19 impacted 2020-2021 school year not withstanding) to increasing enrollments.

Figure 12. Total Enrollment (including Graduates) at New York's Medical Schools, 2018-2021



Source: AMSNY and TEConomy estimate of 2020-2021 graduate figure.

The size of these medical school enrollments is also reflected in the number of recent graduates, with New York's medical schools graduating nearly 2,600 physicians in each of the past three years. Within these enrollments and graduates, there is an increasing emphasis on the development of primary care physicians while limiting the amount of debt medical students accrue. This emphasis has led to unique programmatic activities among AMSNY members.

Educational Focus: Expanding the Physician Workforce

Description:

According to data published by the AAMC (Association of American Medical Colleges), the United States could see an estimated shortage of between 37,800 and 124,000 physicians by 2034, including shortfalls in both primary and specialty care. Within primary care ((e.g., family medicine, general pediatrics, geriatric medicine) the study estimates the U.S. will see a shortage of between 17,800 and 48,000 primary care physicians over the next decade.

Challenges:

Similarly, the Healthcare Association of New York has specified these needs within New York State in the report, "Where Are the Doctors?" According to the report's survey results, 84% of the responding hospitals, medical centers and health systems reported that recruitment of primary care physicians is a key strategy for improving access to care with 77% responding that their current primary care capacity is insufficient to meet current patient needs. This report further documents the key reasons for the primary care shortage includes:

- an aging primary care workforce
- medical school debt
- fewer residents choosing primary care (lower salary)
- lack of interest in practicing in underserved areas of the state

Examples of AMSNY Members in Action:

All AMSNY institutions are working to improve the ability of students to enter and excel in the physician workforce. Various mechanisms include increasing support for medical school tuition and expenses, assistance with housing, and other support mechanisms. Recently two AMSNY members are meeting these needs in inventive educational pathways:

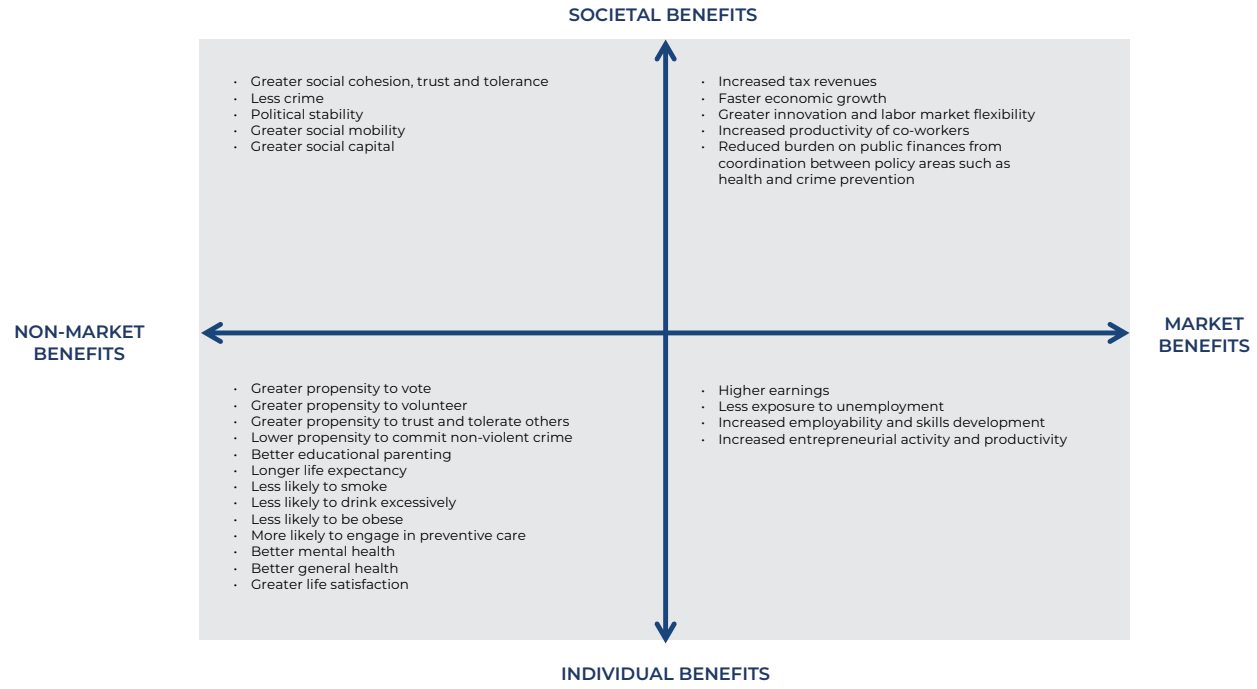
- **CUNY School of Medicine (CSOM)** at City College of New York in New York City is a new seven-year BS/MD program that received its preliminary accreditation from the LCME in 2015 but has been built on the 46-year tradition and success of the Sophie Davis School of Biomedical Education. CSOM enrolls students directly from high school and integrates the college and medical school courses over the 7-year program with a seamless transition in which all students in good academic and professional standing receive their BS after 3 years and continue in the medical school program. CSOM graduated it first class of physicians in Spring 2020.
- **NYU Long Island School of Medicine** is devoted to educating primary care physicians of the highest quality capable of delivering the very best care to patients and who are prepared to become leaders of both our community's and nation's healthcare system. Through innovation designed to meet the needs of the 21st century, this school provides students a scientifically rigorous learning environment in a diverse and inclusive fashion that is comprehensive and compassionate founded on the principles of translational science, population health, outstanding clinical science and application of health systems science. Health Systems Science was adopted as a key pillar of the curriculum alongside the basic and clinical sciences. The

Health Systems Science curriculum focuses on how health care is delivered, how healthcare providers work together and strategies to deliver safer, higher-quality patient care. NYU Long Island School of Medicine welcomed their inaugural class in Fall 2019.

In addition to enrollment in degree programs, the medical schools are also major providers of Graduate Medical Education and managed/affiliated Residency and Fellowship programs. Information provided by the medical schools indicates a combined 12,183 physicians enrolled across GME, including both residencies and fellowships.

As noted above, there are wide-ranging benefits that accrue to populations with increasing levels of higher education. A useful overview of these benefits is provided in a paper by the Department for Business Innovation and Skills (BIS) in the UK which examined the private/social and market/non-market returns of higher education.[40] The BIS authors note that "the report covers only benefits from higher education participation, so that benefits arising from research exploitation, spin-off companies, export earnings through international student fees and spending and other aspects of higher education are not included." The report provides a useful "two-way taxonomy of benefits, with individual/society as one dimension and market/non-market (or wider) benefits as the other"[41] which is recreated on Figure 13.

Figure 13. Categorization of Positive Impact Benefits Associated with Higher Education



Source: Department for Business Innovation and Skills (BIS), 2013.

40 Department for Business Innovation and Skills. 2013. "The Benefits of Higher Education Participation for Individuals and Society: key findings and reports." October 2013, BIS Research Paper No. 146.
41 Ibid

Continuing Education

Progress and advancements in healthcare practice, technologies, medicines and medical devices is continuous and thus requires that physicians, nurses and other health professionals participate in continuing education to keep up with these advancements. The ability of modern medicine and medical technologies to improve human health can only occur if our professional healthcare providers have the necessary knowledge of these advancements to prescribe them or use them in their practice. Because of the societal benefits associated with maintaining currency in medical knowledge, regulatory bodies mandate that medical professionals participate in formal accredited continuing education programs.

New York's medical schools are at the forefront in providing this continuing medical education (CME) in the state. AMSNY member institutions, in aggregate, reported that over 378,000 individuals participated in their continuing medical education activities for FY2019-20 (equivalent to an average of over 22,000 educational participants in CME per medical school).

General Knowledge Diffusion and Transfer

As respected, independent institutions, New York's medical schools frequently serve as subject matter experts for government, media, industry and the general public.

Among the hard-won lessons from the ongoing COVID-19 pandemic is the importance of evidence based, data driven information on critical health issues and during public health emergencies. It is evident that misinformation, and even deliberate disinformation, has had adverse impacts on public health and the ability of New Yorkers to make informed decisions regarding their personal health and our collective responsibilities in supporting the health of others. New York's medical schools have been a key contributor in providing rational, evidence based information to help inform all levels of society. This has held true across other health crises; for example, faculty from the medical schools are frequent contributors to informing the public about HIV/AIDS through both formal public health channels and via media and other resources.

More broadly, medical schools facilitate knowledge transfer through a variety of formal and informal channels. Faculty, research scientists and their graduate students publish and present academic findings to other researchers, governments, businesses, the press and the general population. Medical schools also offer a range of presentations, lectures and non-credit courses that focus on both academic and personal development topics. The general public, in addition to having access to some of the aforementioned resources, also benefit from outreach programs.

