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The Burmese Star Tortoise

Fight or Flight?

Silicon Optoelectronics

Basic Science: What and Why?

Professor Louis Brus

The Columbia Science Review

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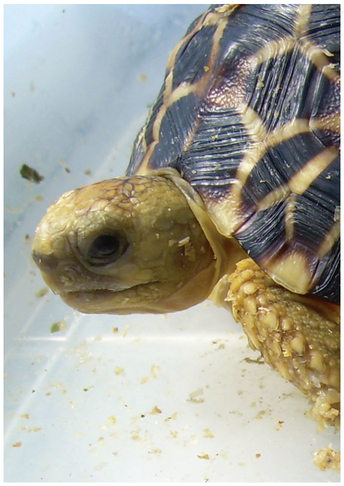


4000 ma
First signs of life develop 600 ma after Earth is formed

180 ma
Pangea landmass begins to break up

160 ma
Guanlong wucaii is the oldest Tyrannosaur belonging to the middle to late Jurassic era

Fight or *Flight?*

A look into the lineage of Tyrannosauridae and birds

Imagine looking out of your window as various types of birds fly gloriously in the sky above. The firmament ever clear, each bird glides across the wind with effortless guile. Now visualize that these majestic birds attacked you with razor sharp claws, intending to kill you for sustenance, or better yet, just for the thrill of the hunt. **By Christopher John Schell**

This is something unimaginably difficult to picture, right? Well, much evidence has accumulated that helps to prove the theory that birds such as the small wobblers and city-raised pigeons are ancestrally linked to dinosaurs. Lately, this evidence has proven to be persuasive enough to tip the scales in favor of those who advocate the dinosaur-bird theory.

The Crowned Dragon

Within the "many-colored badlands of Xinjiang on the far western side" (Holtz) of Beijing, a team led by Xing Xu of the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing came across two fossils that are now considered to be the oldest members of the tyrannosaur family. This newly found creature of February 2006 was labeled by Xing Xu as *Guanlong wucaii*, meaning 'the crowned dragon of the five colored rocks.' This 3-meter-long predator was uncovered along with another "juvenile" 'crowned dragon' (Gugliotta). The adult dragon was estimated to be about 12 years old, as the younger colleague was only found to be about 6-7 years of age (by way of carbon dating, bone structure, and the protrusion of a head crest). This ancient tyrannosaur was found to be 30 million years older than its mighty successor, the T. rex, making the fossils about 160 million years old. At this age, the 'crowned dragon' was shown to belong to the middle to late Jurassic period.

Both dragons embodied distinctive features that tied them both to the Tyrannosauroidea genre ('tyrant dinosaurs') and the Coelurosauria genre (which preceded the Tyrannosauroidea genre at the beginning to the middle-Jurassic period). James Clark, co-leader of the group that discovered the two fossils, stated that "Guanlong shows us how the small coelurosaurian ancestors of tyrannosaurs took the first step that led to the giant T. rex almost 100 million years later" (Zhang). The presence of U-Shaped teeth in the front of the jaw and fused nasal bones that fashioned one single unit were native to the Tyrannosauridae "including sharp, cutting teeth, a flared tailbone and configuration of its snout" (Gugliotta). In a skeletal outlook, the teeth were shaped like larger, curved incisors and the tailbone was stiffened limiting its ultimate mobility. Also, the snout was fused as a singular configuration with expanded pneumatic sinuses in the skull to allow flow-through respiration. These features tied it closely to the tyrannosaurs, yet unlike its large heirs, *Guanlong* was relatively small and was around the size of a large wolf or dog. Mark A. Norell, a paleontologist at the American Museum of Natural History, commented on the stature of the newly found creature. He stated, "This is a very gracile animal; T. rex

150 ma
Large dinosaurs are diverse and birds evolve from Theropod ancestors

100 ma
Giant theropod dinosaurs Carcharodontosaurus and Giganotosaurus are even bigger than Tyrannosaurus

65 ma
Cretaceous-Tertiary transition occurs as nearly half of dinosaurs become extinct from large asteroid impact

is elephantine" (Gugliotta). Guanlong also sported longer arms with three fingers instead of two. These features were similar to those of coelurosaurs, who had small builds and features that gave the impression of being carnivorous scavengers. This coelurosauria group is speculated to have branched into both genre of Compsognathidae (smaller scavenger dinosaurs such as Compsognathus) and Tyrannosauroidea (large, predatory animals, dominant particularly in the Late Cretaceous period). The most unusual characteristics of this 'tyrant' were those of the thin crest atop the snout and the small fossil imprints of protofeathers. Scientists characterized this crown as a "tall, narrow projection with numerous hollow excavations" (Holtz). Paleontologists described the bone structure itself as a thin membrane, possibly getting larger with the factor of age (the older the dinosaur, the bigger the protrusion). Because of the crown's skinny and feeble nature, it was speculated to be for "visual signaling… species recognition and mating displays" (Holtz). Scientists also postulated that the crest was situated over an air-filled sac. This sac within the Guanlong is similar to the sacs found within modern birds. These findings were very intriguing and lent credence to the theory that birds have some type of evolutionary ancestry in dinosaurs.

> "This is a very gracile animal; T. rex is elephantine."
>
> —*Mark A. Norell, a paleontologist at the American Museum of Natural History*

Past traits – Modern saurian

So to what do all these features hint? Looking at the outside appearances (other than the occasional plumage) of the Tyrannosauridea genre alone, there seem to be no apparent ties. However, many studies have come to suggest that the pulmonary system of birds originated in the dinosaurs before them. This "avian pulmonary system" utilizes "flow-through ventilation, relying on a set of nine air sacs that act like bellows to move air through the almost completely rigid lungs" (NSF). The presence of light bones with skeletal air pockets in dinosaurs has implied that dinosaurs also had these air sacs. These sacs were not necessarily for flight, but rather for mobility. With the presence of these sacs, air is continually flowing through the body, enabling even the bigger species of dinosaurs to move fluidly for a longer period of time. As the National Science Foundation has commented in a press release, "skeletal air pockets evolved to lighten the bone structure, allowing dinosaurs to walk upright and birds to fly" (NSF). The presence of air sacs also implies that the dinosaurs that had them could have "maintained a stable and high metabolism, putting them much closer to a warm-blooded existence" (NSF).

