MIT Science News in Review

[Biological Sciences]

Stem Cell Clones Exhibit Gene Expression Irregularities

Clones developed from embryonic stem cells have serious gene expression problem, even normal-looking ones. From their study of mouse clones, Professor Rudolf Jaenisch (MIT) and Professor Ryuzo Yanagimachi (University of Hawaii) reported in the July 6 issue of *Science* that reproductive cloning, besides being inefficient, may be unsafe.

The two research groups made mouse clones from embryonic stem cells and monitored tags on genes called "imprinted genes." These tags do not affect the base sequence. They discovered that the tags on the culture stem cells were very unstable and nonuniform, with the tags being lost during cell division. Even clones made from "sister stem cells" of the same culture were found to have "differences in their gene expression."

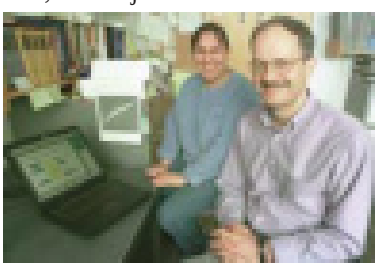
The results of the groups, along with other studies that found abnormalities in clones developed from the nuclear transfer technique using embryonic stem cells, suggest that the problem lies with the stem cell cultures, not with the cloning process.

Researchers now need to devise ways to make the gene tags more stable in the embryonic stem cell cultures to find out if clones made from other techniques not involving stem cells exhibit similar problems. Jaenisch also noted that despite their gene expression abnormalities, "embryonic stem cells might work fine when used as cell therapy."

Studies on Worms Offer Clues for Lengthening Human Lives

Through the study of roundworms and the silenced information regulator (SIR2) gene, MIT Professor of Biology Leonard P. Guarente discovered SIR2's apparent ability to slow down the aging process, helping roundworms live up to 50 percent longer. The details of his work were reported in the March 8 issue of *Nature*.

His research team was able to show that an enzyme co-factor and SIR2 gene in yeast are responsible for making the Sir2 protein, which joins forces with a reduction in calories to decrease aging. By inserting extra copies of chromosomes into the roundworm larvae, Professor Guarente was able to show that "the worms with the extra section containing the SIR2 gene lived extraordinarily long" and to "conclude that, as in yeast, increasing the dosage of an SIR2 gene extends life span." Professor Guarente said it is "remarkable that aging in yeast and aging in adult worms are both regulated by Sir2 proteins."



Professor Guarente will be experimenting on mice in the near future: "It will be interesting to determine whether Sir2 proteins regulate the rate of aging in still higher eukaryotes, which contain both dividing and post-mitotic cells."

A New Noose for Cellular Suicide

Phagocytes were originally thought to originally be cellular undertakers whose role was to pick up and consume the mess of dying cells anywhere in the body. But MIT Professor of Biology Robert Horowitz, along with biology graduate student Peter W. Reddien and former MIT postdoctoral associate Scott Cameron reported in *Nature* that phagocytes are not just the clean-up crew of an organism. In fact, they are more like Dr. Kevorkians, actually helping to kill off other cells. "We propose that engulfment actively promotes the killing process rather than passively eliminates the opportunity for recovery," the authors write.

Horowitz and colleagues investigated the process as part of their series of studies on "apoptosis," or programmed cell death. Apoptosis normally occurs in the body among normal cells, which commit "suicide" in order to help shape developing tissues or maintain proper immune system function. Phagocytes help consume the apoptotic cells. But several biologists believe that this apoptosis and consumption process may go haywire when an organism is infected with some types of diseases, resulting in lemming-like massive cell suicide and the weakening–or death–of the organism.

Horowitz and others have observed that heart cells near tissue killed by a heart attack or neural cells dying during neurodegenerative diseases like Alzheimer's and Parkinson's might be lost as a result of out-of-control apoptosis and consumption. By inserting a genetic mutation into genes coding for phagocytes, the MIT team was able to eliminate the engulfment capabilities of the cells; they then watched the cell death process in the neuronal and embryonic cells of the roundworm. They found that many cells that would have been consumed by phagocytes survived and did not commit cell suicide.