Diversity and Inclusion

One defining feature of medical schools is that they are often located in urban settings. These institutions, and their affiliated universities, hospitals and health systems also provide job opportunities across an extremely diverse range of employment types – ranging from entry level positions through to the highest levels of professional employment. Numerous employment opportunities in combination with a typically urban setting means that these institutions play an important role in jobs that are inclusive and available to residents from diverse backgrounds and across a range of educational attainment.

New York's medical schools are demonstrating high levels of commitment to increasing diversity and inclusion across medical and health science education. Jobs in healthcare and science offer above average salaries, robust benefits and are a pathway for upward social mobility for people from all backgrounds. This does not mean, however, that there has always been equitable access to these educational opportunities, nor that further attention is not needed to engender greater change and opportunity, but there is apparent (as demonstrated in the case study table below) across-the-board commitment by AMSNY member medical schools to enhance opportunities among minority and disadvantaged populations.

Educational Focus: Minorities, Diversity and Inclusion

Description:

As the U.S. population grows increasingly diverse, so do its patient populations. However, the lack of diversity and inclusion in the healthcare sector has significant repercussions. Through their educational function, medical schools can play an important role in supporting programs for diversity in medical education, especially as more students from underrepresented, educationally, and economically disadvantaged backgrounds seek careers in medicine. Through their research function, medical colleges and universities can drive inclusion in the sector by seeking to increase diversity and representation across clinical trials and by addressing disparities in health, treatment, and care delivery.

Challenges:

The increasing racial and ethnic diversity of the U.S. patient population makes increasing the diversity of the medicinal community an imperative. Mounting evidence demonstrates that when physicians and patients share the same race or ethnicity, this improves time spent together, medication adherence, shared decision-making, wait times for treatment, cholesterol screening, patient understanding of cancer risk and patient perceptions of treatment decisions.[42]

One significant challenge related to a lack of diversity and inclusion in the medical profession is that many communities of color are underrepresented in clinical trials, a critical component of the long and complex drug development process. Recent research shows that many communities of color are frequently underrepresented in clinical trial development, including one recent study of oncology treatments that found Black Americans represented fewer than 5% of clinical trial participants, which is less than half of their share of the national population (13%).[43] Racial disparities in clinical trial participation can exacerbate broader health inequities.

An additional challenge relates to disparities in health, treatment, and care delivery among racial and ethnic minorities. Increasing diversity and inclusion in the medical community can help bridge gaps between these workers and the patient populations they serve.

Examples of AMSNY Members in Action:

New York State's medical schools, in conjunction with AMSNY, have developed several "pipeline" programs with the aim of increasing diversity in medicine:

- **AMSNY and its member medical schools** sponsor several diversity in medicine programs for students in high school through post baccalaureate studies.[44] These programs are for students who are underrepresented in medicine, educationally or economically disadvantaged and have not received acceptance to any medical schools. These programs have helped AMSNY medical schools increase the share of underrepresented first-year students by 2% each year over the past three years, reaching 21% in the 2020-2021 school year.
- The **Touro College of Osteopathic Medicine** is receiving national acclaim for its commitment to diversity and inclusion, especially by matriculating underrepresented minorities. Data from the American Association of Colleges of Osteopathic Medicine (AACOM) shows that underrepresented minorities made up 28% of the entering class at its flagship Harlem campus, and nearly 23% of the entering classes at its Harlem and

42 https://labblog.uofmhealth.org/rounds/minority-patients-benefit-from-having-minority-doctors-but-thats-a-hard-match-to-make-0
43 https://www.propublica.org/article/black-patients-miss-out-on-promising-cancer-drugs
44 https://amsny.org/initiatives/diversity-in-medicine/diversity-programs/

Middletown locations – these rates are significantly higher than those at the nation's 40 osteopathic schools that semester (9.6%). Additionally, about half of TouroCOM's graduates who have gone on to residency have ended up in the much-needed primary care specialties. As of 2019, close to one-third took up residencies in underserved communities or primary care shortage areas.

AMSNY member institutions are also using their strengths in research and development to help address disparities in clinical trials, health, and treatment:

- Faculty at the **Albert Einstein College of Medicine** and Montefiore are improving cancer care for minority and underserved communities by increasing access to clinical trials. Backed with a $5.9 million grant from the National Cancer Institute (NCI) to build on its success recruiting minority and underserved patients into cancer clinical trials and delivering the highest quality cancer care. This new grant, part of the NCI Community Oncology Research Program, is a continuation of funding first awarded in 2014.
- Faculty at **CUNY School of Medicine** are supporting diversity in neuroscience research and education. Supported by $2.5 million from the NIH's National Institute of Neurological Disorders, the school has is establishing the Mentoring Institute for Neuroscience Diversity Scholars through an R25 mechanism.
- Students at **New York Medical College** are studying how two concepts known to play a role in the delivery of healthcare – implicit bias and social determinants of health – are factoring into the disproportionate morbidity and mortality of Black and Latino populations during the COVID-19 pandemic.
- Researchers at **NYU Grossman School of Medicine** developed a faith-based intervention that was successful in managing hypertension in Black communities. A lifestyle intervention delivered in churches by community-based health workers led to a significant reduction in blood pressure among African Americans compared to health education alone, according to a study published in the journal *Circulation: Cardiovascular Quality and Outcomes*.
- Researchers with the **New York University Grossman School of Medicine** and the **Touro College of Osteopathic Medicine** are developing interventions at barbershops to screen for diabetes, which affects black men at disproportionately high rates. Their study, published in a Journal of the American Medical Association (JAMA), found that the prevalence of undiagnosed diabetes among clients who agreed to get screened appeared to be nearly three times the rate in New York City overall. This suggests that barbershops can be an effective venue for screening diabetes and an important tool to help black men improve their health.
- At **Weill Cornell Medicine**, researchers are exploring how stroke and heart failure risk rises with social factors like race, educational level and neighborhood poverty. Their analysis finds that social the risks of stroke and heart failure in an individual increase as the number of social determinants of health increase, according to two new studies by Weill Cornell Medicine investigators. The social factors that affect health include race, education level, annual household income and neighborhood poverty.

Reputation and Prestige

Higher education institutions generally, and colleges of medicine specifically, have historically been viewed as prestigious organizations. Excellence in research bolsters the prestige of these institutions and increases the reputation of the communities and host states of these institutions. Additionally, decades of social science research demonstrate that university professors and physicians enjoy high occupational prestige.

The prestige of medical schools serves as a major attractor for "star" research talent into a state or region and all the innovative capacity, research grants and teams associated with those individuals. In addition, top researchers may often have an outsized impact in terms of their innovations serving to jumpstart new companies. An often-cited study by Zucker, Darby and Brewer has demonstrated the connection associated between top scientists and the founding of biotechnology firms over more than a decade.[45] The study found that "at least for this high-tech industry, the growth and location of intellectual human capital was the principal determinant of the growth and location of the industry itself." The authors conclude that "our results provide new insight into the role of research universities and their top scientists as central to the formation of new high-tech industries spawned by scientific breakthroughs."

Societal Well-being and Quality of Life

Public Health

Through the development of research findings and best practices, medical schools contribute to the development and design of important public health programs. The institutions are the educators of many of the frontline public health workforce in New York, and of course provide for the original and continuing education of primary care physicians who play such a critical role in overall public health and wellness. Medical schools also may perform outreach services for their communities across the state through clinics, presentations, and various online informational resources.

The COVID-19 pandemic is certainly front and center in the minds of many New Yorkers when it comes to thinking about public health. The specific work by New York's medical schools in addressing COVID-19 is highlighted on pages 55 through 58. However, infectious diseases in general have long presented ongoing public health challenges. Work to combat infectious disease is a prime example of the full continuum of research and clinical practice work taking place across the AMSNY member medical schools – with programs ranging from fundamental scientific inquiries into the properties of pathogens through to on-the-ground approaches to the delivery of public health solutions – some of this work is highlighted in the following case study on infectious diseases.

45 Zucker, Lynne; Michael Darby; Marilynn Brewer, "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises," *The American Economic Review*, March 1998, pages 290-306.

Public Health Focus: Infectious Disease

Description:

Infectious diseases are caused by pathogenic microorganisms, such as bacteria, viruses, parasites or fungi and, in rare cases, may be caused by prions (misfolded proteins). Some infectious diseases can be passed from person to person, while others may be transmitted by insects or other animals. Infectious diseases can also be acquired through consuming contaminated food or water or being exposed to pathogens in the environment. Disease mutations and the emergence of new strains of pathogens make ongoing research critically important.

Challenges:

The COVID-19 pandemic has focused attention on the ongoing challenge presented by infectious diseases. While globally the most severe impacts of infectious diseases are experienced in less-developed nations, the effect of infectious diseases on public health in developed nations, including the U.S., is still significant. In 2017, for example, U.S. emergency departments saw 4.1 million patients where the primary diagnosis was an infectious or parasitic disease, and 448,000 hospital admissions resulted.[46] Within the U.S., lower respiratory illnesses and diarrhea are the two largest infectious-disease related causes of death, followed by HIV/AIDS.[47] It is increasingly clear that prior exposure to an infectious disease can lead to later health challenges, such as the higher incidence of cervical cancer found in persons previously infected with human papillomavirus (HPV).

