Solving some of the most significant challenges of our time by reimagining how science and technology are applied to the world.
Every day we learn that the systems on our planet are more interrelated than previously imagined.

Some connections have always existed but are just now being discovered. Others are created through human ingenuity and the creative application of technology.

Today, to improve the systems that support the way we live and work, trillions of transistors and billions of sensors are being embedded in business, technological and natural systems, such as rivers, cities, deserts and even the human body. When the gathered data is linked to the Internet and analyzed, it can make our world increasingly intelligent, instrumented and interconnected.
To make these systems smarter, IBM Research collaborates across disciplines to address some of the world's most complex problems and promising opportunities.

We believe that profound breakthroughs will come when businesses, governments, academic institutions and others work together to tap into diverse points of view and expertise. Together, we’re working to understand how systems are interconnected and the role technology plays within them.

IBM Research helps clients discover new connections through exploratory research and gain competitive advantage through applied research. That could mean leveraging new models of computational biology to unlock the secrets of stem cell regulation, or developing a medical imaging system with resolution 100 million times finer than conventional MRI technology to help target medicine for each individual.

We are expanding the notion of how we work and where we innovate.

Though we continue to conduct research in our laboratories in China, India, Israel, Japan, Switzerland and the United States, we also are colocating in the field with a range of partners to share skills, assets and resources to achieve a common research goal. From studying solar energy and water desalinization in the deserts of the Middle East, to monitoring the health of the ecosystem surrounding Ireland’s beaches and lakes, to developing systems to help improve safety on city streets, we are in a very real sense making the world our laboratory.

For more than 60 years, Research has been one of IBM’s key differentiators in the marketplace, making the kind of discoveries that shape the future of business, government, academia and society.

Through the practical application of today’s research, we not only help IBM lead, but we help define the way people interact with technology for decades to come.

We are developing cognitive computing systems designed to mimic the human brain’s ability to sense and respond on very little power, so tomorrow’s computing systems may solve complex problems in real time while requiring less energy than today’s systems consume.
IBM researchers are united in our passion to make the world work better—dedicated to creating an impact for our clients and IBM, collaborating to change the way the world works, and discovering the answers to our greatest challenges.

Along the way, we benefit from the talent and commitment of research engineers, scientists and technical professionals who rank among the very best in the world, in disciplines ranging from astronomy to vacuum physics, from accessibility to advanced business analytics, from computational biology to the science of services.

We are Nobel Laureates, prolific inventors and recipients of the world’s highest honors in science and technology. Together, we are IBM Research—a team not only playing a leading role in improving the world today, but charting a smarter future in which we all can thrive.

This is where our story begins. In the pages ahead, we present a first-hand account of IBM Research in action—immersing ourselves in strategic locations and natural environments across the globe to benefit business and society in far-reaching and lasting ways.

To facilitate privacy on the Web, we are working to encrypt data in ways that enable people to work with information without actually seeing it. By assembling semiconducting nanowires directly onto DNA molecules, engineers may be able to design smarter chips that pack more speed and power at far smaller dimensions. And by reusing and redirecting heat from data center operations, we can help optimize their infrastructures for energy and space efficiency.

Services and service systems also are strategic areas of scientific study at IBM Research. We are sharply focused on the interplay of people, organizational practices and business models to design innovations that help combine the capabilities of people and technology to create new value for IBM clients, and that help improve the quality, efficiency and profitability of business services.

We’re even designing a computing system that can understand complex natural language and quickly answer wide-ranging questions with pinpoint accuracy. Named Watson, the system will first go head-to-head against human contestants on America’s favorite quiz show, Jeopardy! Ultimately, the Deep QA technology will be applied to help solve major business problems.

Fully homomorphic encryption could solve a problem that remained unanswered for 30 years—how to perform calculations on encrypted data without decryption.
Taking research into the world

Asking the questions that lead to progress, IBM long ago abandoned the notion that a scientist’s work had to be confined to the lab. By immersing ourselves in real-world conditions and variables, we can gather and apply knowledge faster and more accurately than ever before.

