MATHEMATICAL AND PHYSICAL SCIENCES

$1,380,000,000
+$124,040,000 / 9.9%

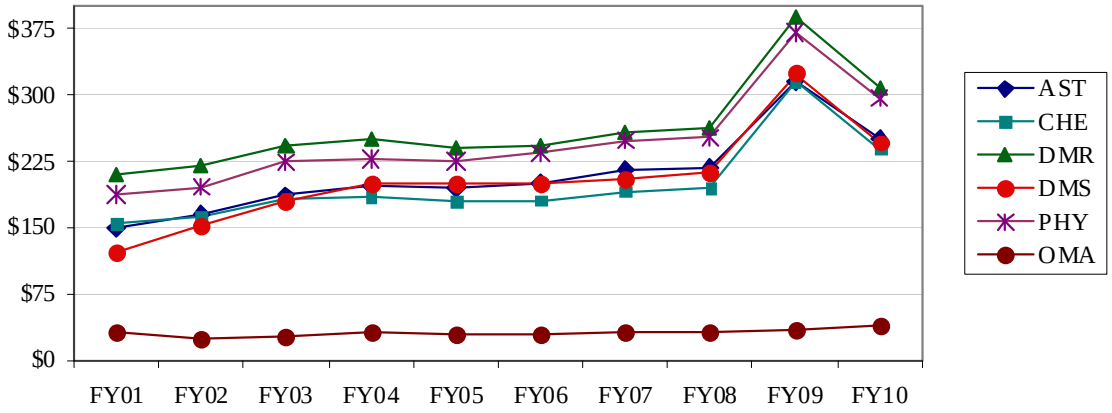
Mathematical and Physical Sciences Funding
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Astronomical Sciences	$217.90	$228.62	$85.80	$250.81	$22.19	9.7%
Chemistry	194.62	211.35	103.00	238.60	27.25	12.9%
Materials Research	262.55	282.13	106.90	308.97	26.84	9.5%
Mathematical Sciences	211.75	226.18	98.00	246.41	20.23	8.9%
Physics	251.64	274.47	96.30	296.08	21.61	7.9%
Office of Multidisciplinary Activities	32.67	33.21	-	39.13	5.92	17.8%
Total, MPS	**$1,171.13**	**$1,255.96**	**$490.00**	**$1,380.00**	**$124.04**	**9.9%**
Major Components:						
Research and Education Grants	773.16	845.24	403.45	934.55	89.31	10.6%
Instrumentation	52.25	47.71	25.95	69.68	21.97	46.0%
Centers Programs	97.37	114.95	-	114.27	-0.68	-0.6%
Facilities Operation & Maintenance	248.35	248.24	60.60	261.50	13.26	5.3%

Totals may not add due to rounding.

The Directorate for Mathematical and Physical Sciences (MPS) supports a broad portfolio of investments in fundamental research, facilities, and instruments that enable discovery and development as well as in integrated education and research activities that contribute to the development of the science and engineering workforce. The portfolio includes MPS participation in NSF-wide and interagency research and education, and emphasizes discovery, innovation, and learning aligned with the overall goals of the Administration and NSF's mission and vision.

MPS Subactivity Funding
(Dollars in Millions)



MPS in Context

MPS provides about 46 percent of federal funding for basic research at academic institutions in the mathematical and physical sciences, ranging from about 35 percent in physics to over 60 percent in the mathematical sciences.

MPS funding enables research that ranges from basic, fundamental, curiosity-driven research to technologies that have immediate societal and economic impact. Basic research plants the seed-corn of creative and innovative ideas, some of which has been proven to lead to technologies that transform society and enhance our Nation's global economic competitiveness. MPS-funded research underpins biomedical advances and national security technologies. Support for this broad range of research has been documented in numerous studies conducted by the National Academies (e.g., *Rising Above the Gathering Storm*, 2006) and professional societies (e.g., *Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine*, 2005).

MPS is the steward of numerous major research facilities (astronomical observatories, gravitational-wave and neutrino observatories, light sources, high magnetic field laboratories, nuclear physics laboratories), which together form an important component of the Nation's scientific research infrastructure. MPS strategically invests in the development of the next generation of facilities and is increasing its Centers programs while protecting individual investigators and small group investigators. MPS emphasizes the entire pipeline of the science and technology workforce, supporting undergraduate and graduate students as well as postdoctoral fellows.

MPS also invests in sustainable energy, climate research, education, nano-science, cyber-enabled discovery and innovation and convergence of the physical sciences with the life sciences.

The FY 2010 Request for the MPS includes $10.0 million *to leverage* activities across MPS aimed at increasing support for transformative research. Examples of mechanisms to be used for identifying potentially transformative research include special solicitations and competitions, and increased use of specialized funding mechanisms, notably NSF's EAGER (EArly-concept Grants for Exploratory Research).

Directorate-wide Changes and Priorities

Research and Education Grants (+$88.63 million, to a total of $933.87 million).

MPS assigns high priority to providing strong support of individual investigators and small groups pursuing fundamental research across all MPS disciplines. This is paramount to meeting science opportunities in MPS disciplines, to maintaining a competitive workforce in these areas, and to enabling a vital interdisciplinary effort. Extraordinary research opportunities exist in all of the MPS sciences, as well as opportunities to connect with National priorities. Within the context of disciplinary and interdisciplinary research, MPS emphasis areas interact with each other, with National priorities, and with the overall portfolio in a synergistic fashion, reflecting commonalities in the underlying complex physical systems. In FY 2010, MPS will continue its research in areas such as Physics of the Universe, Mathematical Sciences, Complex Biological Systems, MPS-Life Science interface, Quantum Information Sciences, and Sustainability.

Major emphases in Research and Education in FY 2010 include:

- *Science and Engineering Beyond Moore's Law (+$10.0 million, to a total of $18.68 million).* MPS

leads NSF's effort in Science and Engineering Beyond Moore's Law (SEBML)[1], a multidisciplinary research investment with strong ties to economic competitiveness and potential for transformation. Related to both nanotechnology and cyberinfrastructure, it builds on past NSF investments in these areas and energizes them with new directions and challenges. SEBML activities include research into new materials, devices, and processes that exploit the capability to create and manipulate specific quantum states and new algorithms that take advantage of hardware and architecture characteristics to deliver maximal total computing power, including those that utilize quantum interactions. MPS works with the other directorates in areas such as developing new connection architectures with new control principles, massive parallelism, and designed asynchronicity and indeterminacy and creating new software that allows the effective use of new devices. MPS's SEBML investment crosses the Chemistry, Materials Research, Mathematical Sciences, and Physics Divisions.

- *Climate Research (+$7.0 million, to a total of $7.0 million).* In FY 2010, MPS will invest in NSF's Climate Change effort. Two major themes under consideration are understanding molecular interactions at atmospheric interfaces and development of mathematical methods and effective computational techniques needed for simulation and analysis of climate models. The long-term goal of this program is to assert U.S. leadership in understanding causes and consequences of climate change and to develop effective strategies in response.

- *Cyber-enabled Discovery and Innovation (CDI) (+$6.75 million, to a total of $18.56 million).* MPS will continue its collaborations with other directorates in NSF's high priority CDI activities, creating synergy with related work in Cyberinfrastructure and enhancing the government-wide Networking and Information Technology Research and Development (NITRD) effort. MPS supports CDI out of the research of all its divisions, with the Division of Mathematical Sciences investing most heavily. Modeling, algorithms, software, and simulation are essential research components in all MPS disciplines, as are virtual computing networks accessing common databases and analytic tools. Examples include the synthesis and characterization of new molecular systems; the prediction and discovery of new materials and new states of matter; the creation, manipulation, and control of quantum mechanical states in solid and condensed states of matter; the development of mathematical structures to describe complex, multi-scale networks as typified by electrical power grids and the internet; and the creation of visualization and "mining" techniques for both sparse and dense data.