Research!America reports that infectious diseases are associated with an economic burden of over $120 billion in in the U.S. annually. The economic disruption caused by COVID-19 will, however, cause impacts orders of magnitude higher in 2020. The threat posed by infectious diseases is of expanding concern from multiple perspectives:

- Increasing levels of urbanization place people in close proximity to one another, increasing the probability of rapid disease transmission.
- Accessibility to global air travel means that exotic pathogens are readily transported worldwide.
- Climate change is expanding the geographic range of pathogens and disease carrying vectors.
- Large and increasing elderly populations in developed nations, including the U.S., have less physiological capacity to fight infections.
- Misinformation and disinformation are rife within social networks and online, promoting concepts (such as the anti-vaccination movement) that are in opposition to proven, evidence based methods of infectious disease control.

The ongoing challenge presented by infectious diseases highlights the intense importance of ongoing scientific research and development undertaken at U.S. academic medical centers.

Recent AMSNY member NIH Funding:

AMSNY member institutions received 1,594 annual research awards with total funding of $763.0 million from the National Institute of Allergy and Infectious Diseases (NIAID) over the 2018-2020 period.

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46 https://www.cdc.gov/nchs/fastats/infectious-disease.htm

47 Stephanie Soucheray. 2018. "*Infectious disease deaths decline across US, but not evenly*." CIDRAP News, March 27, 2018. http://www.cidrap.umn.edu/news-perspective/2018/03/infectious-disease-deaths-decline-across-us-not-evenly

Another area of cross-cutting attention and public health concern for New York's biomedical researchers, clinicians and public health professionals is the ongoing crisis of substance abuse. The opioid crisis in the nation has been very much felt in New York, for example, and represents an area of concerted attention for the work of New York's medical schools.

Public Health Focus: Opioid Epidemic

Description:

Naturally found in the opium poppy plant, opioids are a class of drugs used to treat moderate to severe pain.[48] Opioids attach to proteins called opioid receptors on nerve cells in the brain, spinal cord, gut and other parts of the body.[49] Opioids then block pain messages sent from the body through the spinal cord to the brain. While they can effectively relieve pain, opioids carry some risks and can be highly addictive, with opioid-related overdoses and deaths increasingly common. As a result, these drugs have become synonymous with the "opioid epidemic," which refers to the adverse effects associated with the proliferation of prescription opioids (e.g., oxycodone, hydrocodone, morphine, and methadone), illegal opioids like heroin and more recently, synthetic opioids such as fentanyl.

Challenges:

The opioid epidemic has had a profound impact on the lives of millions of Americans, including New Yorkers. As noted in New York State's 2019 Opioid Annual Report: "The landscape of this epidemic has changed significantly in the last decade. While in 2002 it was still relatively rare to have an opioid overdose in most communities, it is now commonplace and has spread throughout New York by impacting every county, city and town."

The number of NYS residents hospitalized and dependent on opioids indicates high levels of usage across the state: In 2017, there were over 25,500 opioid overdose hospitalizations including opioid abuse, dependence, and unspecified use, as well as over 12,300 visits to Emergency Departments for opioid overdose (rates of 130.5 and 63.2, respectively) in NYS. Meanwhile, over 62,000 New Yorkers (368.9 per 100,000) were admitted to NYS Office of Addiction Services and Supports (OASAS) certified treatment programs for opioids in 2018. According to one CDC estimate, the combined costs nationally of opioid use disorder ($471 billion) and fatal opioid overdose ($550 billion) exceed $1.0 trillion, and in New York State, the combined total costs were $60.0 billion.[50]

The end result of many opioid use disorders (OUDs) is, unfortunately, death. From 1999–2019, nearly 500,000 people died from an overdose involving any opioid, including prescription and illicit opioids.[51] In New York State alone, there were 3,224 overdose deaths among residents in 2017, of which 1,044 involved commonly prescribed opioids, 1,356 involved heroin, and 2,238 involved synthetic (i.e., man-made) opioids (other than methadone).[52] There was a 200% increase in the number of opioid overdose deaths in NYS between 2010 and 2017.

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48 https://www.cdc.gov/drugoverdose/opioids/index.html
49 https://www.asahq.org/madeforthismoment/pain-management/opioid-treatment/what-are-opioids/
50 https://www.cdc.gov/mmwr/volumes/70/wr/mm7015a1.htm#T1_down
51 Wide-ranging online data for epidemiologic research (WONDER). Atlanta, GA: CDC, National Center for Health Statistics; 2020. Available at http://wonder.cdc.gov.
52 https://www.health.ny.gov/statistics/opioid/data/pdf/nys_opioid_annual_report_2019.pdf

Among the many challenges associated with opioid dependency, those with OUDs are at higher risk for human immunodeficiency virus (HIV), hepatitis C and chronic diseases.[53] Opioid use is also tied to an increased number of newborns diagnosed with neonatal abstinence syndrome and requiring immediate, specialized care. Opioid use also carriers a considerable economic impact on society, with societal costs such as healthcare costs for treatment and emergency medical responders, growth in the foster-care system and overburdened county coroners and medical examiners.

Recent AMSNY member NIH Funding:

AMSNY member institutions received 164 annual NIH research awards over the 2018-2020 period totaling $109.8 million for research into the causes, effects and treatments for opioid abuse.

While all of the areas of research, education, and outreach activities highlighted under the functional impact review have specific impacts and benefits across New York there are two areas of activity that deserve some additional attention in this report because of the current signature nature of the impacts or because of a very specific New York research focus:

- **The impact of the COVID-19 pandemic**
- **Long-term health impacts for 9/11 responders**

In both of these cases, New York's medical schools have directed their special resources, infrastructure and talent to meet the needs of their fellow New Yorkers.

Public Health Focus: COVID-19

Description:

The COVID-19 pandemic has significantly impacted the lives of us all. In the U.S., as of April 30, 2022, the disease has infected more than 81 million people and taken the lives of over 991,000 Americans.[54] For New York State, the statistics stood at 2.8 million positive cases as of April 30, 2022, with more than 70,000 deaths reported to the CDC.[55]

Challenges:

As a densely populated and highly internationally connected global hub, New York State, and especially New York City, was hit hard and early by the pandemic. A significant concentration of cases occurred in New York City with the first confirmed case on February 29, 2020. The disease spread quickly, reaching 913,811 cases and 32,253 deaths in the City in the first few months of the pandemic (as of April 22nd, 2020)[56].

New York was up against a very challenging pathogen. As noted in a recent report by TEConomy for Pfizer, COVID-19 is a particularly vexing virus:[57]

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53 https://www.health.ny.gov/statistics/opioid/data/pdf/nys_opioid_annual_report_2019.pdf
54 https://covid.cdc.gov/covid-data-tracker/#cases_casesper100klast7days
55 https://covid19tracker.health.ny.gov/views/NYS-COVID19-Tracker/NYSDOHCOVID-19Tracker-Fatalities?%3Aembed=yes&%3Atoolbar=no&%3Atabs=n
56 https://www1.nyc.gov/site/doh/covid/covid-19-data-totals.page#summary
57 Simon Tripp, David Hochman, and Mitch Horowitz. 2021. "*Response and Resilience: Lessons Learned from Global Life Sciences Ecosystems in the COVID-19 Pandemic.*" https://www.teconomypartners.com/wp-content/uploads/2020/11/Response-and-Resilience-Lessons-Learned-from-Life-Sciences-Ecosystems-and-COVID-19.pdf

Severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2, is a particularly challenging virus to control. Its incubation period is quite variable, at between 1 and 14 days, and symptoms may present between 2 and 14 days after infection. These symptoms range from being so mild that they go unnoticed through to quite rapid onset of acute life-threatening respiratory challenges and organ failure. The virus is transmitted human-to-human predominantly via respiratory droplets and aerosolization. Patients recovering from COVID-19 demonstrate far from a uniform immune serology, and it is unclear the level of protection accorded through prior infection. In some respects, it is a "perfect storm" of a virus—slow enough in causing symptoms to allow asymptomatic individuals to continue daily interactions that unknowingly spread the virus, just deadly enough to overwhelm healthcare systems in major hot spots, but apparently not deadly enough for some people to change their behaviors and take it seriously (thus perpetuating transmission).

Viral variants have continued to cause systemic stresses, even as multiple COVID-19 vaccines have been brought to bear against the disease.