1.1 Managing human impact on rivers by streaming information
1.2 Reducing traffic jams by creating them
1.3 Helping premature infants by sensing complications before they happen
Managing human impact on rivers by streaming information

The majority of the world’s population lives near a river or estuary. Yet, we typically do not have a good understanding of what is happening below the surface of the water to help people predict and manage changes in the river that could impact local communities that rely on the waterway.

The River and Estuary Observatory Network (REON) is a joint effort between the Beacon Institute for Rivers and Estuaries, Clarkson University and IBM Research. REON is the first technology-based monitoring and forecasting network for rivers and estuaries.

Minute by minute, REON tracks physical, chemical and biological data from New York’s Hudson and St. Lawrence Rivers through an integrated network of sensors, robotics and computational technology distributed throughout both rivers.

A networked array of sensors in the river will provide the data necessary to observe spatial variations in such variables as temperature, pressure, salinity, turbidity, dissolved oxygen and other basic water chemistry parameters. All of these sensors transmitting information in real time will result in massive amounts of data.

Helping make sense of all that data is a new stream computing architecture developed by IBM’s Thomas J. Watson Research Center called InfoSphere Streams. It can analyze thousands of information sources to help scientists better understand what is happening in the world—as it happens. REON data can be applied to visualize the movement of chemical constituents, monitor water quality and protect fish species as they migrate, as well as provide a better scientific understanding of river and estuary ecosystems.

The real time capabilities of stream computing can be modified into powerful applications for environmental science, financial services, government, astronomy, traffic control, health care as well as many other scientific and business areas.

Sharon Nunes, IBM Vice President of Big Green Innovations and John Cronin, Director and Chief Executive Officer of Beacon Institute for Rivers and Estuaries

“The integration of science, technology and policy remains one of the great, unresolved challenges of contemporary environmentalism.”

John Cronin, Director and Chief Executive Officer of Beacon Institute
Changes to Cities Alter Traffic Patterns

A single new building can have a major impact on traffic congestion and drive times. IBM Research’s traffic simulator helps predict problem areas so traffic managers can change the outcome.

CO2 emissions
Traffic flow
Traffic volume
Signals

“This is the best field for applying our cutting-edge technologies, including large-scale traffic simulation, real-time data analytics, and spatio-temporal data mining. By developing and combining these technologies, we can make cities smarter.”

-Sei Kato, IBM Researcher, Computer Science

Reducing traffic jams by creating them

Each year nine billion gallons of fuel are wasted in traffic congestion. Across the globe, driver frustration and increasing pollution are causing city planners to rethink how cities are designed and optimized.

IBM Research—Tokyo and the Department of Social Informatics at Kyoto University have jointly developed a system that can simulate a broad range of urban transportation situations involving millions of vehicles. It shows modification of existing traffic laws, or a minor alteration in the timing or frequency of traffic signals and signs.

These large-scale, high-speed simulations provide real-time analysis of traffic status, levels of carbon dioxide emission, traffic volume, and travel time throughout a metropolitan area. The system will enable urban planners to address the booming congestion problem through innovative transport measures, such as a road-user charging system and planning carpool or other high-occupancy routes to reduce traffic jams.

By adding a variety of attributes to the model, the system also can simulate traffic conditions resulting from a range of driver types—such as truckers and taxi drivers—with a variety of new and future vehicle types.
1.3
Helping premature infants by sensing complications before they happen

Today, information pours in faster than we can make sense of it. It’s being authored by billions of people and flowing from a trillion devices, sensors and all manner of instrumented objects. And with different types of information residing in different environments and stored in different formats, quickly extracting meaning from this information is becoming almost impossible.

Making the most use of patient data was a challenge felt by doctors at The Hospital for Sick Children in Toronto, who were trying to devise ways to use real-time information to detect subtle changes in the condition of critically ill premature infants. Physicians monitoring premature babies typically rely on a paper-based process that involves manually looking at the readings from various monitors and getting feedback from the nurses who provide care. With seven different sources producing data at 1,006 readings per second, doctors and nurses were drowning in information.