Since the late 1960s, the most accepted theory of birds as dinosaurs has been the link between *theropods* – a diverse group of bipedal dinosaurs originating from Coeluosaurs – and modern birds, using an array of traits familiar to both. In 1969, Dr. J.H. Ostrom made a very elaborate analysis and description of the theropod *Deinonychus antirrhopus*, comparing its similarities effectively to that of Archaeopteryx. Features such as the clavicles (collarbone) fused to form a furcula (wishbone), hinge-like ankle joints, hollow bones, and flexible wrists composed of *semi-lunate* carpals (half-moon shaped wrists) are attributes not unlike those found within modern birds. Dr. Ostrom's comparative work has come to tie theropods very closely to birds such as the ostrich, the emu, and the kiwi. Now, with the emergence of the *Guanlong* fossils (also an early theropod), the bird-dinosaur hypothesis is even more believable since *Guanlong* was a member of the Coeluosaurian group which evolved into its theropod successors and since *Guanlong's* structural make-up is similar to that of birds.

Though much evidence has accumulated in favor of this argument, this tie is still inconclusive and will not be definitive until a complete fossil record of any and every theropod is discovered. Since complete theropod specimens are extremely difficult to come by, it is hard to say whether or not we will be able to decisively give judgment to this heated debate. But like Archaeopteryx, *Guanlong* has given us further information on this subject for paleontologists and scientists alike to examine and observe.

References:

Holtz, Thomas R. Jr. A Jurassic tyrant is crowned. Nature Magazine: News and Views. Vol 439, Feb. 9, 2006.
Gugliotta, Guy. Scientists Find Oldest Ancestor of T. Rex. Washintonpost.com, Thrusday, February 9, 2006; A03
Carey, Bjorn. T-rex's weird-looking ancestor found. MSNBC News, http://www.msnbc.msn.com/, 11:15 a.m. ET Feb. 9, 2006
Dayton, Leigh. T-rex ancestor 'feathered'. The Weekend Australian: Science and Nature. Feb. 9, 2006.
National Science Foundation. Study Documents Bird-like Breathing Systems in Long-Extinct Dinosaurs. Press Release 05-118, July 13, 2005.
Wilan, Ken Howard. The link between dinosaurs and birds. The Boston Globe, Thursday, August 25, 2005.
http://www.ucmp.berkeley.edu/diapsids/avians.html. Are Birds Really Dinosaurs? & (link on page to) Theropod Dinosaurs. DinoBuzz

Silicon Nanocrystals: Amping Up the Light

By Srinivas Chivukula

Electrons have been the traditional carriers of signals in electronic circuits, but recently, ground breaking research has shown that something we would never have thought likely to be able to do it, light, too can help transmit these signals, in the latest field of technology: optoelectronics. What's even better about using light for the purpose is that a wide range of wavelengths, ranging all the way from ultraviolet to infrared can be used, and speeds thing up. Multiple switches and amplifiers which would have been a waste of extra circuitry material in an electron-electronic circuit can be combined onto a single chip in an optoelectronic circuit.

If valence electrons are made to be released, by applying a voltage, or by stimulated emission of light, they leave behind holes of opposite charge. If now, the electron, using a much smaller amount of energy, is attracted back to the hole, and they combine, a hole-electron pair

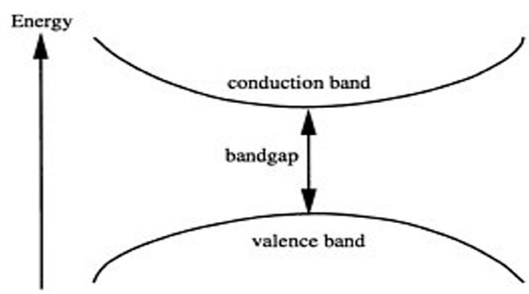


Figure 1. Silicon is an indirect bandgap semiconductor and is thus inefficient in emitting light since electrons in the conduction band require energy to fall into the valence band.

called an exciton is formed, which releases photons (tiny packets of light), in the process of formation.

There are now, two types of materials we consider: those with a direct bandgap and those with an indirect bandgap. In materials with a direct bandgap, mere absorption of energy suffices to create the exciton. Semiconductors that have an indirect bandgap are inefficient at emitting light. This is because any electrons present in the conduction band quickly settle into the energy minimum of that band. Electrons in this minimum require some source of momentum allowing them to overcome the offset and fall into the valence band. Photons have very little momentum compared to this energy offset – hence, the momentum "kick" of a photon being emitted would normally not be enough to dislodge the electron from the conduction band. Since the electron cannot rejoin the valence band by radiative recombination, a process in which through the release of energy, an electron falls from the conduction band to the valence band, conduction band electrons typically last quite some time before recombining through less efficient means. Silicon is an indirect bandgap semiconductor, and hence has an extremely low photoluminescence, (the ability of emitting light when there is a change in energy of the electrons) which cannot be put to efficient use in optoelectronics (see Figure 1).

Silicon, being a semiconductor with an indirect bandgap has posed a problem to rapid advancement of the still relatively new optoelectronic technology. Silicon is an inexpensive material, however, and would undoubtedly have been the material of choice in signal transport had its radiative rate (the amount of light given off by the electron per unit time, when it undergoes a change in energy) been higher. Recent research, however has shown that silicon nanocrystals embedded in silicon dioxide have a much higher and viable radiative rate, of the order of tens of microseconds, than pure silicon itself. Using this new form of silicon does not make the bandgap to be direct, but takes advantage of quantum confinement to increase the rate of indirect combination of electrons.

So how are these Silicon nanocrystals made?

The commonest method to produce these Silicon nanocrystals on a large scale is to first impregnate Silicon Dioxide (Quartz) with Silicon ions. To prevent the crystals from being oxidized by atmospheric moisture, the crystals are placed in a furnace containing Argon gas, at a 1000°C. This serves a dual purpose by also initiating the Silicon nanocrystal nucleation (a process similar to seeding, where crystals are made to develop over existing material) and growth. An unavoidable consequence of this, however, is that a few dangling bonds occur. The Silicon atom, in particular has two dangling bonds per surface lattice atom. Because these dangling bonds do not constitute the lowest energy configuration, the surface tends to reconstruct or absorb atoms to reduce the surface energy. In essence, a dangling bond of an atom is a bond which cannot be realized because the neighboring atom to which the atom in question usually binds is missing. Dangling bonds, are thus a center for electron absorption. In practice, to passivate these dangling bonds with Hydrogen, Argon gas is replaced with forming gas, which is a mixture of Hydrogen and Nitrogen, in a 1:10 ratio.

