Nanoscale Science in Everyday Life

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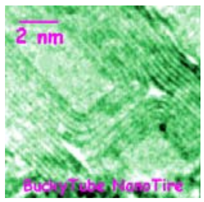
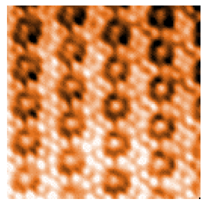




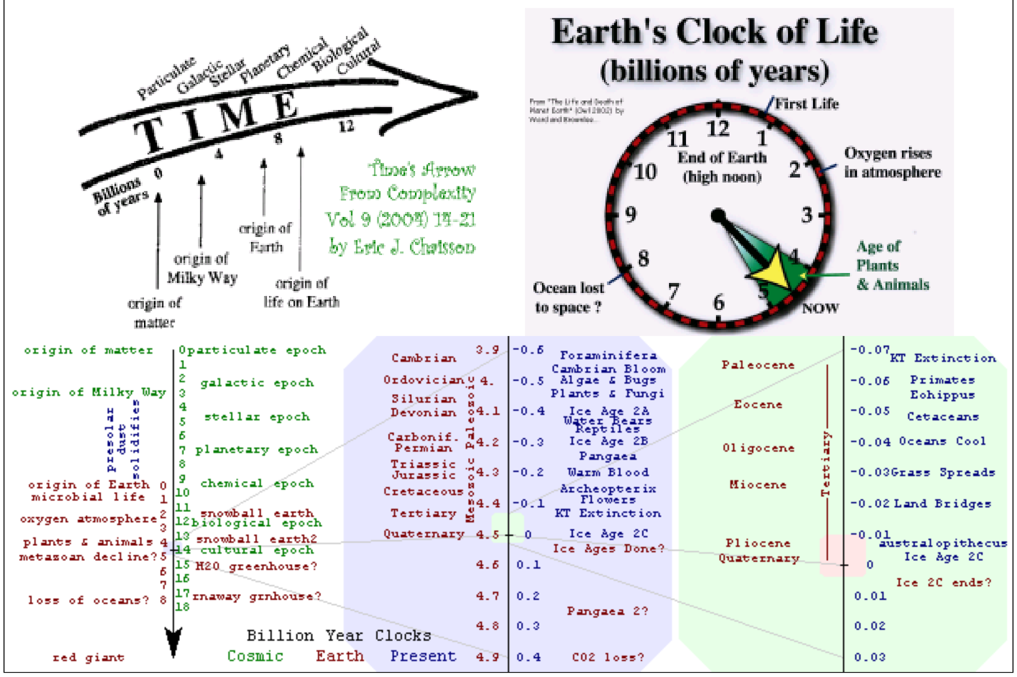

Can anyone guess what these images are of, as well as what kinds of microscope took them? For example, can you find in this collection where a nanophotographer may have inadvertantly captured her own shadow on film, where 10-fold symmetry reveals something unexpected, or a pattern that might be the glow-in-the dark footprint of a recent UFO landing?

Outline

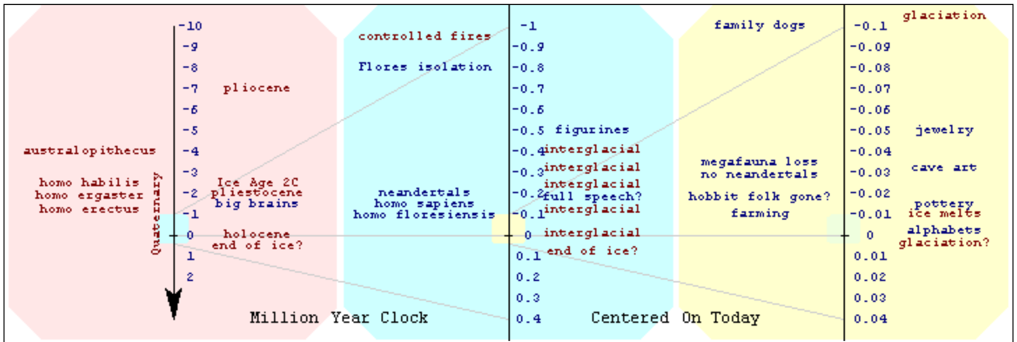
- Time scales
  - *Can we take on both long and short term challenges?*
- Size Scales
  - *Size Effects, Global and local blind spots*
- Nanodetective Adventures
  - *Electronics, SpaceDust, Nanoparticles...*

We begin with the subject of time scales, to show the importance of thinking on more than one scale at once, as well as to show that we collectively share some non-trivial challenges that nanoscale science may help with in the days ahead. From there, a look at the importance of size scales in everyday life will lead who knows where...