Scientists from IBM’s Thomas J. Watson Research Center, working with the University of Ontario Institute of Technology and The Hospital for Sick Children, went to work applying a new advanced data analysis paradigm, called stream computing, to build a solution that enables massive amounts of data to be correlated and analyzed for patterns. The software can ingest a constant stream of biomedical data, such as electrocardiogram, heart rate, blood pressure, oxygen saturation and respiration. With this information in hand, researchers were able to develop a data processing engine that is flexible, reliable and scalable to support multiple rules on multiple information streams for multiple patients.

The resulting analysis holds significant promise for alerting doctors and nurses to detect subtle changes and may someday allow them to take action before the infant takes a turn for the worse. The hospital may provide better care based on more detailed information presented in a more intelligent fashion. Doctors and nurses may be able to more quickly and proactively react to significant medical events. And the premature baby may have a better chance of survival.

Life-threatening infections may be detected up to 24 hours in advance by observing changes in the physiological data streams of premature babies.
Improving business performance

By conserving natural resources, and discovering new ones, IBM researchers are discovering new methodologies to pump up the bottom line. Analytics, algorithms and advanced computing are just a few of the means by which we’re setting the stage for the next generation of business innovation.

2.1 Reimagining the energy grid by synchronizing supply

2.2 Reducing CO$_2$ while boosting business efficiency

2.3 Mapping beneath the seafloor to help reduce the risk of dry holes
Reimagining the energy grid by synchronizing supply

Electric vehicles are often celebrated from an environmental standpoint, given their ability to provide transportation without the CO₂ emissions of traditional vehicles. However, they also can play a key role in developing an intelligent infrastructure to provide a reliable and sustainable power system of renewable energy.

Scientists from IBM Research—Zurich are working with a Denmark-based collaborative to explore the use of electric vehicles as a storage device for smoothing power fluctuations from renewable resources—especially wind power—on the Danish island of Bornholm. Partners in the collaborative include Denmark’s largest energy company, DONG Energy, the Technical University of Denmark, Siemens, Eurusco, the Danish Energy Association and Oestkraft, the distribution network owner on the island. The project is called EDISON, short for Electric Vehicles in a Distributed and Integrated Market using Sustainable Energy and Open Networks. The goal is to use this small pilot of about 15 electric vehicles to develop a model for deploying roughly 200,000 wind-powered EVs nationwide by 2020.

Denmark already is a leader in wind power—wind produces more than 20 percent of the country’s power. In Bornholm, researchers currently are studying how the energy system will function as the number of electric vehicles increases.

By developing smart technologies that synchronize the charging of electric vehicles with the availability of wind in the grid, IBM researchers can help utility companies determine when an increased share of power in the system should be supplied to conventional electricity demand, and when excess electricity should be directed toward charging electric vehicles—thereby helping to create an interconnected and sustainable energy system.

Bornholm has enough wind turbines installed to meet 40% of its needs, yet wind currently accounts for only 20% of the island’s energy, because wind fluctuations lead to grid instability.

OPTIMIZING THE GRID IN BORNHOLM
In windy conditions, energy supplied by turbines charges car batteries. With low wind, stored energy from electric automobiles is sent back to the grid to prevent blackouts.
Reducing CO₂ while boosting business efficiency

Modern-day companies are operating under increasing constraints. As if minimizing environmental impact, improving operating efficiencies and reducing costs aren’t difficult enough, the challenges are compounded by their need to deliver a better experience for their clients. By providing a deeper understanding of overall supply chain logistics, IBM Research—China developed “Green Supply Chain,” an analytical tool that helps clients optimize their business decisions for lower CO₂ emissions, lower cost and improved service levels—or all three simultaneously.

Chinese shipping and logistics giant COSCO used Green Supply Chain to gain a better picture of its supply chain infrastructure. The tool can be used to evaluate the CO₂ emissions of materials and aid in identifying alternatives; consider CO₂ emissions when selecting suppliers for sourcing; determine CO₂ emissions associated with manufacturing production processes; evaluate the environmental impact of warehousing and storage requirements; and analyze CO₂ emissions for various transportation and distribution modes, shipment sizes and service levels.