The radiating rate can further be increased by coupling gold into the Silicon nanocrystal. This transfers energy from the silicon nanocrystal exciton to the surface plasmon at the gold/silicon interface. Surface plasmons are surface electromagnetic waves that propagate parallel along a metal/dielectric interface. For them to exist, the complex dielectric constants of the two media must be of opposite sign. This condition is met in the infrared-visible wavelength region for air/metal and water/metal interfaces (where the real dielectric constant of a metal is negative and that of air or water is positive). Typical metals that support surface plasmons are silver and gold. For nanoparticles, localized surface plasmon oscillations can give rise to the intense colors of solutions of plasmon resonance nanoparticles and/or very intense scattering.

In order to scatter the light after energy transfer from the silicon nanocrystals to the gold/silicon interface layer, there needs to be a roughness of nanometer sized features which is achieved using nanoporous gold. Quite surprisingly, and especially when compared to how much effort goes into making the silicon nanocrystal, the production of this nanoporous gold is quite simple. It involves taking a gold-silver alloy containing both metals in equal proportions, and

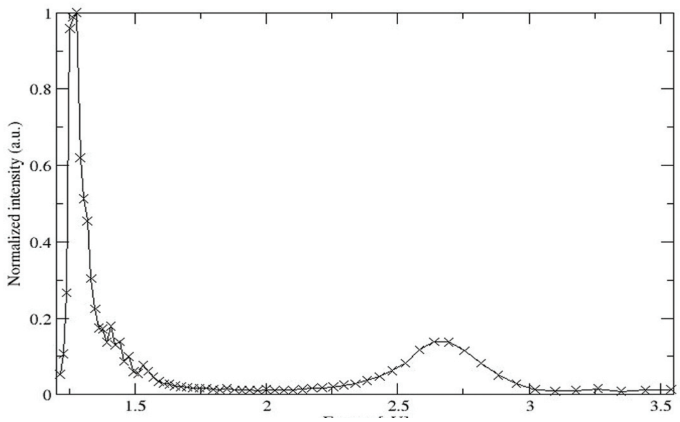


Figure 2. Applying a thin nonoporous gold (npg) to silicon nanocrystals in silicon dioxide, photoluminescence and radiative rate increases when excited nanocrystals emit red light and transmits its energy to the npg. The energy is scattered and is absorbed by the npg, which transmits it to the nanocrystal where the light is emitted.

dissolving the mixture in nitric acid to rid it of the silver. The result is the thin nonoporous gold (npg) film. By applying a layer of this npg to silicon nanocrystals in silicon dioxide, the photoluminescence and consequently, the radiative rate too increases.

Julie Biteen , of the Atwater group at the California Institute of Technology (CalTech), has focused her research on the use of silicon in optoelectronic circuitry. In one experiment conducted by Biteen et al., she used an argon laser to excite the nanocrystals. Upon this exposition, three events occur in succession. To begin, the nanocrystal is excited and emits red light when the exciton combines. Next, the excited nanocrystal transmits its energy to the npg where the energy travels as a surface plasmon and is then scattered. Lastly, the npg absorbs the incident light and transmits it to the nanocrystal where the light is emitted. This is all shown graphically in the figure 2.

The Results

She then used a charge-coupled device (CCD) to measure the photoluminescence. CCD's are useful little things which store data in pixel format, which is basically light energy stored as electrical energy. They find extensive use in digital cameras, for instance. By sending light through a monochromator, and by calibrating the CCD with a known source, and receiving it through the CCD, we can also obtain a spectrum. Between the reference normal sample, and the npg sample, Biteen found a fourfold increase in photoluminescence. (see Figure 3).She used an acousto-optic modulator (AOM), to split the beam of incident light at frequencies that would allow the decay rate to be measured by a photomultiplier. Now, if the excitation is turned off, the lumninescence energy starts dropping exponenentially and the time of its drop gives the inverse of the radiation rate, or the lifetime. To help measure the radiative rate, she used a photomultiplier tube, which is an extrememely sensitive detector of light. Photomultiplier tubes consist of vacuum tubes in which photons excite electrons, amplifying their signal by as much as eight times of magnitude, so that pulses may be measured even from single photons. Biteen made the emitted light travel through a monochromator(which allows light only of a certain wavelength to pass through), and then through the CCD, and found the intensity and the peak wavelength of the emitted light from the spectrum obtained. The emitted light, she also directed to the PMT, and with the help of the AOM, obtained a graph of photoluminescence with respect to time, and this helped her to find out the lifetime. She also found out the decay rates, using a formula first published by Guillos et al. in 1995.

Future Possibilities

Perhaps, sometime in the future, silicon nanocrystals could be used as optical amplifiers in fiber optics systems. Erbium doped fiber amplifiers are now in use, which amplify signal by retransmitting signal with increased amplitude, when in an excited state. However, since a high power pump laser is required to excite the erbium ions, this method is not very practical. But, thanks to silicon nanocrystals, there is a solution to this. If silicon nanocrystals are within nanometers of the erbium ions, then absorbed energy of the nanocrystal, which absorbs 10,000 times more efficiently than erbium ions do, can be transmitted to erbium ions, saving the need for a high power pump laser, and using much cheaper pump sources. Increasing the radiative rate of silicon nanocrystals to achieve optical frequencies is, and will remain, for the timebeing, critical to improving upon optical amplifiers.