A study by Breana Lui, et. al. published in mid-year 2021 has examined the economic impact in terms of lives lost across the state. Reported in the Journal of Comparative Effectiveness Research, Lui and colleagues examined the years of potential life lost (YPLL) and statistical value of lives (VSL) data for COVID-19 in New York State, New York City and the five boroughs over a period of approximately one year since the start of the pandemic. As of their reporting on 8 March 2021, "the economic burden of lives lost was US$119.62 billion in New York State, with New York City accounting for an overwhelming majority of the cost at US$90.45 billion."[58]

Examples of AMSNY Member Research in Action:

As of April 30, 2022, AMSNY medical schools have received 222 awards (during FY 2020, FY 2021 and FY 2022 combined) used for COVID-19 related research. These awards represent over $620 million in research and programmatic funding.

As the pandemic hit, AMSNY member institutions reacted rapidly, pivoting much of their deep research expertise and signature research infrastructure to address the crisis and combat the disease. Contributions by AMSNY member institutions via research and innovations have contributed greatly to global and national advancements against the pandemic and been crucial in state and local scientific and clinical response to COVID-19. It is important to note that these contributions have been made and sustained while the pandemic itself impacted the operations of the AMSNY research community. The pivoting of resources and people to address the pandemic by AMSNY members, represents a humanitarian commitment of New York's medical schools to preserving life and to protecting society and the economy in the face of an unprecedented threat.

Doing justice to the wide array of individual medical school research projects, programs, and actions taken to address the pandemic would require a project unto itself. Rather than seek to highlight each and every undertaking of the AMSNY member institutions in combatting the pandemic, Figure 14 provides classification of ten core domains of research and innovation activity undertaken, and highlights many of the areas of research and innovation activity that have been directed across these domains by NY medical schools.

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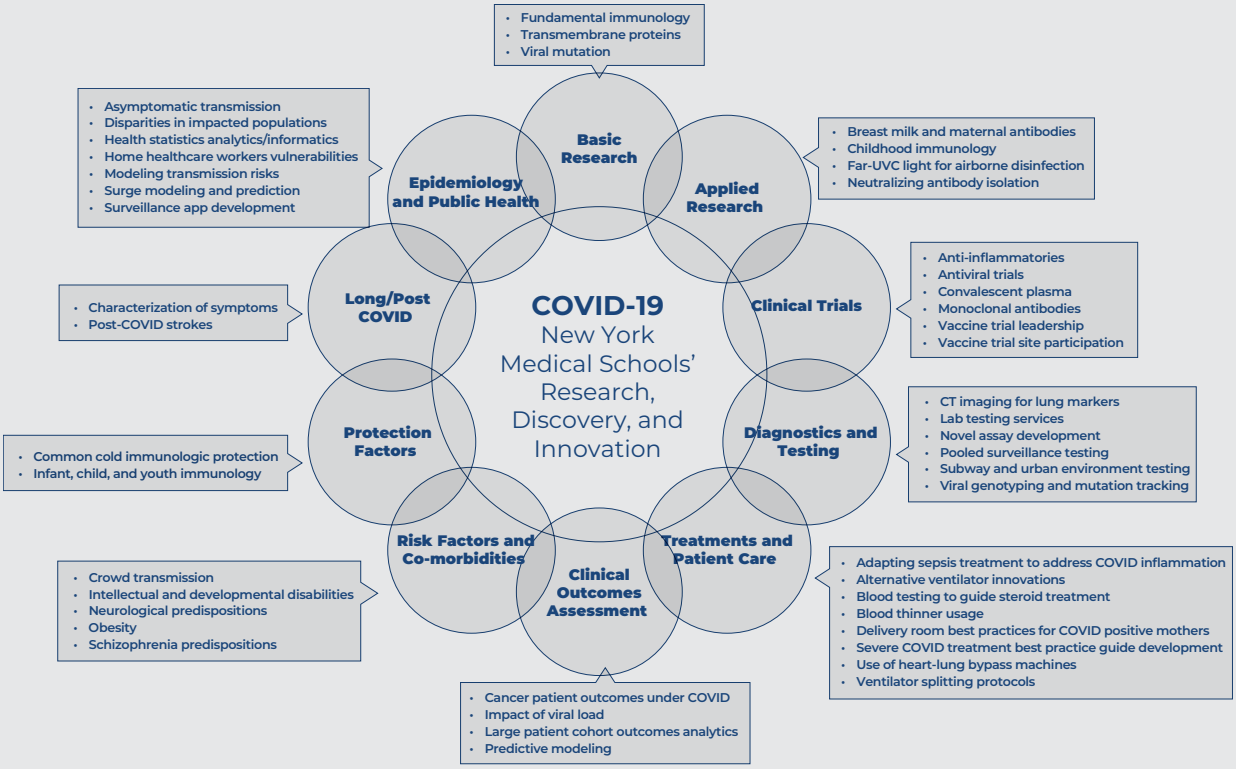
58 Briana Lui, Michelle Zheng, Robert S White, and Marguerite Hoyle. "*Economic burden of lives lost due to COVID-19 in New York State.*" J Comp Eff Res. Published online 2021 Jun 1. doi: 10.2217/cer-2021-0086

Figure 14. AMSNY Member Institutions' Research, Discovery, and Innovation Activity Domains in Combatting COVID-19.



Source: TEConomy Partners, LLC.

AMSNY member institutions have been engaged across an extremely broad spectrum of research, discovery and innovation activities, from basic and applied research on the virus and its disease-causing etiology, through to the development and clinical trials of drugs and vaccines to combat the disease. The medical schools have been on the front lines in supporting the accurate diagnosis of infections and in tracking and predicting disease spread. Research teams have provided deep insight into best practice treatment of COVID positive patients, and elucidated factors associated with both risk and protection related to the disease and its clinical progression. It is anticipated that research on COVID-19 and its impacts will be sustained into the future, not only because the disease remains with us, but also to address future pandemic preparedness and to understand the long-term clinical impacts of the disease on recovering patients.

Beyond Research & Treatment Innovations – Other Actions by AMSNY Members to Address COVID:

In addition to the research and innovation activities of AMSNY member institutions directed towards COVID-19, the institutions have proactively engaged and collaborated in many other ways during the pandemic, including:

- Standing up special field hospitals and modifying existing emergency room, critical care and other clinical environments to address the unique triage and treatment requirements of a fast-moving infectious disease.
- Conducting clinician education programs and webinar events to transfer current knowledge and promote best practices in COVID-19 prevention, diagnosis and treatment.
- Working to support the mental health and mitigate stress across frontline clinical and essential workers.
- Rapidly scaling existing telemedicine platforms and adopting new virtual healthcare technologies to provide effective and uninterrupted remote care.
- Providing counseling and support for patients recovering from COVID-19 or experiencing long-term symptoms.
- Graduating fourth-year medical students as early as possible to address physician shortages and facilitating volunteer efforts by health science student populations in support of COVID-19 clinical actions.
- Working collaboratively to secure personal protective equipment and supplies for the frontline healthcare workforce.

It is clear that the COVID-19 pandemic was experienced particularly acutely in New York. What is equally clear is that AMSNY member institutions stepped forward to address the challenge and worked to pivot their considerable resources, expertise, and infrastructure to the needs of the moment. Were it not for these efforts, the pandemic's negative effects across the state of New York would have been significantly magnified.

Public Health Focus: 9/11 First Responders

Description:

In the wake of the September 11th attacks, many individuals from a variety of trades worked around the clock to search for the missing and help clean up from the disaster site in lower Manhattan. Unfortunately, these acts of heroism were met with prolonged and devastating health effects. It is estimated that over 400,000 people were exposed to toxic contaminants, risks of traumatic injury and physically and emotionally stressful conditions in the days, weeks and months following the attacks.[59] Common health conditions faced by 9/11 responders include chronic cough, asthma, sinus congestion, certain cancers, stress-related disorders and depression, among others.

Challenges:

For the past two decades, challenges have persisted for 9/11 first responders. Some experts estimate that the number of deaths from 9/11 diseases have outnumbered the almost 3,000 people who died on September 11, 2001.[60]

In 2019, the U.S. government permanently reauthorized the September 11th Victim Compensation Fund, which allocates funds to pay for claims for deaths and illnesses related to the attack. As part of this bill, $10.2 billion will be authorized for the fund for the next 10 years, with additional billions authorized until 2090. By essentially covering the surviving 9/11 responders for the rest of their lives, this is considered a major victory for first responders, who have been pushing for permanent funding for over a decade.