After receiving a detailed analysis of its operations, COSCO reduced the number of its distribution centers from 100 to 40, lowered logistics costs by nearly 25 percent and reduced CO₂ emissions by 15 percent. From an environmental perspective, these reductions enabled COSCO to avoid 100,000 tons per year of CO₂ emissions, while maintaining service levels for clients and incurring no additional costs.

“IBM is unique in its ability to combine the delivery capabilities of IBM Global Business Services with the solution development capabilities of IBM Research. We saw IBM’s use of [this technology] in its own supply chain as a strong vote of confidence.”

Dalei Huang, CTO of COSCO e-Logistics
2.3 Mapping beneath the seafloor to help reduce the risk of dry holes

The days of easy oil are over. The new frontier for exploration—and the biggest hope for major discoveries—lies offshore in reservoirs beneath the seafloor, miles below the surface of the water.

Repsol, one of the 10 largest private oil companies in the world, was seeking ways to reduce the number of dry holes drilled and to shorten the time to first oil in the deep waters of the Gulf of Mexico. Since the region is known for complex geological conditions, Repsol worked with scientists from IBM’s Thomas J. Watson Research Center to build a powerful new system capable of running the next generation of seismic algorithms.

Researchers from the IBM Multi-Core Computing Group worked closely with parallelization experts from the Barcelona Supercomputing Center (BSC) to optimize mathematical algorithms for peak processing. Testing of the system demonstrated that the processor ran algorithms as much as six times faster than existing seismic analysis platforms, and provided more detailed rendering of complex subsurface structures—resulting in fewer dry holes and wasted resources. In the end, Repsol gained the ability to take a closer look at its seismic data while reducing the time required to run complex imaging algorithms from four months to two weeks.

The Gulf of Mexico holds up to 37 billion barrels of undiscovered oil.

Today’s oil producers are drilling as deep as 30,000 feet beneath the Gulf of Mexico, twice the depth of the previous generation.
Impacting society on a global scale

IBM Researchers apply science and technology to solve the challenges of a rapidly evolving planet. We’re making extraordinary headway by creating new resources for people to stay healthy and enabling them with more opportunities to connect and prosper, whether they reside in developed or developing regions of the world.

3.1 Fighting infectious disease by spreading data
3.2 Improving communication by talking to the Web
3.3 Creating drinking water by filtering oceans
3.1 Fighting infectious disease by spreading data

Even in 1918, influenza spread quickly and had a devastating impact on entire populations. Today, exponential increases in air travel and the rising interconnectedness of our world means infectious diseases can be that much more dangerous. We won’t see a wave coming—it will simultaneously appear around the globe. Therefore, rapid detection and data sharing is critical to minimizing the spread of disease.

The Ministries of Health and Agriculture in Jordan, Israel, and the Palestinian Authority started to plan for the battle against infectious diseases long before the threat came to the region. Despite the changing and unstable political situation in this region, the Middle East Consortium on Infectious Disease Surveillance (MECIDS) managed to meet and draft a common plan of action for the three neighboring regions to contain disease outbreaks.

PHIAD supports hierarchical data flow across different domains. Each regional system collects data from local sources, such as doctors and veterinarians. The regional system then forwards appropriate information to a system at the national level, which is administered by a disease control organization such as the Ministry of Health. PHIAD can extend this hierarchy of data sharing to international partnerships. At each level, different data-sharing policies concerning person identification, location identification, authorship and results can be implemented.

By creating an electronic platform that lets public health workers focus on critical tasks such as detecting emerging public health trends, pinpointing potential outbreaks and performing sophisticated analysis, PHIAD can help contain diseases and minimize their impact.

“We need to give priority to collaboration that will strengthen Israel’s technology and research into health care. The technology that is being developed [in IBM Research] is outstanding.”

Shimon Peres, President, State of Israel
IBM researchers are building the Spoken Web, a system that will someday allow individuals to access a wide array of currently unattainable information. In this scenario, a rural farmer would be able to dial into the system and connect to a network of voice sites and voice links—thereby participating in multiple types of knowledge sharing—all through a mobile phone or land line.