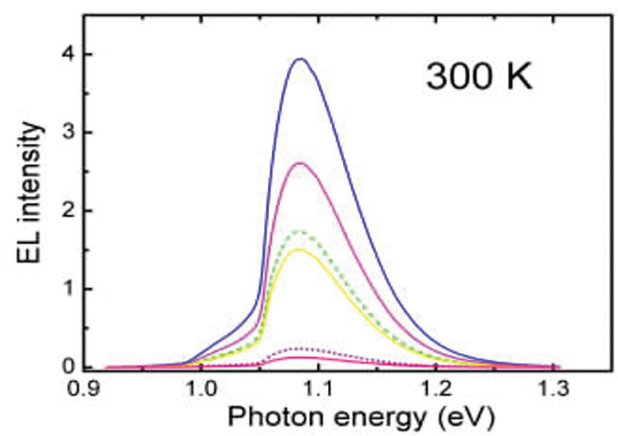


Figure 3. There is a four-fold increase in photoluminescence using nonporous gold.

References

J.S. Biteen, D. Pacifici, N.S. Lewis, and H.A. Atwater, Nano Letters 5 1768 (2005).

R.J. Walters, Julie S. Biteen, H.A. Atwater, and G.I. Bourianoff, "Nanocrystal research targets optoelectronic components," Laser Focus World (September 2004).

http://www.fz-rossendorf.de/pls/rois/Cms?pNid=0

v http://www.seanstarkweather.com/_images/CURJ_Summer%202005.pdf

vhttp://www.fz-rossendorf.de/pls/rois/Pic?pOId=11980

vi http://darwin.nap.edu/books/0309051754/html/images/p20007ce4g63001.jpg

vii http://www.tkk.fi/Yksikot/Elfys/research/ongoing/Si_Led/fig2.jpg

Basic Science
What and Why?

By Anthony Joseph DeCostanzo

"The name 'biomedical' to me connotes more of a basic science approach… whereas the term 'medical' is more neutral and less exclusive of either basic/clinical science…" So went the email response to my suggestion of a name-change for the P&S Medical Review. My colleague Peter continued, "the prime example is, of course, the NEJM, which publishes a broad spectrum of articles."

We are trying to agree on a name inclusive of the work of both graduate and medical student contributors to our revival of the now inactive P&S Medical Review, a student publication that had been consistently published between 1993 and 2002 at Columbia University's medical center campus. Peter (a medical student) is making the case that the term medical is more inclusive than biomedical when used to simultaneously refer to the disciplines of both clinical and basic research. His next statement, that The New England Journal of Medicine (which publishes exclusively clinical research) is an example of a journal that publishes both clinical and basic science, betrays the confusion that is the first subject of this article: Peter doesn't know what basic science is.

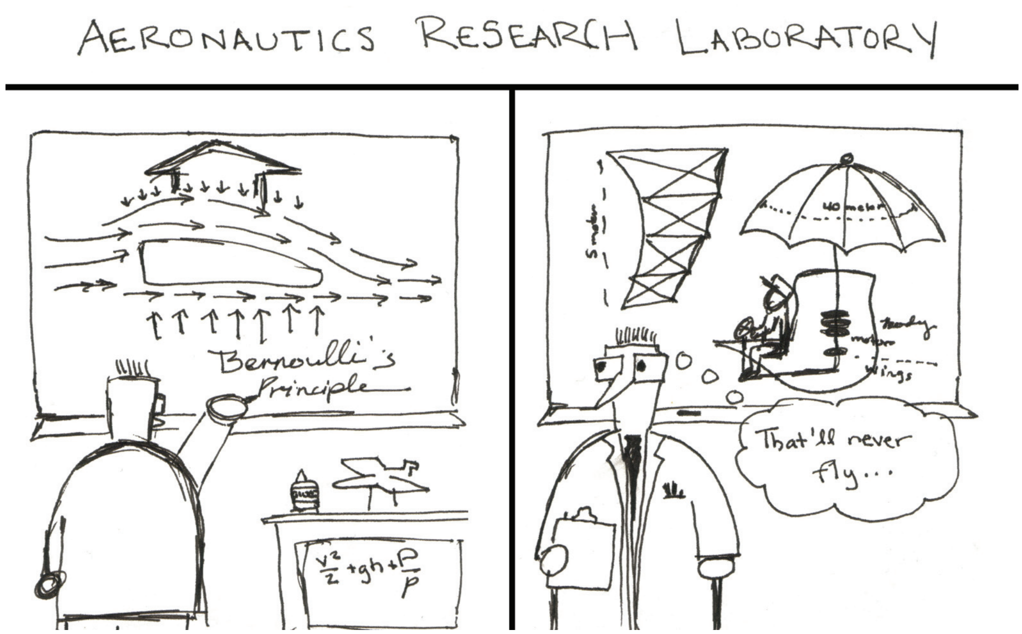
Alas the purpose of this article is not to harangue my colleague Peter, but rather to draw attention to the fact that basic science as a term may not be as well understood by those outside as it is by those inside, and that this misunderstanding may contribute to the public's lack of concern with regards to basic science funding. In the above case the divergence is between clinical versus basic, but this is likely a general confusion about basic science verses applied science.

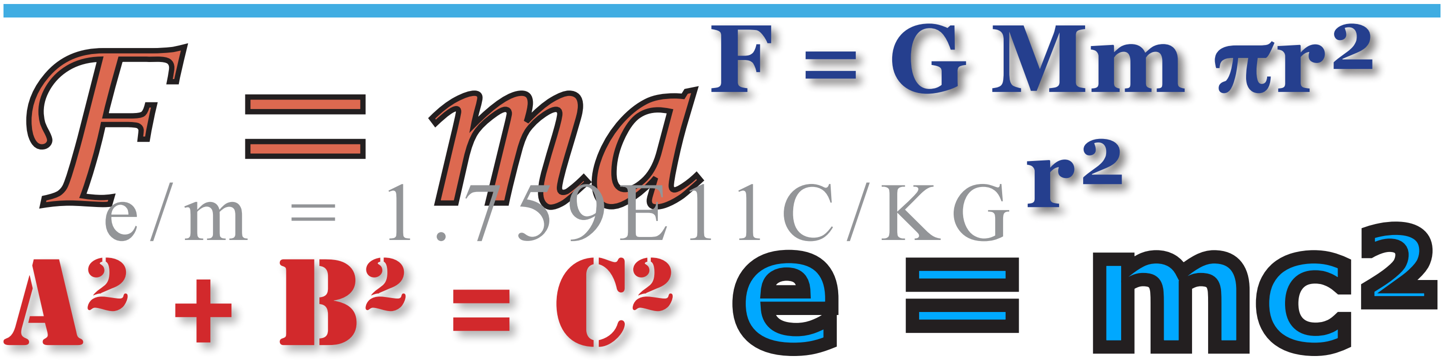
Donald Stokes of the Brookings Institution traced the coining of the term "basic research" back to 1945 when Vannevar Bush, the director of the Office of Scientific Research and Development under Franklin D. Roosevelt, stated that "basic research is performed without thought of practical ends." (1) Bush continued that "general knowledge and an understanding of nature and its laws" should not be constrained by premature consideration of practical use. This is in contrast to applied research which is directed toward a particular need or use. Where the discovery of the structure of DNA is an example of a basic science discovery, a clinical drug trial is surely applied. When public funding is running thin, both basic and applied scientists feel the pinch, but in the long-term it is likely to be the former that is most profoundly affected. The reason is simple: industry.