If drugs were produced to inhibit the engulfment, the authors suggest, syndromes ranging from stroke to heart disease may not kill off as many cells, and may prevent considerable human deaths.

Artificial Enzyme Synthesizes RNA

In the May 18 issue of *Science*, MIT Associate Professor of Biology David Bartel and his colleagues at Whitehead showed that a new ribozyme created in their lab uses information from a template RNA to make new RNA. It can accomplish the task with 95 percent accuracy, and the length or the exact sequence of letters in the original template does not restrict its ability.

These results imply that RNA could have had the capability to replicate itself and sustain life in early evolution before the existence of DNA and proteins. In all respects, the findings of this research will help evolutionary biologists address questions regarding how life began on earth.

Although Professor Bartel expressed that "we will never be able to prove the existence of the RNA world because we can't go back in time," he believes that we can still "examine the basic properties of RNA and see if these are compatible within the RNA world scenario."

MIT Researchers Distinguish Two Different Classes of Memory Cells

MIT researchers recently found that a subunit of brain cells in the primary motor cortex (responsible for voluntary movements) establishes a new firing pattern when an animal is learning a new set of voluntary movements.

In an article published in the May issue of *Neuron*, MIT's E. McDermott Professor of Brain and Cognitive Sciences, Emilio Bizzi, MIT graduate student Camillo Padoa-Schioppa, and Chiang-Shan Ray Li of Chang Gung University in Taiwan reported that the motor cortex is not only responsible for the processing of, but also the reorganization of neuronal activity during learning.

The data indicates that the brain is capable, by using a subpopulation of cells, of storing the slightly altered skill, setting up its own pattern of neuron firings while not writing over the old pattern.

Monkeys served as the subjects of the study, and they were trained to use a joystick to move the cursor to different targets on the screen. Once the monkeys had mastered the pattern of the eight targets, the joystick settings were altered so that they had to overcome an orthogonal force in order to move the joysticks. The monkeys experienced some difficulty, but with practice became equally adept at reaching the targets with the new joystick settings.

The monkey's brains were tracked for movements, and 162 individual neurons were found in action. "We found that two different classes of memory cells coexist and balance each other after exposure to the force field," Padoa-Schioppa said.

The authors explained that these findings suggest neural plasticity is the rule rather than the exception. The plasticity found might help in understanding the mechanism by which the brain is able to deal with either old or new situations. As Padoa-Schioppa points out, "You want to learn something new without forgetting something old."

[Physical Sciences]

Soap Bubbles Key for Atom Behavior Simulation

Previously, soap bubbles have been used to study the deformation of bulk metals. Subra Suresh, the R. P. Simmons Professor and Department Chair of Materials Science and Engineering, and his colleagues Andrew Gouldstone and Krystyn J. Van Vliet report in the June 7 issue of *Nature* that they have developed new ways to use these simple bubbles to understand more about nanoscopic deformation.

A layer of bubbles (one bubble thick) replicates the atomic layer on a material. These bubbles were prodded, and the results were compared to nanoindentation on the surface of real metals. The data from two sets of tests matched both qualitatively and quantitatively.

With the knowledge gained from this bubble model, the team hopes to aid the prediction of defects that occur during mechanical contact.

Acoustic Sensors Could Search for an Ocean under Europa

Existing acoustic techniques could be used to determine if Jupiter's moon, Europa, has oceans under its layers of ice. At the June 5 Chicago Acoustical Society of America meeting, an MIT research group led by professor Nicholas C. Makris described how small sensors planted in the ice of Europa could monitor ice fractures and detect evidence of an ocean.

Magnetic and gravitational information already suggests that an ocean exists on Europa. Multiple acoustical sensors could measure how the low-frequency sound waves produced by breaking ice propagate through the moon to detect the thickness of ice and possibly of the water layer.