One of the most significant technology innovations of the past century, the World Wide Web has given people access to vast repositories of data, enabled new business models and transformed the way people communicate. Most individuals on the planet, however, cannot access the Internet—whether due to lack of computers, connectivity or basic literacy. In India, for example, most people cannot afford a personal computer. Yet cell phone usage is rocketing, expected to reach 500 million users by early 2010.

IBM Research—India has developed a technology called Spoken Web that brings the power of the Internet to the masses, only in a whole new form and through a very familiar interface—the telephone. Spoken Web enables individuals to create voice “Web sites” using a mobile or landline phone. Together, the interlinked Voice Sites create a network of information analogous to hyperlinked Web sites. Overall, Spoken Web brings the Internet to places it could not reach before.

So a rural farmer in India in need of advice on why his summer chana crop is yellowing and dying, can access a knowledge-sharing Voice Site for farmers currently being deployed in Gujarat Province. Through the Voice Site, farmers can ask and have questions answered, listen to announcements and access programs on topics of interest. By creating the Spoken Web, IBM researchers are enabling the kind of knowledge-sharing and community-building that takes place on the Web every day.

“... saved my crop from being ruined. That was very useful.”

Farmer, State of Gujarat, India
3.3 Creating drinking water by filtering oceans

Even though more than 70 percent of the Earth’s surface is covered by water, more than a billion people today have no access to a safe water supply. Additionally, more than 41 percent of the Earth’s population lives in water-stressed areas.

At IBM Research—Almaden, the materials, processes and computational models originally developed for nanotechnology currently are being leveraged for application in desalination and water purification. These so-called nano-membranes, smart materials measuring only nanometers in width, have the potential to significantly reduce energy requirements for filtration. To start, researchers have developed highly water-permeable coating materials that demonstrate significant anti-clogging efficiency during the osmosis and reverse osmosis process, which is widely used for water desalination.

Additionally, and in partnership with Central Glass in Tokyo and King Abdullah University of Science and Technology (KACST) in Saudi Arabia, researchers have developed a smart material based on a new polymer that exhibits unique pH-dependent behavior. Both salt rejection and flux improve at high pH, which translates into lower energy consumption and the possibility of new applications. This technology also could be applied for efficient removal of the toxic pollutants arsenic and boron from drinking water.

By exploring these well-defined nanostructured membranes, researchers are attempting to create a “water superhighway” at the molecular level to reduce operating costs and energy consumption in the desalination process.

The United Nations estimates that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity.

More than five million people, most of them children, die every year from illnesses caused by drinking poor quality water.
The people behind the progress

We are IBM Research—a community of forward-thinking scientists and technical professionals who rank among the very best in the world, in disciplines ranging from astronomy to vacuum physics, from accessibility to advanced business analytics, from computational biology to the science of services. Though we live and work across the globe, we share a common vision—to make progress possible.
Our global network of scientists work on a range of applied and exploratory research projects to help clients, governments and universities apply scientific breakthroughs to solve real-world business and societal challenges.

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“IBM Research gives me the freedom and opportunity to explore how our brains work, enabling us to build computers that imitate nature.”

“My work is at the core of leveraging human intelligence, especially visual perceptional systems to facilitate decision making from huge amounts of data.”

“My research helps people see and exchange information in novel ways. My goal isn’t to make machines smarter; it’s to make people smarter.”

“I am passionate about my work because it highlights the interactions between people, processes and technology.”
**A history of breakthroughs**

For more than 60 years, IBM Research has challenged the status quo by exploring the boundaries of science and technology, bringing discoveries to light that have had a lasting impact on the world. We continue to expand the frontiers of healthcare, energy and telecommunications, to name only a few. In a very real sense, the history of IBM Research has altered the modern history of technological progress.