Take the current funding situation in biomedical research in the United States as a case in point. The proportion of total pharmaceutical company research and development expenditures that has gone to phase1-3 clinical trials has increased from 28% in 1994 to 41% in 2003, and in the same period the proportion going to phase 4 trials has increased from 5% to 11%. On the other hand, the ratio of clinical to basic funding from the NIH has remained essentially the same (2). In other words clinical research is increasingly less dependent on NIH funding since it receives an increasingly greater proportion of industrial research dollars, while basic research is still just as dependent on NIH dollars.

This may give credence to the recent outcry by basic biomedical scientists concerning the federal R&D funding conditions that have battered the NIH and other federal agencies for the last two years, and which threaten again the 2007 budget (3,4,5,6). At the time of writing, the latest appropriations draft would have leave the NIH budget flat at $28.5 billion, which for the second straight year would be a net decrease when adjusted for inflation[7].

To be sure, NIH funding has fared well over the last





decade, doubling between 1994 and 2003 (7). However, this leaves open to question the value of basic biomedical research, and basic science in general. Whereas many attempts have been made to quantify the return on investment from clinical research funding (8,9,10,11) it is far more involved to attempt the same for basic science since by definition (at least by the definition of Vannevar Bush) it is performed without a socially useful product in mind.

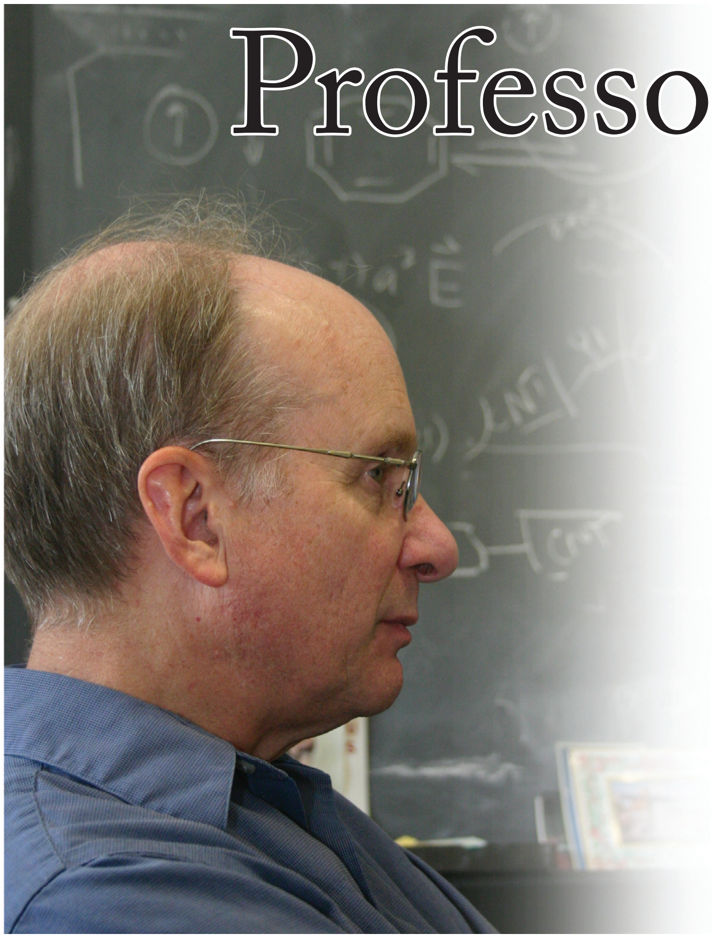
The work for which the 2006 Nobel Prize in Physiology or Medicine was awarded to Andrew Z. Fire and Craig C. Mellow concerned a mechanism through which *C.elegans* (a small roundworm) regulates gene transcription – a basic science question. This feature has since been shown to be a general mechanism that other organisms including mammals use to regulate gene transcription. Does this work provide a return for society's investment? The discovery has also provided a tool through which researchers can silence genes at will, thereby paving the way for generations of discoveries to come. If this methodology can one day be successfully employed for gene therapy then the return on investment will be obvious, but at this moment in time we can make no such determination, other than to say that every scientist using this tool has the potential to make such a direct return on society's investment. And so the tree of influence expands outward from a single discovery ad infinitum. Much akin to the proverbial butterfly causing a monsoon by the beating of its wings, a single discovery has incalculable influence reaching far beyond any single researcher's imagination (or the imagination of any bureaucracy).

A full review of the value of basic science is well beyond the scope of this short commentary, and a comprehensive calculation will at best only provide a roughly estimated monetary figure. Furthermore, if this figure were attainable, it would not include intangibles such as the effect of understanding life or existence on one's quality of life. Suffice it to say that if you are a scientist, communicating what you do and why you do it to the people around you may do as much for science as the work you do within science.

The federal government's fiscal year 2007 began on Oct 1st, but at the time of writing the House has not taken action on the NIH appropriation, while Senate action is still pending on NIH, NSF, DOE and NASA. There is time to visit or write your Representative or Senator to have your voice heard.