- *CAREER (+$5.46 million, to a total of $49.50 million).* The CAREER program remains the primary mechanism for jump-starting junior faculty toward independent careers in research and education, a key Administration priority. All MPS divisions invest in CAREER.

- *Graduate Research Fellowship (+$4.11 million, to a total of $4.11 million).* To promote the education and participation in the research enterprise of the next generation of mathematical and physical scientists, MPS is contributing to the NSF-wide Graduate Research Fellowship program. This is part of a Presidential Initiative to triple the number of new fellowships by FY 2013.

Instrumentation *(+21.97 million, to a total of $69.68 million).*

In FY 2010 MPS will make a focused investment across the directorate in Research Resources, particularly mid-scale instrumentation. For example, in the Division of Astronomical Sciences, an additional $9.65 million will support instrumentation activities such as the Advanced Technologies and Instrumentation (ATI) grants program, technology development for future large facilities, such as the Giant Segmented Mirror Telescope (GSMT) and the Large Synoptic Survey Telescope (LSST), and

[1] Moore's Law: In 1965 the co-founder of Intel, Gordon E. Moore, predicted that computing power based on semiconductor integrated circuits would double every 18 to 24 months, a predication that has staying power for over 40 years.

large projects and experiments beyond the scale of single investigators. In the Division of Materials Research, an additional $5.14 million will support the design and construction of a variety of mid-scale instruments, including synchrotron and neutron beamlines, high-field magnets, detectors, and preparation environments at major U.S. facilities. The funding increase also includes support for research and development on X-ray coherent light sources. The Divisions of Physics and Chemistry will increase their research resources support by $1.80 million and $1.50 million respectively.

MPS Centers *(-$680,000, to a total of $114.27 million).*

MPS manages or co-funds over forty different individual centers in five centers program areas. For more information, see the Centers section in the NSF-Wide Investments chapter. Major funding changes in FY 2010 include:

- *Centers for Chemical Innovation (CCIs) (+$8.50 million, to a total of $24.0 million).* CCIs promote the integration of research and education through the extensive involvement of students and postdoctoral fellows in all phases of work, as well as partnerships with industry and National Laboratories. CCIs are expected to be agile, responding to opportunities as they arise, and to creatively engage the public. The FY 2010 request reflects the establishment of two new Phase II Centers (for a total of five) and four new Phase I Centers (for a total of eleven).

Facilities Operations and Maintenance *(+13.26 million, to a total of $261.50 million).*

MPS manages over ten multi-user research facilities. Detailed information on each can be found in the Facilities chapter. Major funding changes in FY 2010 include:

- *Atacama Large Millimeter Array (ALMA) (+*$6*.57 million, to a total of $17.57 million).* ALMA operations continue to ramp up in preparation for early science expected to start in mid-2011, with a first call for proposals from the science community in late 2010. FY 2010 funding will provide for growth in staff for Chile operations; user support, development, and implementation of the North American ALMA data archive and software systems; and education, training, and engagement of the North American scientific user community.

- *National High Magnetic Field Laboratory (NHMFL) (+$5.45 million, to a total of $31.95 million).* The FY 2010 increase for NHMFL will allow the facility to strengthen user support programs and in-house research, education, and training at all levels as well as meet increased operation costs. FY 2010 funding will cover increased electricity and cryogenics costs, purchase of critical parts for replacement of aging equipment, completion of the planned split-magnet development, and support for technical staff, education, and training.

Program Evaluation and Performance Improvement

The Performance Information chapter describes the Foundation's performance evaluation framework, which is built upon the four strategic outcome goals in NSF's Strategic Plan: *Discovery*, *Learning*, *Research Infrastructure*, and *Stewardship*. Performance evaluation is conducted at all levels within the Foundation, using both qualitative and quantitative measures – including an agency-wide annual review of research and education outcomes by an external expert committee and periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Other performance indicators, such as funding rates, award size and duration, and numbers of people supported on research and education grants, are also factored into the performance assessment process.

In FY 2009, a MPS Committee of Visitors (COV) review took place for the Division of Physics. All MPS Divisions are responding to and implementing recommendations from recent COVs. COVs for the Divisions of Chemistry and Mathematical Sciences are scheduled for 2010.

In addition, the National Research Council of the National Academy of Sciences is currently preparing the Astronomy and Astrophysics Decadal Survey. Funded by NSF, NASA, and Department of Energy, the Committee on Astro2010 is surveying the fields of space- and ground-based astronomy and astrophysics, recommending priorities for the most important scientific and technical activities of 2010-2020. The Committee hopes to release an unedited, pre-publication report to the public in mid-2010.

Number of People Involved in MPS Activities

	FY 2008 Estimate	FY 2009 Estimate	FY 2009 ARRA Estimate	FY 2010 Estimate
Senior Researchers	7,316	7,724	1,134	8,191
Other Professionals	1,901	1,997	209	2,113
Postdoctorates	2,160	2,348	645	2,486
Graduate Students	7,606	8,021	2,224	8,474
Undergraduate Students	6,163	6,244	920	6,535
K-12 Teachers	347	306	68	319
K-12 Students	280	304	91	313
Total Number of People	25,773	26,944	5,291	28,431

MPS Funding Profile

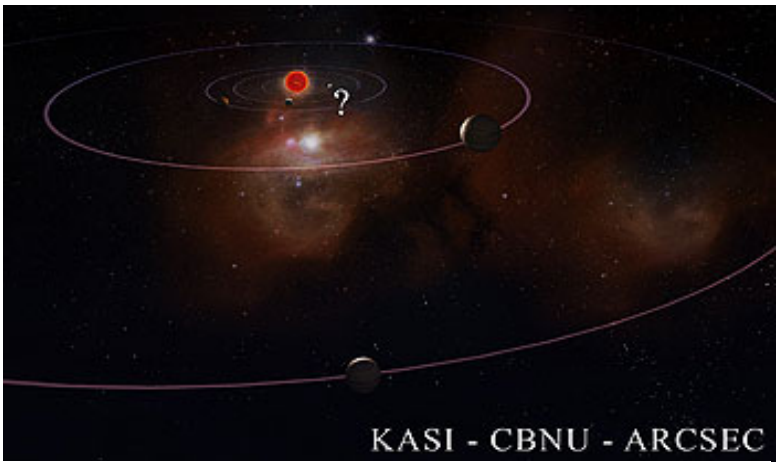
	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate
Statistics for Competitive Awards:			
Number of Proposals	7,839	8,400	9,300
Number of New Awards	2,271	3,400	2,750
Regular Appropriation	2,271	2,400	2,750
ARRA	-	1,000	-
Funding Rate	29%	40%	30%
Statistics for Research Grants:			
Number of Research Grant Proposals	6,470	6,600	7,000
Number of Research Grants	1,720	2,600	1,950
Regular Appropriation	1,720	1,850	1,950
ARRA	-	750	-
Funding Rate	27%	39%	28%
Median Annualized Award Size	$104,999	$107,000	$107,000
Average Annualized Award Size	$132,748	$145,000	$145,000
Average Award Duration, in years	3.1	3.1	3.1

Recent Research Highlights

► **A Stellar Discovery:** The biggest black hole ever discovered is 15.7 times the mass of our Sun and about 3 million light years from Earth in a neighboring galaxy named M33. Contrary to popular myth, black holes are not empty space but the dark, dense remnants of giant stars that have burned themselves out. An international team of scientists detected the massive black hole and the exceptionally large companion star that it orbits – 70 times the size of our Sun – with a combination of X-ray data from NSF's Gemini Observatory and ground-based optical images and spectroscopy data from NASA. The discovery is not only exceptional, it is puzzling. The star that created the black hole was even heavier than its behemoth companion. At that size, the star would have been large enough to share its atmosphere with its companion, yet apparently it did not. This observation challenges current theories of how binary pairs exchange mass.