The majority of 9/11 Responders are now over the age of 55, and while many people face risks of diseases such as cancer as they age, the rate of some cancers among first responders is considerably higher than in the general population.[61]

Researchers at **Icahn School of Medicine at Mount Sinai** studied 28,729 police officers and recovery workers from the 9/11 site, and compared to the general population, they found first responders were getting cancer at a 9% higher rate and were at especially high risks for thyroid cancer (219% higher), leukemia (41% higher) and prostate cancer (25%).[62]

The most common conditions facing 9/11 First Responders include: Chronic Rhinosinusitis, Gastroesophageal Reflux Disease, Cancers (especially non-melanoma skin and prostate cancers), Asthma, Sleep Apnea and Post-Traumatic Stress Disorder.[63]

Recent AMSNY member NIH and CDC Funding:

AMSNY member institutions received 104 annual research awards from 2018-2020, with total funding of $52.3 million from NIH and the National Institute for Occupational Safety and Health (NIOSH, part of the Centers for Disease Control and Prevention) for research into the conditions, effects and potential treatments for the various conditions afflicting the 9/11 responders.

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59 https://www.cdc.gov/wtc/history.html
60 https://www.lohud.com/story/opinion/perspective/2018/09/06/deaths-9-11-aftermath-soon-outpace-number-killed-sept-11/1137572002/
61 https://www.cancercenter.com/community/blog/2020/09/9-11-cancer
62 https://consumer.healthday.com/cancer-information-5/mis-cancer-news-102/nearly-20-years-later-cancer-rates-higher-in-9-11-first-responders-753874.html
63 https://www.cdc.gov/wtc/pdfs/statistics/paag20201231-P.pdf

Clinical Care

The impacts that medical schools generate regarding actual clinical care are quite diverse. Clinical care is continually improved through research advancements and innovations resulting from basic, applied, translational and clinical research activities at medical schools. Similarly, the primary education mission of medical schools in the education and training of physicians, nurses, and other healthcare professionals is a clear contributor to quality clinical care – as is the ongoing continuing education engagement of these institutions.

High quality clinical care in New York also results from the highly specialized expertise of medical school faculty – faculty who are typically engaged as active clinicians, providing medical and healthcare services through affiliated university hospitals and health systems. Being on the frontiers in their respective health science disciplines, medical school faculty bring deep expertise to the care of patients and may also be engaged in early-stage clinical research and trials that can directly benefit patients.

Clearly there are multifaceted positive benefits for individuals and society in ensuring access to high-quality clinical care for patients. These impacts do, however, vary widely across individual diseases and health conditions. Similarly, many diseases or disorders impact individuals across the lifespan, with varying levels of associated lifetime cost, impact on personal productivity and quality of life. Quantifying an average benefit associated with access to care, or developing a methodology for measuring the impact of quality of care, is therefore a highly complex analysis. It is clear, however, that highly significant public and private benefits, and monetary and non-monetary benefits, are being generated for New York State through the positive effects of AMSNY member medical schools on medical and health sciences education and the advancement of research and associated clinical practice.

Nowhere was the expression of these benefits better seen than in the response to the COVID-19 pandemic by AMSNY member institutions' faculty and students. Beyond the frontline involvement of the numerous medical school faculty and members of the schools' faculty practice units, the students (and ultimately graduates) of AMNSY medical schools became involved in direct clinical care to the thousands of incoming patients seeking COVID-19 related care. Students were involved in a variety of activities to assist in overall care and help ease the burden on existing hospital staffs. Fourth year students who were set to graduate in the Spring of 2020 to begin residencies were allowed in some instances to accelerate graduation to enable them to function as "junior physicians" in hospitals with critical workforce shortages.

Summary

Functional impacts represent the principle reason for the development and operation of medical schools and reflect the benefits and overall societal value generated by their core missions of higher education, clinical care, research and community service.

When all the activities undertaken by New York's medical schools are considered, it is apparent that these important institutions generate highly diverse impacts for the economy and society. AMSNY member medical schools support, serve and enhance New York State across all four broad functional impact categories:

- **Knowledge Expansion and Innovation**
- **Economic Development**
- **Educated and Skilled Human Capital**
- **Societal Well-being and Quality of Life**

These diverse impacts provide significant examples of the often immeasurable societal value that the AMSNY member medical schools provide to New York State and its residents.

Appendix A: AMSNY Members in Action

Research Focus: Heart Health and Cardiovascular Disease

Some examples or highlights of recent work being undertaken in the area include:

- At **Albert Einstein College of Medicine**, researchers are exploring the use of wearable tech to improve the detection of leg arterial disease. Lower extremity arterial disease (LEAD) is a debilitating, but under-recognized, condition usually caused by fatty plaque buildup in arteries carrying blood from the heart to the legs. More commonly known as peripheral artery disease, this increasingly common condition affects more than 8 million Americans, including up to 20% of those over the age of 60, and over 200 million people worldwide. Early detection and treatment of LEAD is especially important because if left untreated, LEAD can result in disability, amputations and death.
- Faculty at **Columbia University Vagelos College of Physicians and Surgeons** are working to reduce deaths from an underdiagnosed form of heart failure: transthyretin amyloid cardiomyopathy (ATTR-CM), a progressive form of heart failure that may be more common than doctors realize. As highlighted in The New England Journal of Medicine, a phase three clinical trial has shown that a drug called tafamidis significantly reduces deaths and hospitalizations in patients with ATTR-CM.
- Scientists at the **Icahn School of Medicine at Mount Sinai** led a landmark study on aspirin for high-risk heart patients. High-risk patients who have undergone a coronary stent procedure may not require long-term aspirin in conjunction with an antiplatelet medication, according to a groundbreaking global study published in The New England Journal of Medicine.
- At the **New York Institute of Technology College of Osteopathic Medicine**, researchers found that a widely used blood test could provide a potentially life-saving treatment for heart failure. While heart failure symptoms are commonly attributed to cardiovascular conditions like coronary artery disease and high blood pressure, a growing number of studies suggest that low levels of the thyroid hormone T3 may significantly contribute to a patient's symptoms and underlying heart dysfunction. The researchers found that it may be possible to use an existing biomarker, brain natriuretic peptide (BNP), to measure and analyze the use and dosage of added T3 to safely restore cardiac hormone balance.
- Faculty at **Stony Brook University's Renaissance School of Medicine** are identifying an important cause of congenital heart disease: the loss of certain function in the PLD1 (Phospholipase D1) gene. They discovered that certain loss of functions in the gene causes congenital right-sided cardiac valve defects and neonatal cardiomyopathy. These findings are detailed in a paper published in the Journal of Clinical Investigation.
- **Weill Cornell Medicine** researchers are studying the use of minimally invasive procedures to replace the heart's aortic valve. Notably, they find that certain approaches are rapidly increasing in popularity despite a lack of research on the new valves' long-term durability, which may be a cause for concern for patients under the age of 65.

Research Focus: Neurological Disorders

Some examples or highlights of recent work being undertaken in the area include:

Alzheimer's disease is one neurological disorder where AMSNY member institutions are especially active:

- Research faculty at **Albany Medical College** are discovering potential new pathways to treat Alzheimer's disease and other age-related dementias. In a study published in the Journal of Experimental Medicine, the researchers found that targeting a specific type of immune cell in the aged brain might help combat Alzheimer's disease and other aging-related dementias. Specifically, activating group 2 innate lymphoid cells (ILC2s) improved the memory of aged mice.
- At **Columbia University Vagelos College of Physicians and Surgeons**, neurologists are pioneering the use of spinal fluid as a reliable way to diagnose Alzheimer's. While accurately diagnosing this condition has been a significant challenge for medicine, this research found that a test measuring amyloid and tau levels in cerebrospinal fluid can accurately identify most patients with Alzheimer's disease.
- Researchers at the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are finding new approaches to Alzheimer's disease that may eventually make it possible to reverse memory loss, a hallmark of the disease in its late stages. In a study published in the journal Brain, the research team found that by focusing on genetic changes caused by influences other than DNA sequences – called epigenetics – it was possible to reverse memory decline in an animal model of Alzheimer's.
- Researchers at the **Icahn School of Medicine at Mount Sinai and Columbia University Vagelos College of Physicians and Surgeons** are identifying previously unknown genetic aberrations found to be associated with Alzheimer's progression. In a large-scale analysis of RNA from postmortem human brain tissue, specific RNA splicing events associated with Alzheimer's disease progression were identified.
- Scientists from the **Renaissance School of Medicine at Stony Brook University** are also finding that that higher education is associated with later onset of Alzheimer's-related accelerated cognitive declines.
- At the **University of Rochester School of Medicine & Dentistry**, researchers are discovering novel approaches to delivering therapeutics more effectively to the brain. This research could have implications for the treatment of a wide range of diseases, including Alzheimer's, Parkinson's, ALS and brain cancer.
- Investigators at **Weill Cornell Medicine** are finding that a Western-style diet triggers changes in the brain that may predispose patients to Alzheimer's disease decades before they show any sign of cognitive decline.