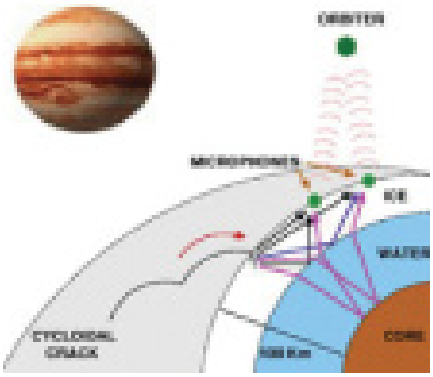
The sensors could also try to link the ice fractures to the moon's orbital period, as well as gather more information on meteors, which strike the ice around once a month.

Makris explained that "ice is very sensitive and conducive to sound" and that ice fractures of the size found on Europa produce 0.1-100 Hz frequency sound waves. Information on how those waves bounce off the inner layers could be used to determine the inner structure of the moon.

The actual experiment needs consideration; it could be as many as ten years before it takes place, but the techniques are currently being developed. The question of whether there is water on Europa could also lend insight to the possibility of life elsewhere in our solar system.

Planet-size Kuiper Belt Objects

An icy planetary object larger than Pluto's moon, Charon, has been discovered in the Kuiper Belt. James L. Elliot, MIT professor of Earth, Atmospheric, and Planetary Sciences and director of the Wallace Astrophysical Observatory, in conjunction with members from the Lowell Observatory and the Large



Binocular Telescope Observatory on Mount Graham, Arizona, spotted the Kuiper Belt Object 2001 KX76 on May 22, 2001.

Robert Millis, director of the Lowell Observatory, explained that "this object is intrinsically the brightest Kuiper Belt Object found so far." Based on assumptions about how its brightness relates to its diameter, 2001 KX76 may have a diameter of 788 miles. This is larger than Ceres, the largest known asteroid, and larger than Charon which has a diameter of 744 miles.

2001 KX76 has a distinctly reddish color typical of many primitive bodies in the outer solar system. It is among the least evolved objects available for study by planetary astronomers. Along with other Kuiper Belt Objects, 2001 KX76 illustrates the remnants from the formation of the solar system.

Since 1992, astronomers have discovered more than 400 Kuiper Belt Objects, but tens of thousands remain to be discovered. Millis commented, "Until the Kuiper Belt has been thoroughly explored, we cannot pretend to know the extent or context of the solar system."

OH Level Fluctuation 1978–2000

An MIT-led research group found that levels of OH (hydroxl radical, the atmosphere's main cleansing agent) have fluctuated greatly between 1978 and 2000.

OH is the atmosphere's main defense against many gases associated with ozone depletion and the greenhouse effect. Its levels have not been measured directly, rather they are inferred from global, long-term measurements of the man-made gas that it neutralizes.

The study's main findings include that on average, the concentration of OH in the southern hemisphere is 14 percent higher than the concentration of OH in the northern hemisphere; and globally, OH levels increased from 1978–1988, but have since decreased. One explanation is that aerosols may be reflecting and absorbing the sun's ultraviolet radiation, which would lower OH production rates.

Another possible explanation for the data is that the northern hemisphere's atmosphere is most susceptible to industrialized waste emissions, so the mix of nitrogen oxides and carbon monoxide are to blame for the variations in OH levels.

Continued monitoring of the atmosphere is needed to better understand long-term implications of industrial emissions.

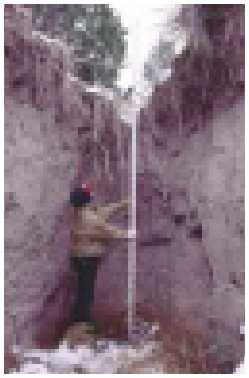
Vegetation Included in Erosion Model

Erosion is one of the most serious environmental problems a country can have. MIT scientists have created a landscape

model that "mimics the interaction of soil, geology, climate and (now) vegetation."

Interpreting the history of landscapes from current vegetation and drainage patterns and predicting the evolution of landscapes in the future are the jobs of landscape modelers. The numerical model of earth systems prior to the Channel-Hillslope Integrated Landscape Development (CHILD) has not included vegetation.

In China, five billion tons of soil are lost every year, and preservation plans include importing seed from other countries. Landslides in Italy are a constant danger. CHILD can be used to help such nations develop strategies for saving their soil and lower the risk of landslides.



CHILD may also be used for commercial purposes to understand undersea formations. This tool will be particularly useful to oil companies and others who need to acquire knowledge about the ocean floor.