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<th>Year</th>
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| 2009 | **Nano MRI**  
IBM researchers, in collaboration with Stanford University, achieve volume resolution 100 million times finer than conventional MRI. |
| 2008 | **World's First Petaflop Supercomputer**  
IBM breaks the petaflop barrier with Roadrunner—the fastest supercomputer on Earth at the time. |
| 2005 | **Cell**  
IBM announces the Cell architecture, ushering in a new era of power-efficient and cost-effective high-performance processing. |
| 2004 | **Blue Gene/L**  
The Blue Gene/L supercomputer is designated the world's fastest supercomputer with a peak speed of 596 Teraflops. |
| 2003 | **Carbon Nanotubes**  
IBM researchers discover a process for synthesizing carbon nanotubes (CNTs), making them a feasible replacement for silicon transistors. |
| 1997 | **Deep Blue**  
In a six-game match, a chess-playing IBM computer defeats chess grandmaster Garry Kasparov. |
| 1994 | **SiGe**  
IBM Research patents a method for making low-cost semiconductor chips from silicon germanium, an alloy that improves speed and versatility. |
| 1987 | **High-Temperature Superconductivity**  
IBM researchers J. Georg Bednorz and K. Alex Müller were awarded a Nobel Prize for Physics for their discovery of high-temperature superconductivity in a new class of materials. |
| 1986 | **Scanning Tunneling Microscope**  
IBM researchers Gerd K. Binnig and Heinrich Rohrer receive the Nobel Prize in Physics by providing the first-ever look at atom-by-atom surface topography. |
| 1984 | **Blue Gene/L**  
The Blue Gene/L supercomputer is designated the world's fastest supercomputer with a peak speed of 596 Teraflops. |
| 1983 | **One-Device Memory Cell**  
IBM researcher Bob Dennard invents the single-transistor dynamic RAM (DRAM) memory cell. |
| 1982 | **FORTRAN**  
IBM introduces FORTRAN (FORMula TRANslator) to customers which becomes the most widely used computer language for technical work. |
| 1967 | **Fractals**  
IBM researcher Benoit Mandelbrot introduces the world to fractal geometry, in which seemingly irregular shapes have identical structure at all scales. |
| 1966 | **One-Device Memory Cell**  
IBM researcher Bob Dennard invents the single-transistor dynamic RAM (DRAM) memory cell. |
| 1965 | **Ramac**  
The first machines with magnetic hard disks for data storage are launched with the IBM Ramac (Random Access Method of Accounting and Control). |
Work with us

Our continuous investment in research and development makes this a very exciting time at IBM Research, where the next wave of discovery promises to be more innovative than the last. But we can’t do it alone. We need to work together.

IBM Research Services:
Enables the IBM Global Business Services and Global Technology Services account teams and clients to work directly with prominent scientists and leverage their skills to gain business advantage.

Industry Solutions Laboratory:
The IBM Industry Solutions Laboratory (ISL) is a joint effort between IBM Research and the IBM Global Sales and Services teams that brings together clients and researchers in a unique and effective way. The ISL gives companies from a wide variety of industries the opportunity to see how our advanced technologies and solutions could impact their businesses, while IBM researchers obtain a market’s-eye view of the ways in which their technology can be applied to real-world problems. The involvement of IBM researchers in ISL activities gives clients a vision of the future that few competitors can match. The four ISLs are located in Hawthorne, New York; Delhi, India; Beijing, China and Rüschlikon, Switzerland.

First-of-a-Kind (FOAK) Program:
In our Industry Solutions Laboratories, IBM researchers partner with IBM clients to dig deeper into how promising research can turn into market-ready products and services. Through the FOAK program, clients work with our research teams to solve problems that do not have ready solutions, and our researchers get immediate client feedback to further enhance their projects.

Business Analytics Solution Centers:
A growing network of global analytics centers addressing the growing demand for the complex capabilities needed to build smarter cities and help clients optimize all manner of business processes and business decisions. The Centers are located in New York City, Berlin, Beijing, Tokyo, London and Washington, D.C.

IBM Research Labs:
www.researchlabs.ibm.com/portal/
An experimental Web site that enables visitors to select from a list of beta and future IBM technologies and assets, and begin experimenting with them quickly. After testing them out, users can provide feedback to the IBM researchers working on the projects, as well as rate the experiments directly on the site. Available to the general public or targeted for specific clients, the experimental technologies on the site include collaboration software, tools for creating business applications, visually democratizing information for data analysis, and for recording and automating processes performed in a Web browser.

To learn more about these programs, or other ways to partner with IBM Research, please contact your IBM representative or visit www.ibm.com/research

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