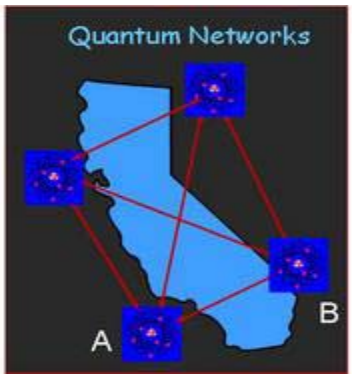
An artist's conception of the largest black hole discovered and its companion star. This unusual pair of stellar objects resides in nearby galaxy M33 and challenges current theories of how binary pairs exchange mass. *Credit: Illustration: NASA/CXC/M.Weiss.*

► **Star Systems Like Our Own May Be Common:** The discovery of a solar system nearly 5,000 light years away with scaled-down versions of Jupiter and Saturn suggests our galaxy could contain many star systems similar to our own. Although the star is much dimmer than our Sun, temperatures at both planets are likely to be similar to that of Jupiter and Saturn because they are closer to their star. One of the planets has 70 percent of Jupiter's mass, and another has 90 percent of Saturn's mass. The two planets were revealed when the star they orbit crossed in front of a more distant star being observed from Earth. The nearer star magnified the light shining from the farther star in a process known as "gravitational microlensing." The data analyzed for this discovery was collected on 11 different ground-based telescopes in countries around the world, including New Zealand, Tasmania, Israel, Chile, the Canary Islands, and the United States.



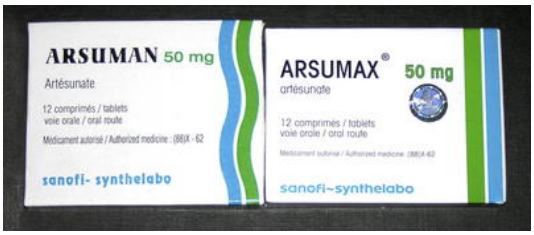
Astronomers have discovered a solar system analogous to ours, containing scaled-down versions of Saturn and Jupiter. Their finding suggests that our galaxy hosts many star systems like our own. *Credit: KASI - CBNU - ARCSEC (KASI is the Korea Astronomy and Space Science Institute, CBNU is the Chungbuk National University, and ARCSEC is Astrophysical Research Center for the Structure and Evolution of the Cosmos.)*

► **A Quantum Leap:** If technology continues to follow "Moore's Law," the continually shrinking size of circuitry packed onto silicon chips will eventually reach a point where individual elements are no larger than a few atoms. At this scale, the laws switch from classical physics to quantum physics. The concept of quantum technology, which would be exponentially more powerful than today's computer technology, addresses this concern. Researchers at Caltech have succeeded in showing the operation of "quantum repeaters," a crucial component of quantum information technology. The device distributes "entanglement" into segments in a way that could lead to commercially viable quantum technology. Entanglement occurs when the behavior of two particles or components are correlated in spite of the physical distance separating them. Einstein once referred to the phenomenon as "spooky action at a distance." The significant achievement of the Caltech group is that they demonstrated an initial version of one segment.

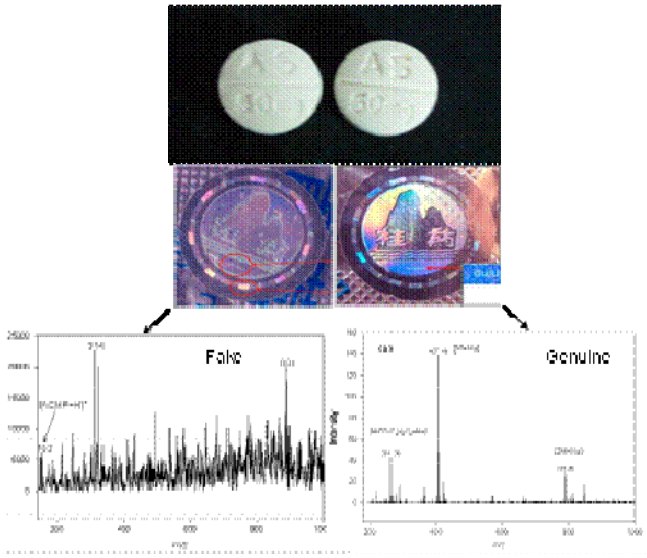


Quantum networks based on entanglement distribution could be used for secure communication, with its security guaranteed by the laws of physics. *Credit: H. Jeff Kimble, Caltech.*

► **Malaria Drug Counterfeiters Caught:** Researchers at the Georgia Institute of Technology developed a rapid chemical assay based on mass spectrometry to screen the quality of malaria drugs in Asia and four African countries. Motivation for this research came from a recent onslaught of counterfeit malaria tablets in those countries. The bogus tablets contained little or no therapeutic levels of an active ingredient known as artesunate. Malaria remains a public health problem in the countries subjected to the fake tablets, with estimates in excess of 2 million cases per year and more than 10,000 deaths per year. The research team used their method to test the quality of hundreds of tablets in a short period of time. The work allowed evidence-based suggestions as to where some of the fake artesunate was manufactured. Armed with this information, authorities in China were able to arrest some of the suspects.



Genuine (Right) and Counterfeit (Left) Arsumax (Artesunate) from Cameroon. *Credit: Manuela Sunjio.*



Contrasting mass spectra compare chemical signatures for counterfeit and genuine artesunate tablets. *Credit: Facundo Fernández.*

► **New Mathematical Models Lead to Improved Stent Design:** Coronary artery disease is the major cause of heart attack in the United States. Clinical treatments for the disease can only be studied in detail with a reliable model that describes the response of arterial walls to pulsating blood flow. A research group at the University of Houston has developed mathematical tools to study the interaction of arterial walls and pulsating blood flow. The group also has made considerable progress designing improved stents for propping open narrowed arteries and better stent-grafts that are more compatible with the human body. Nine months after publishing their results in Endovascular Today, Endologix, Inc., launched a new stent-graft on the market with the exact geometry suggested in the publication.