Nobel Prize in Physics Shared by MIT Professor and Alumni

Professor Wolfgang Ketterle, Dr. Eric Cornell, and Dr. Carl E. Wieman shared the 2001 Nobel Prize in Physics for their work with the Bose-Einstein Condensate (BEC).

Ketterle is MIT's John D. MacArthur Professor of Physics and is associated with MIT's Research Lab of Electronics and the National Science Foundation MIT-Harvard Center for Ultracold Atoms. Cornell received his Ph.D. from MIT in 1990 and is now a senior scientist at the National Institute of Standards and Technology (NIST). Weiman also received his Ph.D. from MIT (1973) and is currently a physics professor at the University of Colorado at Boulder.

was an Indian physicist who made key theoretical calculations regarding light particles. Bose shared his research with Einstein, who extended the theory to a certain atom. Einstein theorized that if a gas of atoms was brought to a very low temperature, then all the atoms would go to their lowest possible energy state. BEC was first observed in 1995.

BECs are created with atoms, which are cooled to approximately one-millionth of a degree Kelvin. Atomic matter waves form, and the atoms lose their individuality. Atoms move in tandem as a single wave of matter that behaves uniformly. Usually atoms in a gas will move around in a random and independent manner.

Ketterle's group separated BECs and expanded them into one another. He observed the formation of clear interference patterns. This experiment concretely showed that the condensate was formed entirely of atoms behaving uniformly. Ketterle also created a stream of BEC drops that can be considered a primitive "atom laser beam," made with matter, not light.

Revolutionary applications in precision measurement, nanotechnology, and quantum computation can stem from this newly discovered method to control matter.

[Technological Sciences]

From Microwaves to Missiles: A New High-Speed Electron "Switch"

Experiments at the MIT Bates Laboratory reveal that high-powered microwave transmitters might be the next tool used in the Navy's Missile Defense System and could be the basis for all sorts of new radar equipment used for the tracking of high-speed projectiles.

This news came after Bates engineers faced a dilemma: They needed to adjust their linear electron accelerator to beam pulses of up to 120,000 volts and 100 amperes (equivalent to a maximum power of 12 megawatts) and to switch the pulses on and off at a rate of less than one-millionth of a second.

Too hard? Not if you use microwaves. The Bates team created twelve modulators to provide pulsed power to twelve tubes called klystrons, producing microwaves that accelerate the electron beam just fast enough to create a new high-speed "switch." The new switch will improve the efficiency and ease of accelerator operation at Bates, allowing electron beams to be delivered at maximum energy and at high pulse-repetition frequency.

"We expect to increase transmitter and accelerator availability by 5 to 10 percent, equivalent to providing a substantial amount of increased beam time each year," said Bates Associate Director Chris Tschalaer to a Tech Talk reporter.

The other advantage of the new Bates system is that the high-voltage switching technology can replace vacuum tube modulators in the transmitters of shipboard radar systems or in missile tracking systems that need to track faster projectiles.

"I believe this new technology represents the next step forward in modern high-power radar design. The Bates Laboratory should be proud of its contribution to modulator engineering," said Chip Wolcott, a member of the Bates team.

An Implant for the Ear

Over 500,000 Americans are profoundly hearing impaired. But many of them are getting a second chance to hear, thanks to advances made by Donald Eddington and his colleagues at MIT's Research Laboratory of Electronics and the Harvard-MIT Division of Health Sciences and Technology. Eddington and his colleagues have been working for years on "cochlear implants"–devices that replace the ear's key membrane, which vibrates when it interacts with sound waves, sending nerve signals that create the sensation of sound.

Eddington is no novice in the implant field. He helped pioneer the work on such devices in the 1970s, with controversial experiments using electrical stimulation to boost hearing in deaf individuals. Now, many deaf persons use the implants he and other scientists helped to design.

The key challenge in producing such a device is mimicking the tiny hair cells that grow out of the spiral-shaped cochlea. The 15,000 tiny hairs fluctuate with sound waves, but how can one mimic the subtle movements of these numerous hairs with mere

electrodes? Early implants had only one electrode, exciting all nerve fibers at the end of the ear and resulting in a maximum 5 percent word identification for deaf persons who heard common words. These people used lip reading to decipher most of the speech.