Beyond Alzheimer's Disease, AMSNY member institutions are also involved in researching other neurological disorders:

- Scientists at **Albert Einstein College of Medicine** are identifying promising novel therapies for acute migraines. As reported in *The New England Journal of Medicine*, a large-scale, Phase 3 Clinical Trial suggests a drug belonging to a new generation of acute migraine headache treatments was found to eliminate pain and reduce bothersome symptoms for people with migraine.
- Faculty at the **New York Institute of Technology College of Osteopathic Medicine** are addressing the impacts that Parkinson's disease has on younger women. Parkinson's disease is a progressive nervous system disorder that affects not only movement, but also a host of non-motor symptoms such as problems with memory and disruptions of sleep and digestion. Researchers are exploring the many unknowns regarding how Parkinson's affects women, especially those in their 30s and 40s, who are otherwise understudied.
- At the **Norton College of Medicine at SUNY Upstate Medical University**, researchers are exploring the links between early-stage Parkinson's Disease and gut microbiome. In a recent study published in collaboration with a StartUp NY company, the authors discovered that specific bacteria in the oral microbiome accurately differentiate early-stage Parkinson's disease ("esPD") from healthy controls.

- Faculty at **SUNY Downstate Health Sciences University** are identifying key mechanisms linked to neuropsychiatric lupus. In a breakthrough study, the research team identified a specific antibody target implicated in neuropsychiatric symptoms of lupus. These symptoms, including cognitive impairment, mood disorders, seizures, headaches and psychosis, are among the most prevalent manifestations of the disease and occur in as many as 80% of adults and 95% of children with lupus.
- Researchers at the **University of Rochester School of Medicine & Dentistry** are reshaping our understanding of how the brain recovers from injury. By examining how damage in the brain caused by a stroke can lead to permanent vision impairment, the research could provide a blueprint to better identify which areas of vision are recoverable, facilitating the development of more effective interventions.
- Researchers from the **Zucker School of Medicine at Hofstra/Northwell** and The Feinstein Institutes for Medical Research in conjunction with their colleagues at Rockefeller University in New York City, are furthering our understanding of how certain psychiatric diseases manifest and potentially can be treated. Their focus is on how certain psychiatric diseases that involve uncontrollable reactions to stimuli – such as the high and low experiences attributed to bipolar disorder, the impulsivity of an individual suffering from attention deficit hyperactivity disorder (ADHD), and even suicidality – manifest and potentially can be treated.

Research Focus: Cancer

Some examples or highlights of recent work being undertaken in the area include:

- Physicians in the **Albany Medical College's** Division of Urology are offering a new medication to treat prostate cancer that has been shown to reduce the risk of death from the disease as well as significantly lower the risk of cancer spreading to other parts of the body.
- In a study published in *Science Translational Medicine*, **Albert Einstein College of Medicine** researchers report that an experimental peptide (small protein) drug shows promise against the often-lethal cancer acute myeloid leukemia (AML) and describe how the drug works at the molecular level.
- At **Columbia University Vagelos College of Physicians and Surgeons**, researchers are engineering bacteria to serve as a "Trojan horse" for cancer immunotherapies. The emerging field of synthetic biology - designing new biological components and systems - is revolutionizing medicine. Through the genetic programming of living cells, Columbia Vagelos researchers are creating engineered systems that intelligently sense and respond to diverse environments, leading to more specific and effective solutions in comparison to current molecular-based therapeutics.
- Artificial intelligence was also used by researchers at the **Icahn School of Medicine at Mount Sinai** in a pathology test to characterize tissue samples that can accurately predict clinically significant prostate cancer disease progression following surgery. The researchers published their study in *Nature Prostate Cancer and Prostatic Diseases*.
- Researchers at the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are also using advanced computational methods to detect disrupted pathways in cancer. Cancer is a notoriously complex disease, in part because it may be caused by mutations among hundreds of genes and an extraordinary amount of variation among genetic mutations, even between patients with the same types of cancers. Consequently, cancer researchers at the Jacobs School have chosen to study interactions among groups of genes in certain biological pathways that are disrupted.
- Faculty at **New York Institute of Technology's College of Osteopathic Medicine** are developing new treatments specifically targeting cancers in children.[64] Brain tumors are the most frequent cause of death from childhood cancers, and yet the ability to understand their origin and develop effective therapies has lagged compared to adult brain cancers. Over the past 20 years, only a few new drugs have been approved that were specifically developed to treat children with cancer, and NYIT research hopes to change that.

64 https://www.nyit.edu/box/Profiles/faculty_profile_haotian_zhao_ph.d

- Researchers at **NYU Grossman School of Medicine** are revealing the mechanisms that help pancreatic cancer cells avert starvation. Their recent study shows how pancreatic cancer cells avoid starvation within dense tumors by hijacking a process that pulls nutrients in from their surroundings. The research explains how changes in the *RAS gene* – known to encourage the abnormal growth seen in 90% of pancreatic cancer patients – also accelerates a process that supplies the building blocks required for that growth.
- Doctors at the **Renaissance School of Medicine at Stony Brook University** have developed a technology that manipulates microRNAs for potential use as an anti-cancer therapeutic. The technology has shown promise when used as a therapeutic to treat cancers, and the method may prove to be particularly effective against chemotherapy-resistant cancers such as colorectal cancer.
- Translational research at **SUNY Downstate Health Sciences University** is exploring personalized medicine for the treatment of cancer especially better therapies that specifically target drug-resistance. Several NIH-funded translational studies at the University are looking at the role of p27 and cyclin D-cdk4 (D-K4) in cancer. Targeting DK4 has long been a type of holy grail in the oncology field as it is downstream of almost all oncogenic signaling pathways. Many patients exhibit primary resistance; ultimately, the majority develop secondary resistance to these drugs.
- Researchers at the **University of Rochester School of Medicine & Dentistry** found that flushing the bladder with a common chemotherapy drug immediately after surgery significantly reduces the chances of bladder cancer returning, according to a major study and an international clinical trials network funded by the National Cancer Institute.
- Researchers at **Weill Cornell Medicine** are using artificial intelligence to predict drug targets, which may lead to promising results for experimental cancer treatments. Researchers have developed a novel machine-learning algorithm capable of predicting biological targets of prospective drug molecules. The new tool, described in a paper in *Nature Communications*, may speed the development of new and better drugs, as well as the repurposing of existing drugs. Working with a pharmaceutical company, the scientists used the artificial intelligence (AI) tool to predict the target of a potent anti-cancer compound whose mechanism in cells was not previously known.
- Researchers at the **Zucker School of Medicine at Hofstra/Northwell** are developing a female fertility decision tool for cancer survivors. An NIH-grant is supporting the development and testing of an innovative digital health platform to help young female cancer survivors evaluate their options for having children, making decisions and planning for the future.

Research Focus: Autism Spectrum Disorder

Some examples or highlights of recent work being undertaken in the area include:

- Researchers at **Albert Einstein College of Medicine** and Montefiore Health System are finding that some children can "recover" from autism spectrum disorder (ASD), but problems often remain. While some research in recent years has shown that children can outgrow a diagnosis of ASD, once considered a lifelong condition, their study – published in the Journal of Child Neurology – finds that the vast majority of such children still have difficulties that require therapeutic and educational support.
- Pediatric gastroenterologists and psychiatrists at **Columbia University Vagelos College of Physicians and Surgeons** are helping detect gastrointestinal disorders in children with autism spectrum disorder (ASD). For many kids with ASD, anger, aggression, and other troubling behavior problems are often treated as psychological issues but can actually be traced to gastrointestinal distress. A new study shows that a 17-item questionnaire-developed could be an effective screen to identify children who may have gastrointestinal disorders and who should be referred to a specialist for a fuller evaluation.
- At the **Icahn School of Medicine at Mount Sinai**, researchers at the Seaver Autism Center for Research and Treatment are showing significant genetics-related progress towards teasing apart the genes associated with autism spectrum disorder (ASD) from those associated with intellectual disability and developmental delay, conditions which often overlap. Their research, published in the journal *Cell*, identified 102 genes associated with risk for autism in the largest genetic sequencing study of ASD to date. Additionally, Icahn/Seaver researchers are discovering that

common medications taken during pregnancy are not associated with a risk for autism. In research published in *JAMA Psychiatry*, they find that babies exposed in the womb to the majority of medications that target neurotransmitter systems, including typical targets of antidepressants and antipsychotic drugs, are not any more likely to develop autism than non-exposed babies.

- Researchers at the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are developing a powerful drug discovery protocol for autism that is accelerating the development of new treatments. As described in an article in *Nature Protocols*, a sensitive and reliable new protocol for assessing social deficits in animal models of autism and certain psychiatric conditions is expediting the search for effective treatments.
- Researchers at the Norton College of Medicine at SUNY Upstate Medical University are inching closer to a prototype saliva test to diagnose autism spectrum disorder (ASD). Saliva contains microRNA, which might affect how a child's brain works. Finding microRNA particles with altered levels in children with ASD may lead to an earlier diagnosis of disorder and the delivery of more efficient services for these children.
- At NYU Grossman School of Medicine, researchers are using an iPhone app to screen young children for signs of autism. The app is novel, easy to use, caregiver friendly, and offers a scalable method for collecting high-quality and scientifically valid data, according to a study published in the journal *npj Digital Medicine*.
- University of Rochester School of Medicine & Dentistry are highlighting new autism guidelines that recommend early screening and treatment for developmental delays before diagnosis. To guide diagnosis and care of children with autism, the updated recommendations from the American Academy of Pediatrics (AAP) reflect changes in how autism is diagnosed and treated.