Sources:

1. Stokes, Donlad E. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, D.C.: Brookings Institution Press, 1997.
2. Moses III, Hamilton, Dorsey E.Ray, Matheson David H., and Samuel O. Thier. "Financial Anatomy of Biomedical Research." *JAMA* 294.11(2005):1333-42.
3. Nathan, David G. and Alan N. Schechter. "NIH support for basic and clinical research: biomedical researcher angst in 2006." *JAMA*.295.22(2005):2656-8.
4. Feldman Eva L. "Biomedical research: a culture in crisis?" *Nat Clin Pract Neurol*. 1.2(2005):61.
5. Editorial, *Nat Genet*. 38.7(2006):729.
6. Mandel, George H., and Eliot S. Vesell. "Declines in funding of NIH R01 research grants." *Science*. 313.5792 (2006):1387-8.
7. American Academy for the Advancement of Science: http://www.aaas.org/spp/rd/
8. Johnston, Claiborne S., Rootenberg, John D., Katrak, Shereen, Smith, Wade S., and Jacob S. Elkins. "Effect of a US National Institutes of Health programme of clinical trials on public health and costs." *Lancet*. 367.9519 (2006):1319-27.
9. Luce, Brian R., BR, Mauskopf, Josephine, Sloan, Frank A., Ostermann, Jan, and L.Clark Paramore. "The return on investment in health care: from 1980 to 2000." *Value Health*. 9.3(2006):146-56.
10. Porter, John E. "Federal Funding and Supportive policies for Research." *JAMA*. 294.11(2005):1385-9
11. Cutler, David M., Rosen, Allison B., and Sandeep Vijan. "The value of medical spending in the United States, 1960-2000." *N Engl J Med*. 355.9(2006):920-7.



Professor Louis Brus

Faculty Profile

Photo by Daniel Brujis

By Yang Liu

As students of scholarship in any branch of academia, we know that chasing difficult questions and challenging established ideas sets our minds on an unchartered path of discovery and growth. For Professor Louis Brus, a faculty member in the Chemistry department, an invested interest in basic science as an end in itself has taken his professional career on an exciting and scopic journey. From the beginnings of his effective postdoc experience as a naval officer in the United States Naval Research Laboratory in D.C., to research at then telecommunications giant Bell Labs, today Professor Brus has his own lab in Havemeyer and a one hour teaching date, two or three times a week, with a class of first-time physical chemistry students.

Born in Cleveland Ohio in 1943, Professor Brus came of age at a time when scientific research was undergoing a glamorous makeover. In 1961, he accepted a Naval Reserves Officer Training Corps (NROTC) college scholarship at Rice University, where he took on the newest major on campus: Chemical Physics. This was at the time when atomic scientists rode the wake of saving the country from fascists, and the space race against Russia was symbolically charging the Cold War. In response, public funding for basic science research grew and campuses across the country zealously expanded and strengthened their science programs. "Before WWII, you could not support a family with a career in basic science [research]. There were very few academic jobs, high unemployment..." By 1965, says Brus, "this had completely reversed."

Even under the encouraging social and political framework of the time, Brus's burning desire to learn more about quantum mechanics did not loosen his expectation to one day, like his father, become a businessman. After college, he owed the military four years of active service, which he knew would be excellent preparation for business. Brus says he had studied science in college "because he liked it," but, perhaps due to his early commitment to NROTC, never seriously considered the possibility of making it into a career. Before graduation, however, when faced with the nearing prospect of going straight into the naval service, Brus was fortunate to be able to delay his professional service another four years. He convinced the Navy to give him time to complete a Ph.D in Chemical Physics at Columbia University, where he could study the scientific questions that would not stop beckoning him after the end of his last college class.

Brus studied the photodissociation of sodium iodide vapor under Professor Richard Bersohn during his doctorate education, where he tried to understand how photodissociation excited sodium atoms and changed the rates of their subsequent reactions. In 1969, he joined the navy as a lieutenant and, instead of being sent off to sea, was stationed in DC at the Naval Research Laboratory as a staff officer scientist. There, he worked on the basic science of generating an electricity independent high power infrared laser that could possibly be used in weaponry development. He studied the gas phase reactions that would release the most chemical energy to create the necessary population inversion (a high number of excited electrons compared to resting state electrons) for laser beams. At the end of his four years, he left this research for a position at Bell Labs.

Bell labs gave Brus the chance to do exciting basic science research because at the time it had a near monopoly on the telecommunications industry. At the time, Brus explains, there were relatively few academic scientists in areas important to telecommunication technology (unlike the situation today) and Bell did a lot of its own research and development . While Brus studied the spectroscopy of gas phase reactions in D.C., at Bell he worked on the spectroscopy of solid and liquid phase reactions and their chemical kinetics, which eventually led to an interest in the evolution of molecules to solid state crystals. In 1983, refined laser technology allowed Brus to study the oxidation reduction reactions on the surface of semiconductors crystallites and observe band gap properties of excited electrons in semiconductors. Brus noticed that the band gap, the amount of energy electrons need to move from the highest filled to the lowest empty orbital, was decreasing over the course of a few days because the particle itself was increasing in size. From these observations, he was able to measure band gap as a function of particle size, which helped him pose the questions that still direct his research today. He gives his inquiry into nanoscience two dimensions. The first dimension questions the evolution of solid state properties as a function of nanocrystal and nanoparticle size. When do these properties actually appear as a function of size? Next, he asks whether there are unique properties in intermediate sizes that aren't present otherwise. Are they useful in science, can nanocrystals be used as reagents to make other things? His size dependent observations of band gap properties in semiconductors, along with a concurrent discovery of carbon nanotubes by scientists in Japan, led to a booming interest in nanoscience that has changed the face of many research and development efforts today.