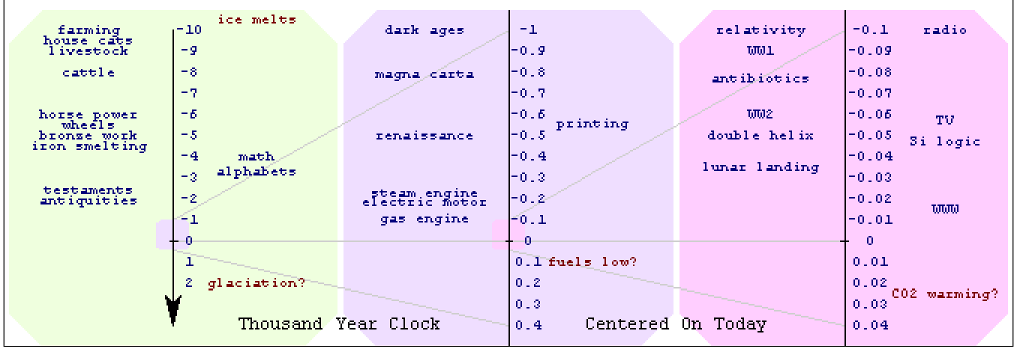
Time scales



This slide discusses a synthesis between two interesting books, one on time's arrow by astronomy book author Eric Chaisson at Tufts University, and the other by geologist Peter Ward and stardust mission PI Don Brownlee (at UW Seattle) on earth's clock. Eric optimistically discusses the cosmic evolution of steady-state systems that trade free energy for increasingly complex subsystem correlations. This integral view of evolution lets students see how real-time observations of stellar and planetary evolution are a seamless part of the living fabric on earth. Ward and Brownlee, who elaborated on the rarity of planetary chances for metazoan evolution in their book Rare Earth, discuss on the billion year time scale how earth is only a temporary home for such complex systems. At the bottom of the slide, we begin zooming in on the present in a calendar made by combining these billion year clocks. As you can see, we're in the middle of what is likely the third ice age since metazoan lifeforms on our planet came into their own a half-billion years ago. Moreover, solar evolution and carbon loss processes suggest that this age of plants and animals will have run its course on a comparable time scale in the days ahead. We continue zooming in on these calendars starting with the pink box in the lower right corner above...

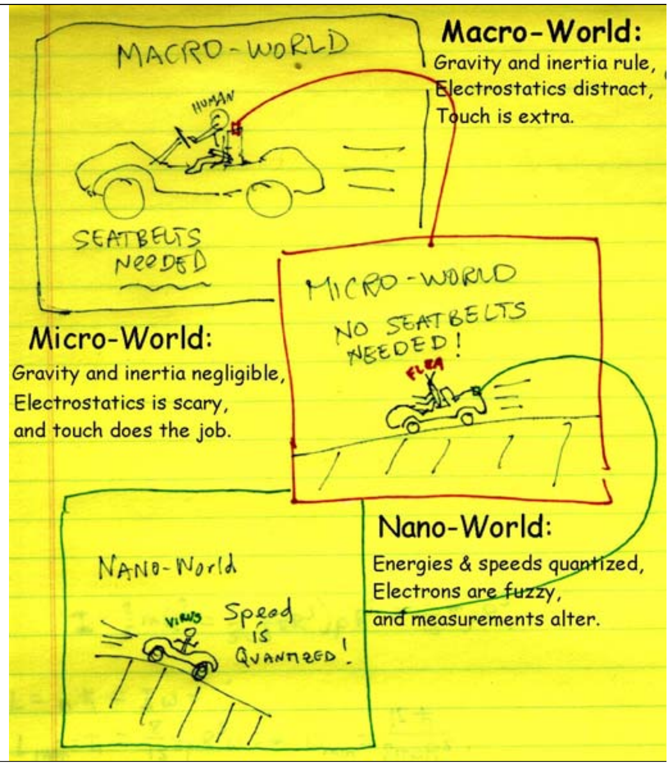


Zooming in to smaller and smaller time scales, we find ourselves on a planet with surface carbon declining, but Si-logic improving by leaps and bounds...