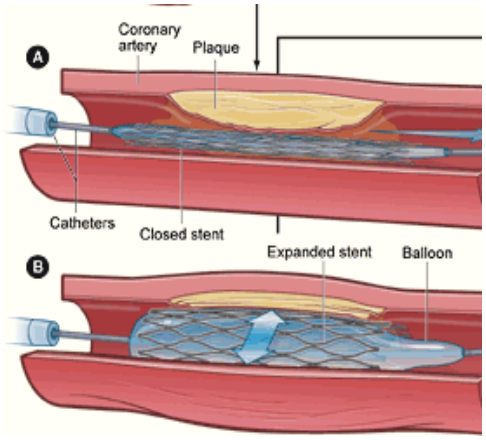
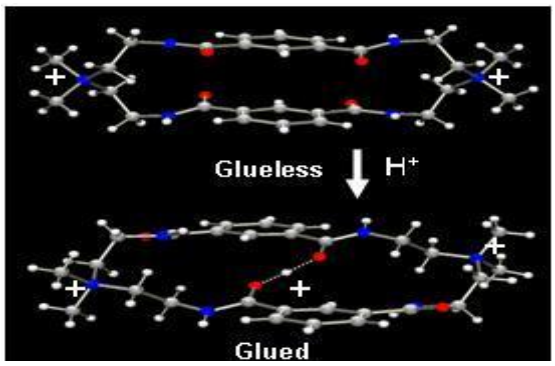
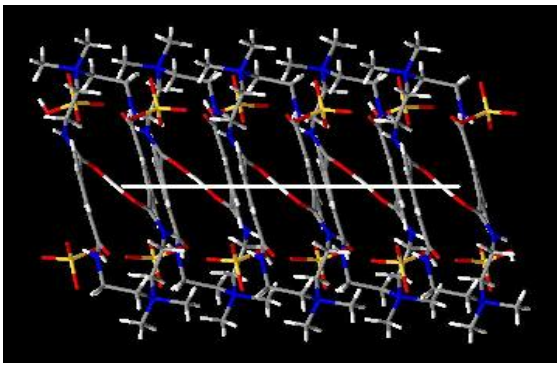


Diagram of coronary angioplasty and stent placement. Image of an artery prior to and immediately following stent expansion. Mathematical modeling is used to optimize the stent design in order to minimize limb thrombosis rates. *Credit: http://en.wikipedia.org/wiki/National_Institutes_of_Health.*

► **A Special Bond:** Using a technique known as X-ray crystallography, scientists at the University of Kansas discovered an especially strong form of hydrogen bond known as a Low Barrier Hydrogen Bond that links two atoms at very short distances. The simple finding of a Low Barrier Hydrogen Bond changing the shape of a cyclic molecule may influence concepts about chemical bonding in biological systems. Low Barrier Hydrogen Bonds are much stronger than ordinary hydrogen bonds and were believed to be less common; however, if they are more prevalent than anticipated, as suggested by this finding, they could play a major role in protein folding, enzymatic activity, and the flow of ions across cell membranes. Unraveling the chemistry at the atomic level of this simple system may help explain more complex biological processes. Ultimately this knowledge may lead to more effective ways of addressing enzymatic "problems" such as diseases that affect living species.

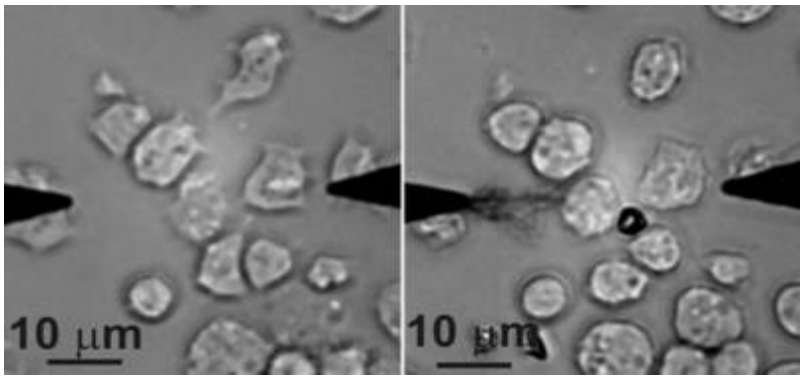


Without any hydrogen bonds, the top cyclic molecule is symmetrical. With a Low Barrier Hydrogen Bond, the bottom cyclic molecule is skewed. This type of bond is unique in that it induces a positively charged molecule to be attracted to the positively charged hydrogen atom. Under normal circumstances, a positive charge is attracted to a negative charge and repels another positive. (Colors: red, oxygen; blue, nitrogen; gray, carbon; white hydrogen.) *Credit: Image provided by Kristin Bowman-James, Department of Chemistry, University of Kansas.*



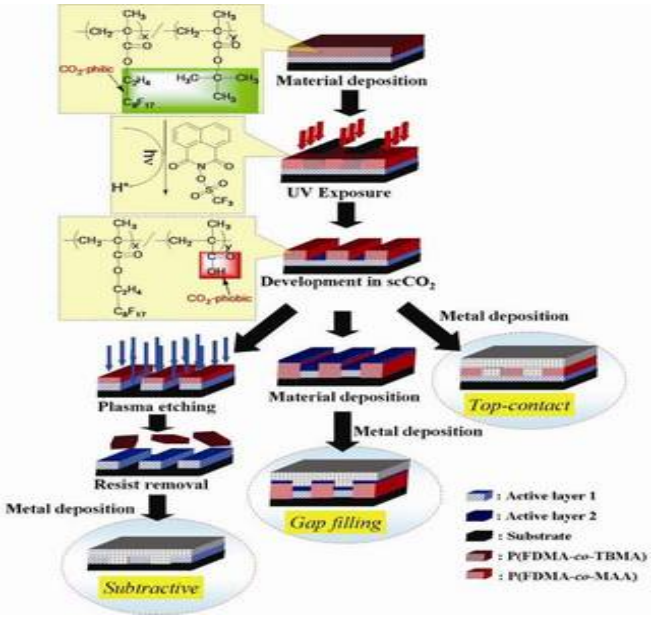
The solid white line in the image shows the direction of the hydrogen (H+) channel or the "proton channel" in the stacked cyclic molecules of a crystal. The yellow and red species are bisulfate ions in the crystal. *Credit: Image provided by Kristin Bowman-James, Department of Chemistry, University of Kansas.*

► **A Nanowire's Tiny Touch Offers Huge Potential for Neuroscience:** Tiny electric wires, one one-thousandth of the size of a human hair, called nanowires, will allow scientists to electrically stimulate a single cell and study the cell's response. A new process developed at Oklahoma State University allows precise control of the wire's diameter, along with growing the wire and attaching it to the cell in a single step. The process consists of passing an alternating voltage across two electrodes immersed in a salt solution. The process produces a perfectly formed nanowire between the two electrical contacts. The researchers control the diameter of the nanowire by varying the frequency of the alternating voltage – the higher the frequency, the smaller the diameter. Using nickel electrodes, the researchers successfully grew a nanowire next to a live cell. This research offers a radically new technology for studying and controlling cells at the nanoscale. Its impact on neuroscience can already be seen.



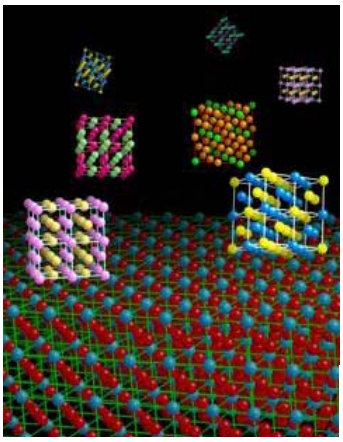
Oklahoma State researchers produce a cell-wire interface by applying 100 milli-electronvolts to the wire. *Credit: Sent by Bret Flanders.*

► **Organic Semiconductors Make Serious Progress:** Researchers at Cornell University and the University of Melbourne, Australia, report their organic semiconducting device is a major step forward in creating a low-cost alternative to traditional electronic devices made of silicon and other inorganic materials. Ordinary solvents used to fabricate semiconducting devices are very damaging to organic materials. To get around this problem, the researchers developed a novel photolithographic patterning process that employs supercritical carbon dioxide as a solvent. Supercritical carbon dioxide has properties midway between a liquid and a gas. It's becoming a more common solvent in processes that range from dry cleaning clothes to decaffeinating coffee. The researchers' organic light emitting device means that rolled-up computer screens, light emitting clothes, and more efficient solar energy harvesting are one step closer to reality.