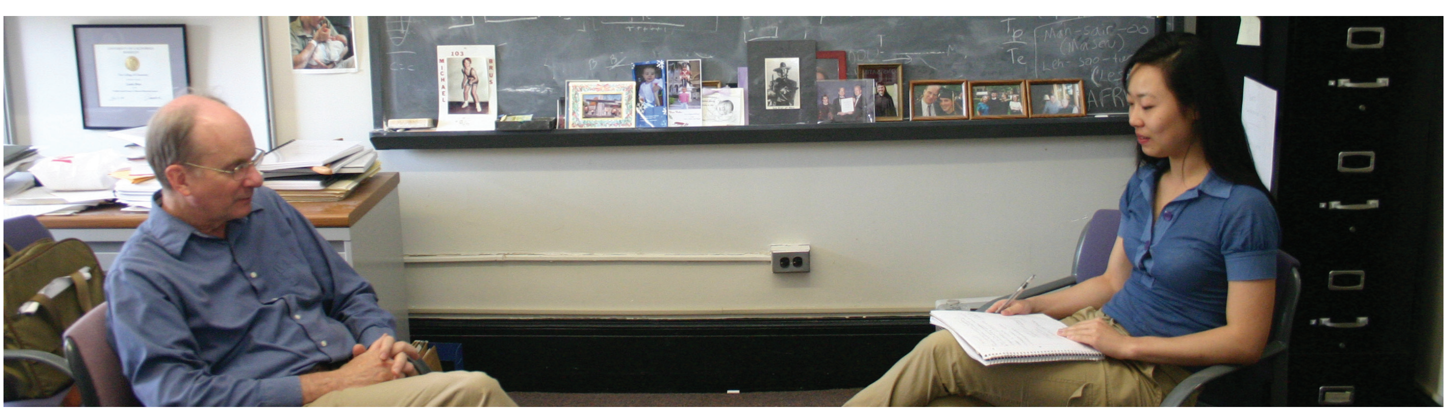
Brus decided to leave Lucent in 1996 because changes in the telecommunications industry changed the opportunities that were available for basic research, and came back to Columbia as a professor with a brewing desire and intention to teach. "I was at a point in my life where I was really interested in teaching and missed the interaction with students," says Brus. "Research as opposed to development is my real interest and in that context it's just natural that you'd be interested in teaching it to people. When you write an article, you're basically teaching what you learned in that research to the entire scientific community. There's an element of instruction." When you are in the classroom, he says, you are teaching present and future researchers.

Acknowledging the value that time and research experience give to a solid and operative understanding of any subject material, Professor Brus teaches the abstract concepts of thermodynamics from multiple perspectives. At any given moment, you can find him twiddling the chalk in his hand while he places a concept in its historical development, explains its relevance in other disciplines (such as statistical mechanics), recommends an informative book, or writes the green chalkboards white with examples. His lectures also brim with personal anecdotes. Even with all these teaching strategies, however, Brus says matter of factly that he doesn't think "any 18 year old in the world can understand thermodynamics. It's just too abstract." Students will read the textbook and memorize the equations, but getting a feeling for the laws, knowing how to apply them in given situations and understanding their practical implications can only come with long experience. And even with decades of experience doing basic research, he admits frankly that the two skills are different, and that "teaching is not easy."

As a veteran of the same lofty, wood ornamented classrooms of Havemeyer, Brus has noticed that fewer students these days are interested in basic physics and chemistry as there were during his tenure as a student. He understands this as a natural expansion of opportunities, historically comparable to the post WWII basic sciences boom that shaped the atmosphere of his education. These days, he says "many strong American students are interested in computer science and biology. and as a country grows wealthier, few go into [basic] science and more go into medicine, law and finance" And while this may be due in part to the prospect of job security, with so few faculty positions opening each year to support the number of basic science graduate students who receive their diplomas, the numbers may soon be changing, says Brus. Because of the tenure system in academia and perhaps moreso the big academic expansion in the '60s and '70s, many jobs opened but the expansion soon stopped as these jobs filled. "It's cyclic," he says, and "I think right now going forward, those who were hired in the sixties are retiring," opening many opportunities for dedicated students. He adds, "In 2006, I think it is generally recognized that every university that strives to be great must support the intellectual activity of world class basic research. Molecular level scientific questions grow more important every year in medicine and society."

There are many practical problems that will only be resolved from a better understanding of the basic sciences. Although Brus is interested mostly in basic science as an end in itself, he says that nanoparticle technology needs to be applied to the most pressing contemporary problems. The energy crisis with the atmosphere, for example, is in tremendous need of some solution that will change the international dependence on oil. There are many areas of science that are not understood and prevent industry from achieving practical and efficient solar cells. Citing also the future of microelectronics, which is undergoing incredible change with better and cheaper chips using electrotransistors, Brus says again with enthusiasm that tremendous discoveries are waiting to be made.

"It's a wonderful time to be doing science because of the invention of all these new tools, and there are all these interesting subjects you may work on." But to get anywhere in this field, there are elements of dedication, preparation, good judgment and chance. He quotes his colleague Professor Nicholas Turro, who says that there is one year in every graduate student's career where nothing works right. At this point, some people quit, but those who are dedicated and internally motivated pull through. After a long career doing research, Brus says, most scientists will say that there are periods where everything goes right - magical moments where every idea seems to strike a chord... and periods when nothing works at all and the well is dry. "I was always interested in the science." says Brus. "If science is your job as well as your hobby, you will work on it with all your mental energy." He cites a personal analogy. It's Saturday morning, and you want to come to work to do science just because it's fun, not because you have to. Saturday mornings you have large blocks of time to think about science without any distractions, and it's these people, who would rather be in the lab than sleeping in, whom Brus finds "really lucky."



A Rare Beauty At Risk Of Extinction And One of the Most Coveted Reptiles:

THE BURMESE STAR TORTOISE

By Ici Li

The Burmese Star tortoise (Geochelone Platynota) of Burma is considered to be the most beautiful tortoise in the world, next to the Radiated Tortoise of Madagascar. It lives in the dry deciduous forests and open valleys and grasslands of Burma, where it serves roles as scavenger and primary consumer in the ecological food chain. In the wild, it grazes on grasses, fungal blooms, and even carrion for its occasional source of protein. Like most tortoises, G. Platynota sleeps for the majority of the day, awaking only once or twice to forage for food.

The Burmese Star Tortoise is currently on the CITES list, Appendix II, making the species illegal for export, and thus, diminishing its chances of survival in captive breeding programs around the world. Fortunately, several breeding programs have been set up in Burma, and in other countries around the world, such as the US and Japan, where keeping the Burmese Star has become quite popular in the reptile industry. In addition, natural wildfires and predation only bring the tortoise more at risk for extinction.

G. platynota adults exhibit the standard chelonian signs of sexual dimorphism in that the males have much longer and thicker tails and a marked plastral concavity. As in G. elegans, mature males are smaller and more elongate in shape than are mature females, which may be quite rounded and highly domed. Large males may reach 23 cm. and large females may exceed 30 cm, although exact published data is sparse.