Here million-year calendars (top) centered on the present show some of the interglacial periods that our ancestors have benefited from in this current ice age. The thousand-year calendars below that zoom in on the current interglacial period, beginning with the development of food production (i.e. farming) that resulted in the development of big cities, written language, and more recently combustion engines. The latter have helped us get rid of a half-billion year's accumulation of fossil fuels in less than a millionth of the time that it took to create it, suggesting that the primary source of free energy being used lately to develop the social complexity that Chaisson describes will (on a mere thousand-year time scale) soon be kaput. If we think only on time scales in the present, we wouldn't notice that humans have used up a resource that took the first half of the age of plants and animals to put into place, and which therefore will not be available to metazoans for the remainder of our time on this planet. Thinking of more than one size scale yields some equally interesting connections, and ones of even more immediate relevance. (For more on those time scales, see: http://www.umsl.edu/~fraundor/ifzx/earthtimes.html)

Challenges differ according to their size scale, as well as their time scale. *What examples come to mind for you?*



Here are few examples of how the physical world around you changes as your size goes from macro to micro to nano. What other things change according to size in interesting and practical ways?

Other size effects include...

- Thick-cut french fries absorb some oil, but thin-cut fries (because of their larger surface to volume ratio) may absorb much more. Where else is this effect important?
- Large objects fall quickly, feathers fall more slowly, but particles smaller than 0.1 micron may never make it to the ground 'cause of molecule impacts! Where else is this effect important?
- Iron roofs don't burn, steel wool burns reluctantly, but nano-iron may oxidize so fast that it catches things around it on fire! Where else is this effect important?
- Ballet dancers can be spun on point (it would seem) *as slowly* as they like, but not so with a virus particle. Why not?

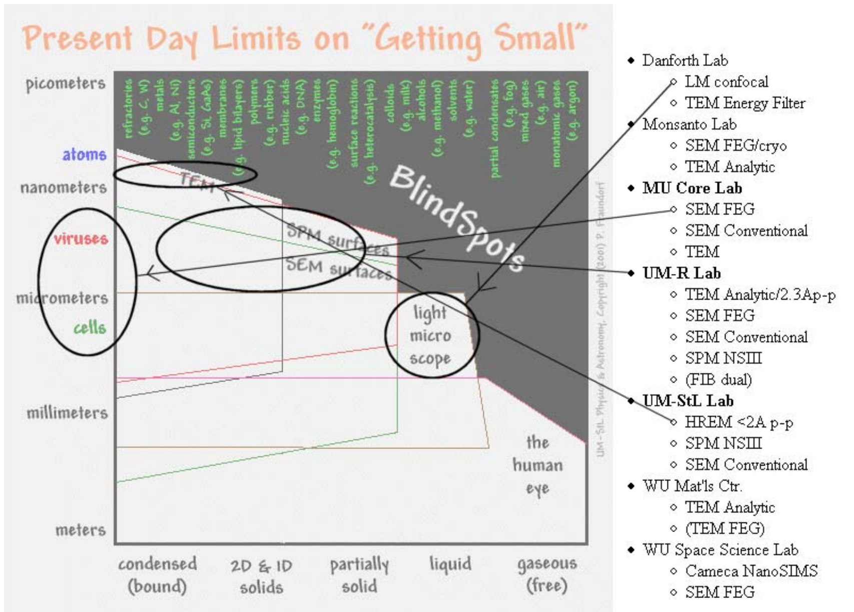
Other size effects involve shape (e.g. gold leaf is flexible, and gold foil less so, while gold bars are not), ability to be cut (e.g. a diamond knife will break before going through a hand specimen of chromite, but that chromite might slice nicely if it's only 0.1 microns across), settling in liquids (e.g. colloids with sufficiently small particles in them, like ink or milk, may never separate into liquid on top of solid unless one increases gravity with help from a centrifuge), hetero-catalysis (catalytic converters and manufacture of the herbicides can be made more efficient and economical with control of the nano-size particles that make them possible), porosity (e.g. aerogel can be made less dense, zeolites more useful as catalyst supports, and activated-charcoal more effective as a water purifier with control of nanosize pores), adhesion (e.g. flour glue and concrete both depend on the fact that touching between very tiny particles has noticeable macroscale effects on material strength, as does a gecko's ability to walk on the ceiling), combustability (like nano-metals, airborne flour particles in a mill are also a combustion hazard), surface effects (e.g. structural uses for surface-tension give us microscopic "fingers" with which to manipulate nano-meter thick films, as well as lily pads an ability to prevent water spots and dirt-buildup on their surfaces). And then there are spiders keeping webs taut, insects water striding, and what else?

Things of everyday use...