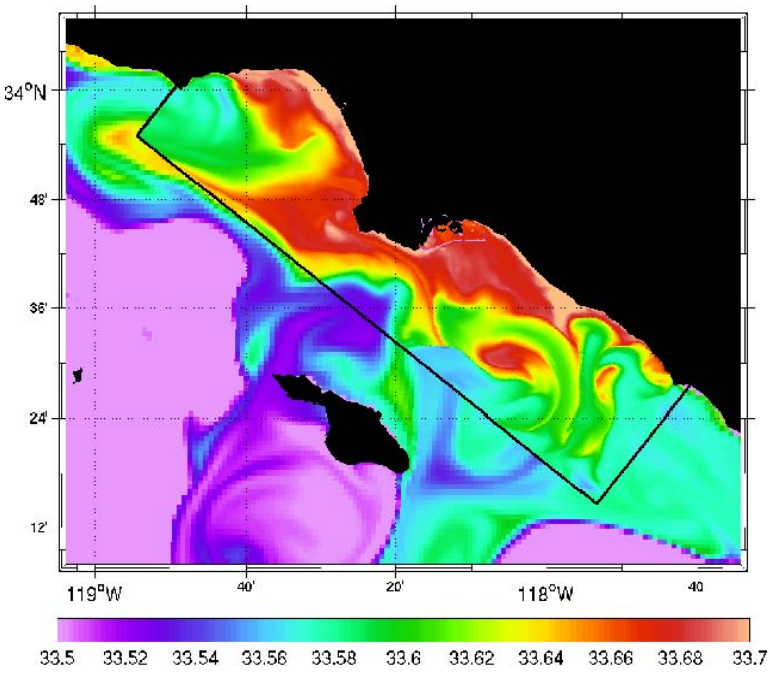
Schematic diagram of photolithographic patterning process in supercritical carbon dioxide. *Credit: Christopher Ober, Cornell University.*

► **Absence Makes a Researcher Grow Curious:** A researcher at Brigham Young University wondered why nature favored some arrangements of the atoms that make up materials over others. He enumerated all the possible regular and periodic arrangements of atoms allowed by geometry and found that some patterns on his list were never seen by scientists. By measuring the effect of chemical bonding, he discovered a trend in nature toward arrangements that are most ordered. Still, some very "ordered" structures were absent. The researcher's own computer calculations predicted some of these absentee structures. This research led to some likely candidates for new arrangements of atoms in crystals that have never been seen, including some compounds of silver, platinum, palladium. and cadmium. Experimentalists are working to see if these new structures can be observed. These results demonstrate progress towards using computers to design new materials with desired properties.



The figure shows possible arrangements of atoms in crystalline materials. This work opens a new avenue in the quest to discover new materials and to predict how atoms are arranged in materials when only the identity of their constituent atoms is known. *Credit: Gus Hart.*

► **Math Model Gives Insight to How Natural Forces Change Shorelines:** A team of investigators from the University of Arizona has developed mathematical tools to model the natural forces that reshape shorelines. Their work offers a powerful new technique to predict the effects of storms and also the effectiveness of remediation efforts. Their tools are ideally suited to model sand bars created by storms – a process previously inaccessible to models of shore processes. A comparison of the team's modeling results with field experiments carried out by the U.S. Army Corps of Engineers is in agreement. Future development of these mathematical modeling tools will allow engineers to deal more effectively with the enormous challenges posed by the action of water on shore topography.



Instantaneous surface salinity distribution on the 65th Julian day in 2002, when an extensive upwelling event was observed in Southern California Bight. The high-resolution nested simulation is capable of reproducing intense upwelling of subsurface water with higher salinity. *Credit: UCLA oceanic modeling group.*

ASTRONOMICAL SCIENCES

$250,810,000
+$22,190,000 / 9.7%

Astronomical Sciences Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, AST	**$217.90**	**$228.62**	**$85.80**	**$250.81**	**$22.19**	**9.7%**
Major Components:						
Research and Education Grants	68.39	74.00	61.20	83.09	9.09	12.3%
Instrumentation	25.50	23.28	6.00	31.53	8.25	35.4%
Centers	3.32	2.66	-	-	-2.66	-100.0%
Science & Technology Center	*3.32*	*2.66*	-	-	*-2.66*	*-100.0%*
Facilities	120.69	128.68	18.60	136.19	7.51	5.8%
Gemini Observatory	*18.69*	*18.71*	-	*19.10*	*0.39*	*2.1%*
Nat'l Astronomy & Ionosphere Ctr.	*10.72*	*9.60*	*3.10*	*8.40*	*-1.20*	*-12.5%*
Nat'l Optical Astronomy Observ. [1]	*38.55*	*39.58*	*10.10*	*41.60*	*2.02*	*5.1%*
Nat'l Radio Astronomy Observ.	*45.09*	*49.79*	*5.40*	*49.52*	*-0.27*	*-0.5%*
Atacama Large Millimeter Array	*7.64*	*11.00*	-	*17.57*	*6.57*	*59.7%*

[1] NOAO includes the National Solar Observatory and the Telescope System Instrumentation Program.

The Division of Astronomical Sciences (AST) is the federal steward for ground-based astronomy in the U.S., working in partnership with private institutions to enhance overall observing capacity and capability. Research support covers an array of observational, theoretical, and laboratory research aimed at understanding the origins and characteristics of planets, the Sun, other stars, our galaxy, extragalactic objects, and the structure and origin of the Universe through awards to individual investigators, small groups, and national facilities. AST supports the development of advanced technologies and instrumentation, planning and design for future observational facilities and collaborative projects in astronomy, and management of the electromagnetic spectrum for scientific use. About 14 percent of the AST portfolio is available for new research grants. The remaining 86 percent is used primarily to fund continuing grants made in previous years including approximately 54 percent to support facilities.

AST provides the U.S. share of funding for the operation of the international Gemini Observatory and supports the operation of the National Astronomy facilities: the National Astronomy and Ionosphere Center (NAIC); the National Optical Astronomy Observatory (NOAO), including the National Solar Observatory (NSO); and the National Radio Astronomy Observatory (NRAO), including the U.S. share of the international Atacama Large Millimeter Array (ALMA) project. These major world-class facilities provide access to a wide range of observational resources on a competitive basis and serve over 3000 users annually.

Changes by Activity

Individual investigator program (+7.50 million, to a total of $57.0 million).

This is primarily for activities in the Astronomy and Astrophysics Research Grants and the Education and Special Programs, to address priorities expressed in the Interagency plan for the Physics of the Universe program.

CAREER program (+$1.0 million, to a total of $4.10 million).
This is to increase the division's support for beginning faculty.

Instrumentation Activities (+$8.25 million, to a total of $31.53 million).
This funds increased activity in partnership with the academic community, taking advantage of opportunities for scientific discovery that requires instrumentation and experimentation at the mid-scale range of $5.0 million to $20 million.

Science and Technology Center for Adaptive Optics
Funding ends in FY 2010 as ten year support for this center sunsets as planned.