With experts only truly starting to understand the exact nature of the tortoise about two decades ago, little to nothing is known about the behavior of the tortoise. Currently, they are found only in a national preserve in Burma. G. Platynota is considered by the International Union for Conservation of Nature and Natural Resources (IUCN) to be critically endangered, and is already considered by many to be functionally extinct in the wild. It has endured many years of being consumed by the native peoples of Burma, and being eaten in the Chinese and Thai food markets. In a recent expedition, a group of trained volunteers and dogs searched for the tortoise for 400 hours, and only five tortoises were found.

The legs and arms of the tortoise are tan to yellow-orange in coloration, with round yellow or white scales protruding from its forelimbs. The carapace of the Burmese Star tortoise is characterized by a dark brown or black color, with six or fewer radiating yellow or white stripes extending from a central areola of each vertebral and pleural scute. It is highly domed, and smooth, separating it from other types of tortoises, such as the Sri Lankan star tortoise, which has the centers of each of its scutes raised in pyramid form. There exist 11 marginal scutes on each side of the carapace, with each having two stripes meeting at a point, forming a V-shaped pattern on each marginal scute. The carapace of the common turtle has four types of scutes: 1 nuchal, 12 bilateral-marginals, 4 bilateral pleurals, and 5 vertebrals. However, for the Burmese star, there exists no nuchal scute, and there are only 11 marginal scutes on each side of the carapace.

In addition, the plastron of the common turtle has 10 types of scutes: intergular, gular, humeral, marginal, auxiliary,

Photo by Ici Li

Ici Li's Collection of 12 yearling tortoises, including this one and the ones depicted below.

along their scute annuli (rings). Angle lines of scute annuli appear in all kinds of tortoises species, which are false lines formed from the scute angles of yearly growth. Typically, these lines lie along the diagonals of each scute, crossing in the middle of the scute. For certain species such as the primitive Manouria Emys Phayrei, these lines can be quite evident. G. Platynota is the only chelonian in the world with its radiations lying exactly along these scute anulli.

Unfortunately, the future survival of this species may depend entirely on private breeding and captive care.

Care

My personal tortoise collection consists of 12 yearling tortoises, which are kept in a 50-gallon clear plastic tub, with alfalfa pellet substrate. Although professional tortoise breeders use eucalyptus mulch, I have found alfalfa pellets to be quite good, because they prevent odors, and are edible. The young tortoises seem to enjoy the substrate, as it provides them with a food source as well something to burrow into. The setup also contains a slab of cuttlebone for the young tortoises to trim their beaks as well as serving as a source of calcium and other important minerals.

I use a standard light fixture of a Reptisun 15 W bulb, with a 7% UVB emission. The presence of UVB is important, as it works closely with the vitamin D3 to build strong shells and bones. The light is kept about six inches above the tortoises, and is turned on for 15 hours a day. The bottom of the setup is equipped with a Zoo-Med heatpad, which is turned on at all times to control the temperature of the substrate.

photo by Ici Li

G. Platynota is extremely resilient to temperatures. In its natural habitat in Burma, temperatures range from 38° F in the winter to well over 100° F in the summer. In captivity, my tortoises have been maintained at 80° indoors, with a basking spot reaching 100°. A tortoise's lungs are situated at the upper region of their carapaces, so emitted heat from above is important to properly monitor their body temperatures.

My tortoises are fed a variety of fruits and vegetables, supplemented with Rep-Cal calcium supplement, as well as Rep-Call Herptivite, sprinkled on their food three to four times a week. I have found that staples for my tortoise diet to include a routine of Mazuri Tortoise Diet, mushrooms, romaine lettuce, dandelions (all parts of the flower, stems, and leaves), as well escarole, kale, string beans, and apples. A well-balanced diet with proper supplements is important to maintaining proper shell growth for these tortoises. My tortoises are also bathed daily as their water source. I also use this technique to keep the young tortoises' shells soft and growing smoothly.

Sexing of Young Tortoises

In my experience, I have found that sexual dimorphic characteristics of G. Platynota are present when they are about a year old. Female Burmese stars will slowly start to develop a cusp on their anal scutes, having a concave formation about their tail. Males on the other end, will have their anal scutes split off to either side of the tortoise, resulting in a convex formation. In any given group, it is quite probable that the larger tortoises are female, because the final size of female tortoises is larger than their male counterparts. Females will also tend to exhibit a highly domed or rounded shell not unlike a bowling ball or squished sphere.

G. Platynota's readiness to breed will be based more on the size of the tortoise than the age. Specimens will reach breeding size when they approach 20 cm for females, and possibly less for males. Males also reach sexual maturity faster than females.

Breeding

Gravid females select nesting areas which are often under overhanging shrubs or grasses and they are able to dig very rapidly with their strong hind legs and stout nails. The nest sites are also frequently located in areas struck by the afternoon sun as it sets, though that may be purely incidental. Nests are flask-shaped, often as deep as 20 cm., and are virtually undetectable when completed.

Those eggs which have hatched have been incubated (after the rest period) for periods ranging from 75-145 days. It is of interest to note that the eggs which required the least actual incubation time were those which were rested the longest prior to being incubated. The author uses totally dry Vermiculite as an incubation medium, sprinkling the eggs with water twice weekly during incubation but not during the resting period.

Hatchlings are approximately 25-30 mm. in size and should be fed a standard tortoise diet as described earlier. It is still too early to tell whether temperature-controlled sex determination works in this species as well as it seems to work in G. elegans. In that species, temperatures of 85F and below have produced males and 88F and above have produced females 95% or more of the time. The same temperatures have been used to incubate the platynota eggs, but most offspring are still too young to determine the sexes. It is anticipated that this hypothesis will be confirmed or rejected in the next decade.

> “With experts only truly starting to understand the exact nature of the tortoise about two decades ago, little to nothing is known about the behavior of the tortoise.”

Sources:

http://www.chelonia.org/sexing/sexing_Geochelone_playnota.htm
http://home.kimo.com.tw/foolzoo/
http://www.arkive.org/species/GES/reptiles/Geochelone_playnota/more_info.html
Dr. William Zovickian's G. Platynota Reproduction Caresheet
My personal knowledge of the species as well as my own observations.
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