"If someone asked their spouse what was for dinner," said Dr. Eddington, "they might able to tell the difference between 'mashed potatoes' and 'green peas.'"

But users today score 40 percent or more on word tests, primarily because Eddington and his colleagues were able to change the single-electrode implant to a six-electrode implant, phasing the activation of the electrodes so that tiny gaps would appear between their firings. As a result, hearing becomes much clearer, and with two implants, one might solve the famous "cocktail party problem" of psychology, which examines how people distinguish between distinct voices at a party.

By putting one implant in each ear, sound waves can arrive in one ear faster than in the other, and the gaps in time between the two ears can be monitored by the multi-electrode implant. The brain can tell, based on these gaps, where in the room a particular speaker is located.

But Eddington isn't satisfied. He recently told Tech Talk reporters recently that new advances in his field are forthcoming. "This is a field that's accelerating," he said. "Given the progress we've seen already, I think there's great promise for new developments over the next ten to fifteen years."

Tracks of Troody

In late fall 2000, a Late Cretaceous–period dinosaur walked across an MIT scientist's desk.

This robotic version of a Troodon dinosaur, affectionately nicknamed Troody, was designed by Peter Dilworth to mimic the way its biological counterpart walked. Dilworth, a member of the MIT Artificial Intelligence Lab, is continuing his project with the creation of Troody's successor, a sturdier robot designed for a museum environment.

Troody is about 18 inches tall, weighs about 10 pounds, has 16 joints and 36 sensors, a vestibular system for balance, and an onboard computer that runs a walking algorithm. Its successor will be about 50 percent bigger and able to turn better, walk quicker, and maybe even run, making it "the first 3-D bipedal, or two-legged, walking and running robot in the world," says Dilworth. Dilworth has also been working with Gregory S. Paul, a paleontologist, to make this robot as true to nature as possible.

Troody was one of the robots designed at the MIT Leg Lab, a division of the AI Lab. The Leg Lab is committed to building walking robots and developing ways to aid handicapped people walk. Robots such as Troody would be able to explore hazardous locations that would otherwise be inaccessible to humans. Troody's ability to traverse unfamiliar regions is vital to this goal. Dilworth says, "I put a notebook on the ground in front of Troody, and it was able to stumble over it without falling. It could theoretically walk over a variety of terrain."

In addition to these long-term goals, Dilworth hopes that both Troody and its successor will be able to encourage children to enter the science or engineering fields.

Tarokh Wins Waterman Prize

Associate Professor Vahid Tarokh from the Electrical Engineering and Computer Science Department is the recipient of the 2001 Waterman Prize. Professor Tarokh won the award for his space-time codes, which have had a significant impact on wireless communications.

Professor Tarokh's space-time codes solve a large and frustrating problem in wireless communications. Messages sent and communications relayed over the wireless network are often of poor quality due to reflection of transmitted radio waves by objects in the environment. The signals that become reflected arrive at the receiver after having traveled different distances. When these different signals reach their destination, they can cancel each other out.

One solution to this problem is to send a copy of the desired signal in a different format to the receiver (sending on a different frequency). This, however, is not a very efficient process, and frequency is wasted. A second solution is to use more than one antenna for reception of a signal. In this scenario, if a message is sent to a person in between two receivers and one receives a faulty signal, the other can back up the signal and the message can get through. The problem with this setup is that multiple receiver antennas on handheld wireless devices will be troublesome because the devices are getting smaller and smaller.

Tarokh finds multiple transmit antennas at a base station to be most efficient and practical. The costs of deploying new transmit antennas can be amortized to the many users of the network. Tarokh receives the Waterman Prize for his space-time code in the difficult design transmission schemes for the multiple transmit antennas. Mathematical theory and research from Radon and Hurwitz (two arcane mathematicians) were essential to Tarokh's work.

The industry has been quick to adopt the space-time scheme and Tarokh "forecast[s] a day when space-time codes will be used to push very high-rate wireless data to laptops and other handheld devices."