Astronomy Facilities (+$7.51 million, to a total of $136.19 million). Changes are:

- *Gemini Observatory (+$390,000, to a total of $19.10 million).* This will enable continued operating and visitor support per the international partnership agreement.

- *NAIC (-$1.20 million, to a total of $8.40 million).* AST support is reduced following the recommendation of the AST Senior Review. This will result in reduced levels of programming, user support, and observing time.

- *Combined NOAO/NSO (+$2.02 million, to a total of $41.60 million).* Within this total, funding for NOAO primary operations and maintenance funding increases by $1.92 million to $27.50 million and the Telescope System Instrumentation Program (TSIP), administered through NOAO, increases by $1.0 million to $5.0 million in FY 2010. NSO funding decreases by $900,000 to $9.10 million, with the Advanced Technology Solar Telescope (ATST) being funded from the Major Research Equipment and Facilities Construction (MREFC) account. For more information on ATST, see the MREFC chapter.

- *NRAO (-$270.000, to a total of $49.52 million)* and *ALMA operations ($+$6.57 million, to a total of $17.57 million).*

Detailed narratives on each facility can be found in the Facilities chapter.

CHEMISTRY

$238,600,000
+27,250,000 / 12.9%

Chemistry Funding
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, CHE	**$194.62**	**$211.35**	**$103.00**	**$238.60**	**$27.25**	**12.9%**
Major Components:	194.62					
Research and Education Grants	165.89	180.47	73.25	195.10	14.63	8.1%
Instrumentation	13.44	7.97	14.75	14.75	6.78	85.1%
Centers	13.79	21.01	-	26.85	5.84	27.8%
Centers for Chemical Innovation	*7.87*	*15.50*	-	*24.00*	*8.50*	*54.8%*
Science & Technology Centers	*3.32*	*2.66*	-	-	*-2.66*	*-100.0%*
Nanoscale Science & Engr. Centers	*2.60*	*2.85*	-	*2.85*	-	-
Facilities	1.50	1.90	15.00	1.90	-	-
Nat'l High Magnetic Field Lab.	*1.50*	*1.50*	-	*1.50*	-	-
Nat'l Nanofabrication Infra. Network	-	*0.40*	-	*0.40*	-	-

Chemistry is a bold and creative science that finds efficient ways to prepare nature's compounds and to make ones that have never existed. Investment in basic molecular sciences is a major contributor to the $637.0 billion U.S. chemical industry. Approximately one third of the industrial output of the U.S. derives from the chemical industry, which in turn requires more than 2,000 PhD graduates per year to operate efficiently. The NSF Division of Chemistry (CHE) plays a crucial role in the vitality of the basic research enterprise, especially in academic laboratories, and needs increased resources to sustain, expand, and improve the community's ability to perform transformative and translational research. In general, about 37 percent of CHE's portfolio is available for new research grants. The remaining 63 percent funds continuing grants made in previous years.

Changes by Activity

Research and Education Grants (+$14.63 million, to a total of $195.10 million).

This will fund the expected increase in the number of unsolicited proposals in basic research and education in chemistry due to a realignment of the Division's disciplinary programs, expected to take place starting in FY 2010. Advances in fundamental science and education that will impact national priorities in areas such as the environmental health and safety of nanomaterials, basic research that underpins improvement in climate models, catalysis enabling sustainability and energy research, the link between chemistry and the life sciences, and cyberinfrastructure. FY 2010 support includes:

- *Molecular electronics and Science and Engineering Beyond Moore's Law (+$3.0 million, to a total of $6.08 million).*
- *Cyber-enabled Discovery and Innovation (+$1.25 million, to a total of $2.45 million).*
- *Climate Research program (total of +$5.0 million).*
- *CAREER program (+$300,000, to a total of $20.80 million).*

- *American Competitiveness in Chemistry Fellowship Program (total of $2.0 million).* This program provides consistent bridges to the top ranked young talent in chemistry as they progress to the professoriate.

- *Discovery Corps Fellowship Program (total of $1.50 million).* This program will be adapted in FY 2010 to address public education about global chemistry issues.

- *Graduate Research Fellowship Program (total of $1.59 million).*

- *NSTC Priorities* – the National Nanotechnology Initiative, Networking and Information Technology Research and Development, and Climate Change Technology Program – will see increased support from CHE.

- The *Environmental Molecular Science Institutes* will be completely phased out in FY 2010. A new program, Environmental Chemical Sciences, will be initiated to provide continuity in this important area.

Instrumentation and Instrument Development (+$6.78 million, to a total of $14.75 million). In FY 2010, facility funding will be maintained but no increases are requested.

Centers (+$5.84 million, to a total of $26.85 million. This includes:

- *Centers for Chemical Innovation (+$8.50 million, to a total of $24.0 million*). This program is designed to inspire research on strategic, transformative "big questions" in basic chemical research. This funding reflects the establishment of two additional Phase II Centers (for a total of five) and four new Phase I Centers (for a total of eleven).

- *Center for Environmentally Responsible Solvents and Processes*. Funding for this Science and Technology Center ends as ten-year support sunsets as planned in FY 2010.

MATERIALS RESEARCH

$308,970,000
+$26,840,000 / 9.5%

Materials Research Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, DMR	**$262.55**	**$282.13**	**$106.90**	**$308.97**	**$26.84**	**9.5%**
Major Components:						
Research and Education Grants	136.29	149.94	78.00	159.27	9.33	6.2%
Instrumentation	9.98	10.00	5.20	15.14	5.14	51.4%
Centers	73.13	84.72	-	81.54	-3.18	-3.8%
Materials Research Sci. & Engr. Centers	*57.15*	*68.51*	-	*66.01*	*-2.50*	*-3.6%*
Nanoscale Science & Engr. Centers	*7.98*	*8.21*	-	*8.21*	-	-
Science & Technology Centers	*8.00*	*8.00*	-	*7.32*	*-0.68*	*-8.5%*
Facilities	43.15	37.47	23.70	53.02	15.55	41.5%
Nat'l High Magnetic Field Lab.	*26.25*	*25.00*	*5.00*	*30.45*	*5.45*	*21.8%*
Cornell Electron Storage Ring	-	*1.00*	*6.50*	*6.60*	*5.60*	*560.0%*
Cornell High Energy Synchrotron Source	*5.60*	*2.51*	*7.20*	*6.67*	*4.16*	*165.7%*
Nat'l Nanofabrication Infra. Network	*2.85*	*2.65*	-	*2.65*	-	-
Other MPS Facilities[1]	*8.45*	*6.31*	*5.00*	*6.65*	*0.34*	*5.4%*

[1] Other MPS Facilities = SRC, CHRNS, CheMatCARS

The Division of Materials Research (DMR) advances the intellectual frontiers of materials research and is a critical component of U.S. competitiveness. DMR awards enable the science and engineering community to make new discoveries about the fundamental behavior of matter and materials; to create new materials and new knowledge about materials phenomena; to address questions about materials that often transcend traditional scientific and engineering disciplines and lead to new technologies; to prepare the next generation of materials researchers; to develop and support instruments and facilities that are crucial to advance the field; and to share the excitement and significance of materials and condensed-matter science with the public at large.

DMR supports a balanced portfolio of research topics through individual investigator grants, small groups, centers, and awards for instrumentation and user facilities, with considerable emphasis on interagency and international partnerships to advance materials research and education. DMR Centers address major interdisciplinary research challenges in materials and condensed-matter sciences. The division also supports world-class facilities for high magnetic fields, synchrotron radiation, and neutron scattering, and provides partial support for the National Nanofabrication Infrastructure Network (NNIN). In general, 17 percent of the DMR portfolio is available for new research grants. The remaining 83 percent is used primarily to fund continuing awards made in previous years, including about 45 percent to fund cooperative agreements in support of centers and facilities.