Clinical Practice Advancement: Precision Medicine

Some examples or highlights of recent work being undertaken in the area include:

- Faculty at **Albany Medical College** are launching a clinical study on precision neuromodulation therapy with Micro-Leads Medical, Inc., a clinical neurostimulation startup developing a high-resolution spinal cord stimulation therapy for treating chronic focal pain without opioids. Backed with a $10 million award for therapy development funding, Micro-Leads will partner with Albany Medical College neuroscientists to further develop its HD64TM implantable therapy system and launch a clinical study in patients.
- Scientists at **Albert Einstein College of Medicine**, Montefiore Health System, and other medical institutions are testing patients' individual cells to guide treatments. As published in Nature Immunology, the research team used a powerful new tool to zero in on individual cells in a patient's diseased organ and reveal the cells' underlying glitches in gene expression-information that could make biopsies more useful for many diseases and allow for more precise and effective treatment.
- Researchers at the **Columbia University Vagelos College of Physicians and Surgeons** are bringing physicians up to speed on precision medicine, especially those who do not have the training or time to incorporate genetic sequencing technologies into everyday practice. Elsewhere, faculty are developing new precision medicine tests that look beyond cancer genes to identify novel therapeutic targets. These tests have received New York State Department of Health approval and are now available to both oncologists and cancer researchers for use at the front lines of patient care.
- At the **Icahn School of Medicine at Mount Sinai**, researchers are creating an RNA and DNA sequencing platform to match a broader swatch of cancer drugs to patients with few options. Their results, published in JCO Precision Oncology, find that a comprehensive RNA and DNA sequencing platform benefits late-stage and drug-resistant multiple myeloma patients by determining which drugs would work best for them.
- At the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo**, researchers are discovering new forms of brain proteins with clinical implications. In research published in the Proceedings of the National Academy of Sciences of the United States of America (PNAS), they revealed that the absence of a single interaction within a

brain receptor reduces its activity. The discovery advances the understanding of how certain brain diseases arise and could lead to developing precision medicines for treating them.

- Researchers at the **NYU Grossman School of Medicine** are working on the nation's leading molecular test to better detect brain tumors in patients. NYU Langone Health and its Perlmutter Cancer Center have launched clinical whole-genome DNA methylation profiling for patients with brain tumors. This leading-edge molecular assay utilizes DNA epigenetic signatures and artificial intelligence with machine learning to correctly identify and subtype brain tumors. This leading-edge molecular assay utilizes DNA epigenetic signatures and artificial intelligence with machine learning to correctly identify and subtype brain tumors.
- At **SUNY Downstate Health Sciences University**, faculty are focusing on personalized medicine for the treatment of cancer. Backed with NIH-funding, the university is leading several translational studies on the role of p27 and cyclin D-cdk4 (D-K4) in cancer. Targeting DK4 has long been a type of holy grail in the oncology field as it is downstream of almost all oncogenic signaling pathways.
- Researchers at **Weill Cornell Medicine** are engineering customized blood vessels to support organ regeneration and identify potential cancer treatments. In a study published in Nature, a pioneering new method for manufacturing functioning human blood vessels demonstrated the ability to carry blood in lab-grown model organs and tumors. The discovery will enable disease modeling and may facilitate the future production of human transplantable organs and identification of new precision drugs to treat cancer. The scientists also found that a key protein could rejuvenate adult human endothelial cells – the building blocks of blood vessels – returning them to a malleable state in which they readily grow and conform to surrounding tissues.
- Researchers at the **Zucker School of Medicine at Hofstra/Northwell** are using genetics to predict responses to antipsychotic medications. According to research published in the American Journal of Psychiatry, genetics can be used to predict a patient's response to antipsychotic drug treatment for schizophrenia.

Clinical Practice Advancement: Regenerative Medicine and Stem Cells

Some examples or highlights of recent work being undertaken in the area include:

- Researchers at **Albany Medical College** are exploring the impact of sepsis and other severe infections on stem cell functions. This research, backed through a five-year grant from the National Institutes of Health's National Institute of General Medical Sciences (NIGMS), will focus on individuals who survive severe infections like sepsis, tick-borne infections or other shock-like illnesses. These patients often see a decline in their overall health and providing new insight into how these infections affect blood stem cells can potentially improve their long-term outcomes.
- Faculty at **Albert Einstein College of Medicine's Gottesman Institute** for Stem Cell Research and Regenerative Medicine are having significant success in differentiating induced pluripotent stem (iPS) cells. Einstein/Gottesman researchers are differentiating iPS cells into liver cells or into liver progenitor cells to better understand and study metabolic liver diseases, into neurons to better understand autism and other neuropsychiatric diseases, and into lenses and mini-retinas for eye-related therapies.[65]
- At the **Columbia University Vagelos College of Physicians and Surgeons**, biomedical engineers grew an adult-like heart muscle from human stem cells. This marks the first human heart muscle from stem cells that shows critical hallmarks of adult human heart function in just four weeks. In 2018, five projects led by researchers at the school were funded by the NYSTEM through Investigator Initiated Research Projects and Innovative, Developmental or Exploratory Activities in Stem Cell Research grants.
- At **Icahn School of Medicine at Mount Sinai**, researchers are discovering how to restore vision using retinal stem cells. Scientists at Mount Sinai have successfully restored vision in mice through activating retinal stem cells,

65 http://blogs.einstein.yu.edu/a-decade-of-stem-cell-research-a-qa-with-paul-frenette-m-d/

something that has never been done before. Their study, published in Nature, could transform treatment for patients with retinal degenerative diseases, which currently have no cure.

- Scientists from the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are exploring how remyelination, the spontaneous regeneration of the brain's fatty insulator that keeps neurons communication. As published in Cell Reports, the team's pre-clinical findings reveal that activation of a specific transcription factor induces in adult stem cells a phenomenon called pathological quiescence. These findings could lead to a novel approach to developing treatments for multiple sclerosis (MS) and other inflammatory diseases.
- At **New York Medical College**, researchers are discovering possible alternatives to embryonic stem cells as treatments for inflammatory disorders. As published in the journal PLoS ONE, mesenchymal adult stem cells isolated from rat bone marrow were found to generate a novel regulatory T cell (mTregs) which has the potential for development to treat inflammatory disorders. This advancement, if translated to human therapies, could be especially beneficial to patients seeking treatments for chronic diseases such as arthritis, atherosclerosis, stroke, pulmonary hypertension, multiple sclerosis, ulcerative colitis and cancer would benefit.
- At the **NYU Grossman School of Medicine**, scientists are using experimental stem cell therapies to speed up wound healing in diabetes. Their study in mice shows the healing of wounded skin in diabetes can be sped up by more than 50% by using injections of stem cells taken from bone marrow. The research focused on a chain of events in diabetes that makes skin sores more likely to form and less likely to heal.
- Researchers at **Weill Cornell Medicine** are discovering news stem cells responsible for growing and healing the hard, outer surface of bone. In a study published in Nature, their findings highlight that bone contains multiple populations of stem cells, each with their own unique roles and anatomic locations.

Public Health Focus: Infectious Disease

Some examples or highlights of recent work being undertaken in the area include:

- **Albert Einstein College of Medicine** researchers are identifying how hantaviruses infect lung cells. Hantaviruses cause severe and sometimes fatal respiratory infections, but how they infect lung cells has been a mystery. As published in *Nature*, an international team of investigators found hantaviruses gain entry to lung cells by "unlocking" a cell-surface receptor called protocadherin-1 (PCDH1), and deleting this receptor made lab animals highly resistant to infection. The findings show that targeting PCDH1 could be a useful strategy against deadly hantavirus pulmonary syndrome (HPS).
- **Columbia University Vagelos College of Physicians and Surgeons** infectious disease researchers, including those from the Aaron Diamond AIDS Research Center (housed within Columbia University since 2019), are engaged in research that focuses on antibodies to prevent HIV transmission by blocking HIV infection. This research is currently involved in a Phase I clinical trial.
- Researchers at the **Icahn School of Medicine at Mount Sinai** are leading an effort to develop the universal flu vaccine, made possible through the NIH NIAID's Collaborative Influenza Vaccine Innovation Centers (CIVICs) program. The Icahn School of Medicine will form a joint vaccine center with Emory University that will become part of the large CIVICs network of research centers.
- Scientists from the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are revealing how antiretroviral drugs may damage the hearts of infants exposed to HIV. All pregnant women in the U.S. with HIV receive antiretroviral therapy (ART). However, not all babies who are exposed to HIV in utero ultimately become infected with it. Research published in the journal AIDS reveals that uninfected babies who are exposed to HIV and antiretroviral therapy in utero exhibit "subclinical but significant" left ventricle dysfunction early in life, suggesting that the drugs may put these babies at risk of adverse cardiac events.