In FY 2010, approximately 17 percent of the funds requested for DMR will be available for new competitive research grants; about four percent will be available for new instrumentation awards. Almost five percent will support increased funding for DMR facilities. About 3 percent of funds will support new mid-size group/small center research awards that complement current DMR individual investigator, small group, and center awards. Remaining funds will support continuing research and education grants from

previous years, as well as cooperative agreements for centers and facilities. In FY 2008, DMR had a funding rate of just over 20 percent.

Changes by Activity

Research and Education Grants (+$9.33 million, to a total of $159.27 million).
Emphasis will be placed on research relevant to NSF-wide activities, including Science and Engineering Beyond Moore's Law (SEBML) and Cyber-Enabled Discovery and Innovation (CDI); support for SOLAR, a cross-divisional MPS activity in solar energy research; funding for young investigators through CAREER and other awards, and for undergraduate research through Research Experiences for Undergraduates (REU) Site awards.

Instrumentation (+$5.14 million, to a total of $15.14 million).
This includes support for the design and construction of mid-scale instruments relevant to materials research that are too costly to be funded through other NSF instrumentation programs. Funding will allow for two to four additional awards in FY 2010, including research and development on X-ray coherent light sources.

Centers (-$3.18 million, to a total of $81.54 million).
In FY 2010 DMR plans to initiate support for medium-size groups/small materials research centers that effectively bridge the gap between individual investigator/small group research and large center research. Changes include:

- *Materials and Devices for Information Technology Research (-$680,000, to a total of $3.32 million).* Support for this Science and Technology Center is phased out in anticipation of a planned sunset in FY 2011.

- *Materials Research Science and Engineering Centers (-$2.50 million, to a total of $66.01 million).* Funding is decrease as selected centers complete their planned phase outs in 2010.

Facilities (+$15.55 million, to a total of $53.02 million). This includes:

- *NHMFL (+$5.45 million, to a total of $30.45 million).* This will strengthen user support programs by paying for increased electricity and cryogenics costs, purchase of critical parts for aging equipment, and completion of the planned split-magnet development.

- *CESR/CHESS combined (+$9.76 million, to a total of 413.27 million).* CESR as a facility for elementary particle physics concluded in FY 2009; as of FY 2010 CESR is primarily dedicated to providing electrons for the operation of CHESS, a synchrotron radiation facility for X-ray light research. This combined increase will allow continued operation of CESR/CHESS as a synchrotron user facility as well as support of research and development necessary for coherent X-ray sources.

Detailed narratives on each facility can be found in the Facilities chapter.

MATHEMATICAL SCIENCES

$246,410,000
+$20,230,000 / 8.9%

Mathematical Sciences Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, DMS	**$211.75**	**$226.18**	**$98.00**	**$246.41**	**$20.23**	**8.9%**
Major Components:						
Research and Education Grants	211.37	226.08	98.00	246.21	20.13	8.9%
Centers	0.38	0.10	-	0.20	0.10	1.0%
Ctrs. for Analysis & Synthesis	-	*0.10*	-	*0.10*	-	-
Nanoscale Science & Engr. Centers	*0.38*	-	-	*0.10*	-	*N/A*

The Division of Mathematical Sciences (DMS) supports research at the frontiers of fundamental, applied, and computational mathematics and statistics and enables discovery in other fields of science and engineering. In turn, advances in science and engineering that are driven by powerful computing environments and that routinely generate large datasets require development of ever more sophisticated mathematical tools. DMS plays a key role in training the Nation's scientific and engineering workforce. In general, 53 percent of the DMS portfolio is available for new research grants. The remaining 47 percent is used primarily to fund continuing grants made in previous years.

DMS supports research programs in algebra, number theory and combinatorics; analysis; applied mathematics; computational mathematics; foundations; geometry and topology; mathematical biology; probability and statistics. In addition, DMS supports national mathematical sciences research institutes; postdoctoral, graduate and undergraduate training opportunities; and infrastructure, such as workshops, conferences, and equipment.

NSF plays a critical role in the mathematical sciences, as it provides more than 60 percent of all federal support for basic research in the Nation's colleges and universities. In certain areas of the mathematical sciences this percentage is even higher, since NSF supports a broader range of fundamental and multidisciplinary research topics than other federal agencies.

In FY 2008, DMS received 2,181 research proposals and made 678 awards for a funding rate of 31 percent.

Changes by Activity

Mathematical Sciences Research Institutes (+$6.0 million, to a total of $26.0 million).

These institutes are supported in 10-year cycles. The current funding cycle for four of the Institutes ends in FY 2009. They are eligible to re-compete in a FY 2010 Institutes solicitation with other projects. The FY 2010 budget can accommodate an increase in the number and size of Institute awards. Four to six awards are expected.

Cyber-enabled Discovery and Innovation (CDI) (+$5.20 million, to a total of $10.40 million).

CDI uses the mathematical sciences to provide new ways of obtaining insight into the nature of complex phenomena in science and engineering.

Science and Engineering Beyond Moore's Law (SEBML) (+$2.0 million, to a total of $2.75 million).

In parallel with Moore's Law for hardware, SEBML continues the algorithmic "Moore's Law", i.e., the exponential increase in speed of basic computations due to innovative new algorithms, and develops new mathematical frameworks for computation.

Solar Energy Research (SOLAR) (+$1.70 million, to a total of $2.40 million).

SOLAR will support multi-disciplinary teams engaged in potentially transformative research on the efficient harvesting, conversion, and storage of solar energy.

Climate Research (CR) will start in FY 2010 at $1.85 million.

CR will support development of mathematical methods and effective computational techniques needed for simulation and analysis of climate models.

PHYSICS

$296,080,000
+$21,610,000 / 7.9%

Physics Funding
(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, PHY	**$251.64**	**$274.47**	**$96.30**	**$296.08**	**$21.61**	**7.9%**
Major Components:						
Research and Education Grants	158.93	181.46	93.00	211.75	30.29	16.7%
Instrumentation	4.00	7.20	-	9.00	1.80	25.0%
Centers	6.35	6.36	-	5.68	-0.68	-10.7%
Science & Technology Centers	*3.95*	*3.96*	-	*3.28*	*-0.68*	*-17.2%*
Nanoscale Science & Engr. Centers	*2.40*	*2.40*	-	*2.40*	-	-
Facilities	82.36	79.45	3.30	69.65	-9.80	-12.3%
Laser Interferometer Grav. Wave Observ.	*29.50*	*30.30*	-	*28.50*	*-1.80*	*-5.9%*
Large Hadron Collider	*18.00*	*18.00*	-	*18.00*	-	-
IceCube	*1.50*	*2.15*	-	*2.15*	-	-
Nat'l Superconducting Cyclotron Lab.	*19.25*	*20.50*	*2.00*	*21.00*	*0.50*	*2.4%*
Cornell Electron Storage Ring	*14.11*	*8.50*	*1.30*	-	*-8.50*	*-100.0%*

The Division of Physics (PHY) supports fundamental research that leads to the understanding of the make-up of the Universe, from the formation of stars and galaxies to the principles of life processes on earth. This research is spread across a range of physics subfields: atomic, molecular, optical and plasma physics, elementary particle physics, gravitational physics, nuclear physics, particle and nuclear astrophysics, biological physics, physics at the information frontier, and theoretical physics. PHY is the primary supporter of all U.S. research in gravitational physics and the leading supporter of fundamental research in atomic, molecular, and optical physics in the U.S. PHY is a major partner with the Department of Energy (DOE) in support of elementary particle physics, nuclear physics, and plasma physics. PHY also has the only U.S. program designed for the support of physics research in living systems. The development of the most advanced cutting-edge computational resources, innovative technology, and new instrumentation is a key part of physics research, and tools developed by the physics community continuously have major impact in other scientific and engineering fields.