- Faculty at **New York Medical College** are developing flu "seed stock" for the production of the world's annual supply of influenza vaccine. As many as 646,000 people succumb to the flu every year worldwide-yet that number would be much greater if not for the efforts of NYMC's microbiologists and immunologists.
- Researchers at **NYU Grossman School of Medicine** have found that HIV-positive New Yorkers are living longer, but still dying of underlying infections. A review of the autopsy reports of 252 men and women who died of AIDS in New York City between 1984 and 2016 reveals several long-term trends in combatting the epidemic. The infectious disease is known for drastically lowering the body's immune defenses and is spread by HIV.
- Faculty at **SUNY Downstate Health Sciences University** are finding that antiretroviral therapy does not restore disease immunity among previously immunized HIV patients. In an article in Journal of Infectious Diseases, their analysis shows that despite successful antiretroviral therapy, antigen specific memory to vaccinations that occurred before HIV infection did not recover, even after immune reconstitution. Additionally, a previously unrealized decline in pre-existing antibody response was also observed.
- At the **Norton College of Medicine at SUNY Upstate Medical University**, researchers are shedding new light on HIV replication processes. When activated, CD4 T cells lead the body's immune system in fighting off infection. But not so with HIV, the virus that causes AIDS. HIV overtakes these activated CD4 T cells, disarming their ability to fight the invading infection. In a study published in *Cell Reports*, SUNY Upstate researchers are exploring why HIV prefers to replicate in these active CD4 T cells and not in resting CD4 T cells.
- At the **University of Rochester School of Medicine & Dentistry**, scientists are studying the effectiveness of a needle-free vaccine patch. As published in the *Journal of Investigative Dermatology*, a new needle-free flu vaccine patch revved up the immune system much like a traditional flu shot without any negative side effects. Though the research is in the early stages and has not been tested in humans, it is an important step toward a technology that could replace needle-based vaccination methods that require administration by health care workers and biohazard waste removal.
- Scientists at **Weill Cornell Medicine** are exploring how modified inactivated vaccines may produce immune responses as effective as live vaccines. Although vaccines containing inactivated versions of disease-causing germs are traditionally not as effective as live vaccines made with weakened pathogens, recent research reveals how a molecule found in live vaccines produces a robust immune response and adding it to an inactivated vaccine can create the same strong results.

Public Health Focus: Opioid Epidemic

Some examples or highlights of recent activities being undertaken in the area include:

- Researchers at the **Jacobs School of Medicine & Biomedical Sciences at University at Buffalo** are developing an innovative, cost-effective program to treat opioid use disorders in Buffalo Emergency Departments. At more than a dozen hospitals in Western New York, the program provides medication-assisted treatment to opioid use disorder patients in emergency departments and rapidly transitions them into long-term treatment at a community clinic, all within about 48 hours.
- Scientists at **NYU Grossman School of Medicine** are working to find new medication treatments that lower the risk of fatal overdose for patients with opioid use disorder. As published in the journal Addiction, people with opioid use disorder (OUD) receiving treatment with opioid agonists (medications such as methadone or buprenorphine) had an 80% lower risk of dying from an opioid overdose compared with people in treatment without the use of medications.
- Faculty at the **Renaissance School of Medicine at Stony Brook University** are studying images of the brain to reveal what is happening in the brains of those with opioid use disorders who, despite profound problems with drugs, are not committed to taking their prescribed treatment medications.
- Faculty at the **University of Rochester School of Medicine & Dentistry** are helping uncover the true scale of the opioid epidemic. In the journal Addiction, their research shows that the number of deaths attributed to opioid-related

overdoses could be 28% higher than reported due to incomplete death records. This discrepancy is more pronounced in several states (e.g., Alabama, Mississippi, Pennsylvania, Louisiana, and Indiana), where the estimated number of deaths more than doubles. These findings may obscure the scope of the opioid crisis and potentially affect programs and funding intended to confront the epidemic.

- At **Weill Cornell Medicine**, researchers in health economics are developing economically feasible interventions to help people with substance use problems and encouraging policymakers to support initiatives that effectively treat addiction and prevent overdoses. Their analysis also finds that opioid overdoses have a financial cost of $78.5 billion per year, including nearly $29 billion to cover substance use disorder treatment and related healthcare.

Public Health Focus: 9/11 First Responders

Some examples or highlights of recent activities being undertaken in the area include:

- Researchers at the **Albert Einstein College of Medicine** are finding that New York City firefighters exposed to the 9/11 World Trade Center disaster site face an increased risk for developing myeloma precursor disease (MGUS), which can lead to the blood cancer multiple myeloma. Their analysis, conducted in partnership with Montefiore Health System, the Fire Department of the City of New York (FDNY) and Memorial Sloan Kettering Cancer Center, was published in JAMA Oncology. Other focused research is showing how exposure to 9/11 World Trade Center (WTC) dust is associated with a significantly increased long-term risk of cardiovascular disease (CVD). The study finds that those who arrived first at the WTC site-when the air-borne dust was thickest-have a 44% increased risk of CVD compared to those who arrived later in the day.
- At **NYU Grossman School of Medicine**, researchers are exploring how the natural breakdown of chemicals may guard against lung damage in certain 9/11 first responders. Their analysis explores how the presence of chemicals made as the body breaks down fats, proteins and carbohydrates can predict whether 9/11 first responders exposed to toxic dust at the WTC site subsequently develop lung disease.
- Researchers at the **Renaissance School of Medicine at Stony Brook University** are examining neuroscience effects on 9/11 first responders. Recent research has provided further evidence that first responders are at risk for developing dementia. In a presentation at the Alzheimer's Association International Conference, analysis highlights how first some responders may display signs of cognitive impairment, neuroradiological abnormalities, and changes in their blood similar to that seen in Alzheimer's disease patients and those with related dementias. Researchers are also studying how post-traumatic stress disorder (PTSD) is associated with cognitive impairment onset in 9/11 first responders. A new study led by the school monitors the health of 1,800 responders, revealing that PTSD is strongly associated with onset of mild cognitive impairment. A new pilot study led by researchers at Stony Brook University and the Stony Brook World Trade Center Health and Wellness Program suggests that there may also be a link between chronic PTSD in responders and neurodegeneration.

Appendix B: Additional Methodology Discussion

Description of IMPLAN Impact Model

The standard analytical technique for the quantification of expenditure impacts is input-output (I-O) analysis is used for this study. I-O analysis, the technique deployed by TEConomy for the economic impact estimations within this report, uses a matrix representation of an economy that quantifies the interrelationships and impacts of spending by one sector of the economy (e.g., education) on all other sectors, consumers, and government. TEConomy uses the IMPLAN software and data systems for application of I-O analysis.

The IMPLAN model is the most widely used economic impact model in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state level employment data from the U.S. Bureau of Labor Statistics (BLS) and other economic data from U.S. Bureau of the Census. This analysis used State of New York specific input-output models from IMPLAN, consisting of regional models built using the county-based geographic context of the Empire State Development (ESD) regions as well as the New York State model. Each IMPLAN model uses detailed sector- and region-specific information to estimate spending and other outcomes and gauge potential impacts. The model incorporates detail of 544 individual industry and economic sectors that cover the entire regional or state economy.

Study Limitations

With any study of this magnitude there are certain limitations both in scope and results. These limitations were further acerbated by the requirements and commitments of the 17 AMSNY member medical schools as they responded to the COVID-19 pandemic as it reached and took root in New York and the rest of the U.S. The economic (expenditure) impact data used herein are for the institutions 2018-2019 academic year (2019 fiscal year). This study began with data collection efforts beginning in late 2019. As the pandemic raged, AMSNY and TEConomy put the project on hold. Final data collection was resumed in early 2021. In order to supplement these FY 2019 economic impact results and begin to capture some of the economic and research effects stemming from COVID-19 actions, various research and education data are presented for a combined 2018-2020 period.

Given the enormity and requirements of dealing with the pandemic, not all AMSNY members were able to provide. complete data. As a result, some of the date provided in this report reflect conservative metrics, no doubt undercounting the complete range of impacts generated and some functional impacts must be addressed through discussions and examples as complete data were not available. Due to limitations in travel and contact, research-related and other vignette examples in this report were developed in large part using information collected by AMSNY from its member medical schools as captured in the AMSNY monthly web-publication *Biomedical Research News*.

Finally, this report is not intended to be used to compare one institution to another, but rather is designed to focus on the importance of medical colleges in New York as a collective group.


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