Based on FY 2008 actuals, 19 percent of the PHY portfolio is available for new research grants. 41 percent supports continuing awards made in prior years; eight percent supports cooperative agreements for large-scale centers and institutes; 32 per cent is dedicated for the support of maintenance and operations for three facilities that are a key part of the division portfolio: the Laser Interferometer Gravitational Wave Observatory (LIGO), the Large Hadron Collider (LHC), and the National Superconducting Cyclotron Laboratory (NSCL).

Changes by Activity

Deep Underground Science and Engineering Laboratory (+$4.0 million, to a total of $36.0 million).
This will support design and research and development as part of a coordinated NSF/Department of Energy plan. This is projected to lead to a baseline funding profile for potential construction of the laboratory as well as provide a basis for estimates of future operations and maintenance expenses and research support.

Physics of Living Systems program (+$2.0 million, to a total of $7.80 million).
This will enable the support of an additional twelve investigators and continue the planned growth in this divisional priority area to a target level of $20.0 million.

Research Resources (+1.80 million, to a total of $9.0 million).
This increase will continue the planned growth of funding to fulfill needs for mid-scale instrumentation for all programs within the division.

Disciplinary programs supporting Science and Engineering Beyond Moore's Law and Cyber-Enabled Discovery and Innovation (+$4.25 million, to a total of $6.95 million).
This will increase the number of investigators supported in these areas by a factor of two.

Facilities (+$9.80 million, to a total of $69.65 million). This includes:

- *Cornell Electron Storage Ring (CESR) (-$8.50 million).* This will complete the close-out of PHY funding for operations and maintenance of the facility as a research tool for elementary particle physics. Operations and maintenance funding for CESR will be assumed by the Division of Materials Research as part of the operations of the Cornell High Energy Synchrotron Source (CHESS).

- *Laser Interferometer Gravitational Wave Observatory facility (-$1.80 million, to a total of $28.50 million).* This reflects a change in the operations and maintenance profile to coordinate with the construction profile for the Advanced LIGO project. Funding for LIGO is expected to return to a higher level in FY 2011. (See the MREFC chapter for more details on Advanced LIGO).

- *National Superconducting Cyclotron Laboratory (+$500,000, to a total of $21.0 million).* This brings the funding level back to the originally planned funding profile.

Detailed narratives on each facility can be found in the Facilities chapter.

MULTIDISCIPLINARY ACTIVITIES

$39,130,000
+$5,920,000 / 17.8%

Multidisciplinary Activities Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change Over FY 2009 Plan Amount	Change Over FY 2009 Plan Percent
Total, OMA	**$32.67**	**$33.21**	**-**	**$39.13**	**$5.92**	**17.8%**
Major Components:						
Research and Education Grants	32.02	32.11	-	39.03	6.92	21.6%
Instrumentation	-	1.00	-	-	-1.00	-100.0%
Centers	0.65	0.10	-	0.10	-	-

The Office of Multidisciplinary Activities (OMA) enables and facilitates MPS support of particularly novel, challenging, or complex projects of varying scale, in both research and education, which are not readily accommodated by traditional organizational structures and procedures. This is done primarily in partnership with the five MPS disciplinary divisions to encourage proposals from all segments of the MPS community and especially activities by multi-investigator, multidisciplinary teams pursuing problems on a scale that exceeds the capacity of individual investigators. Most often, these cooperative undertakings involve two or more partners – within MPS or beyond – that join with OMA to foster new directions of scientific understanding and that broaden and enrich education and research training activities in the MPS disciplines.

Because OMA plays a catalytic role in seed-funding new multidisciplinary activities and enabling broadening participation, the portfolio includes relatively few commitments, in terms of continuing grant increments, from prior years. In FY 2010, the majority of OMA funds will be available for new research grants. Additional funds will be available for grants and supplements supporting innovative educational and/or broadening participation projects, sometimes affiliated with large centers and facilities or with professional organizations. Nearly all awards made with OMA funding are managed within the MPS disciplinary divisions.

Changes by Activity

To enable the long-term impact of the MPS community and to extend the intellectual frontiers of the MPS disciplines, OMA will focus on multidisciplinary research addressing fundamental science critical to advancing computing and communications technologies beyond Moore's Law; cyber-enabled discovery and innovation; mathematical and physical scientific foundations of energy sustainability and the environment; the behavior of quantum matter and the limitations of quantum information processing; the interface between MPS and the life sciences to provide insight into the molecular basis of life processes, as well as the synthesis of bio-inspired and biomimetic materials; and team efforts by scientists, mathematicians, and engineers aiming to develop next-generation instrumentation.

To catalyze the development of a diverse, well-prepared science, technology, education, and mathematics (STEM) workforce, OMA will facilitate MPS participation in NSF-wide programs and in other activities that leverage MPS's research investment. These activities enrich education and training at all levels and facilitate the formation of research-based partnerships that not only increase diversity and broaden participation, but also build physical and intellectual capacity of educational institutions, particularly minority serving institutions, to produce larger, more diverse cohorts of graduates**.**

Total OMA funding (+$5.92 million, to a total of $39.13 million).
This will support activities that take place primarily in disciplinary and interdisciplinary research.

This includes:

- *Solar Energy Research (SOLAR)* solicitation in conjunction with DMS, DMR, and CHE at the level of $3.0 million and *Pro-active Recruitment in Introductory Science and Mathematics* at the level of $1.0 million.

- A total of $4.0 million will support *broadening participation* in the MPS disciplines, including: diversity-targeted partnerships involving minority-serving institutions and MPS-supported groups, centers and facilities; diversity-building partnerships with MPS professional organizations; and graduate student, postdoctoral, and mid-career fellowship opportunities.

- A total of $1.0 million is provided for *collaborative public education and outreach activities* at MPS-supported research centers and facilities. This supports activities that enable effective leveraging of the MPS research investment for public science education, and clear public articulation of cross-cutting science themes with significant MPS involvement, such as cyber-enabled discovery and innovation as well as science and engineering beyond Moore's Law.

- About $1.0 million for investment in *cooperative international research and training* is meant to enhance the global competitiveness of U.S. scientists, engineers, and students.

- Support for *cooperative activities between academic research groups and industry* will increase. OMA will increase co-funding from $300,000 to $500,000 for awards made within the MPS divisions through the Grant Opportunities for Academic Liaison with Industry (GOALI) program, which promotes university-industry partnerships by making project funds or fellowships/traineeships available to support a mix of industry-university links.

- About $3.0 million is provided for conceptual design, research, and development related to candidate MPS *large facilities*, which serve researchers from many disciplines. These funds will be provided for the S4 solicitation for the Deep Underground Science and Engineering Laboratory (DUSEL).

- Funding for the *National Institute for Mathematical and Biological Synthesis* (NIMBioS, formerly CIMBS) a Center for Analysis & Synthesis, remains level at $100,000.