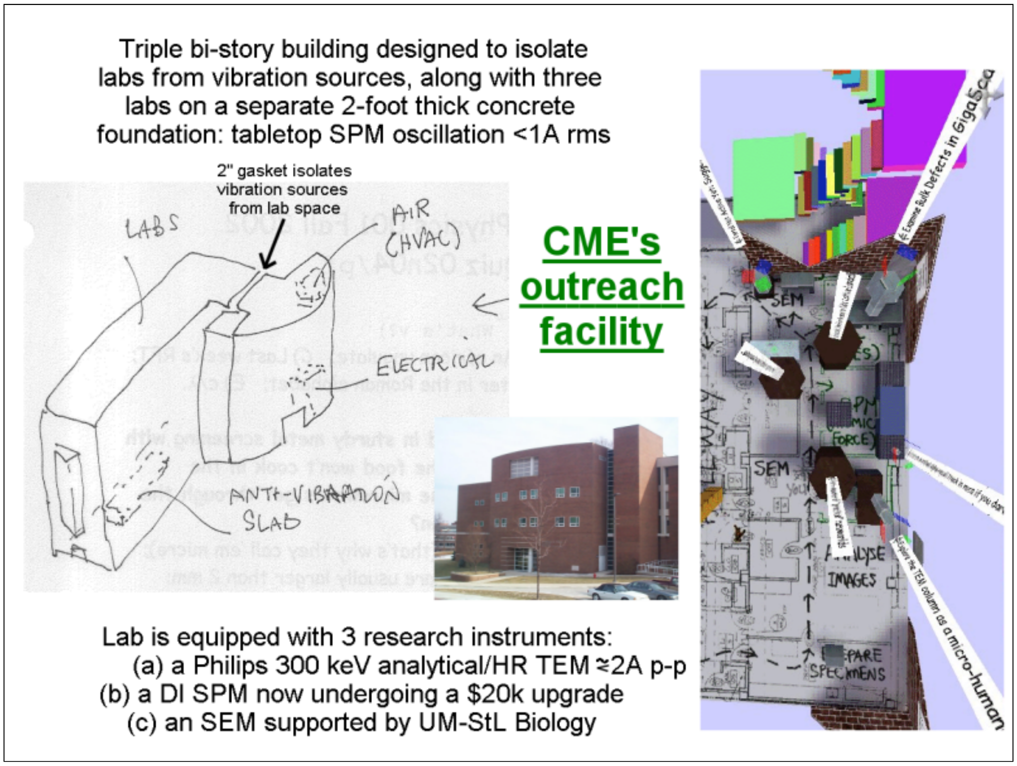
- How to tell when processes on small scales are involved in an experience?
- Guessing what effect size might have, e.g. on making protein spheres “taste” like rich and creamy fat, on making a thin film change color, on making a rope stronger, on keeping particles from settling out of air or water, or on making a sno-cone more likely to give you an “ice-cream headache”.
- Awareness of possibilities and limits of our current tools for interacting with things on small size scales.

Life has been using nanoscale processes (as well as genetic engineering) for billions of years, many of which are still being discovered by us. Hence they are not trivially recognized. On the other hand, people are now trying out new nanoscale processes everyday. Thus insight into their capabilities, and their shortcomings, will be increasingly important. This is also true about the tools, like microscopes, that we use to figure out how these nanoscale processes work. For example, there are some structures that we can examine on the nanoscale, but an equally large number that we can only infer by indirect means...

Blindspots according to size scale, and regional highlights...



This slide shows one way to outline our blindspots in identifying nanoscale structure. Gases are toughest to look at in detail, because their atoms typically move so quickly, while high temperature solids are perhaps most likely to have atoms that will hold still. This slide also highlights the strengths of some regional labs that have expressed interest in serving others across the region, where possible.



Here's a slide about one such regional facility, at UM-StL. If you have a question about nanoscale exploration, perhaps they can hook you up to resources in the area able to help. A Missouri-wide nanoalliance is being developed that may also be of help in this context.

NanoChallenges that walk in...

- What are these mysterious etch pits on a silicon wafer caused by, and are they friend or foe?
- How did red giant stars manage to condense carbon atoms into the form of unlayered graphene, and send them here?
- What size and shape of ferrofluid particle is optimum for repair of a brain aneurism?
- What makes these metal fuel-cell catalysts, on carbon nanotubes, work so well?
- How is the shape of these Alzheimer's-like amyloid protein aggregates affected by a change in acidity.

Examples of the kind of problem that such nanoscale science outreach facilities might get a chance to help out with.

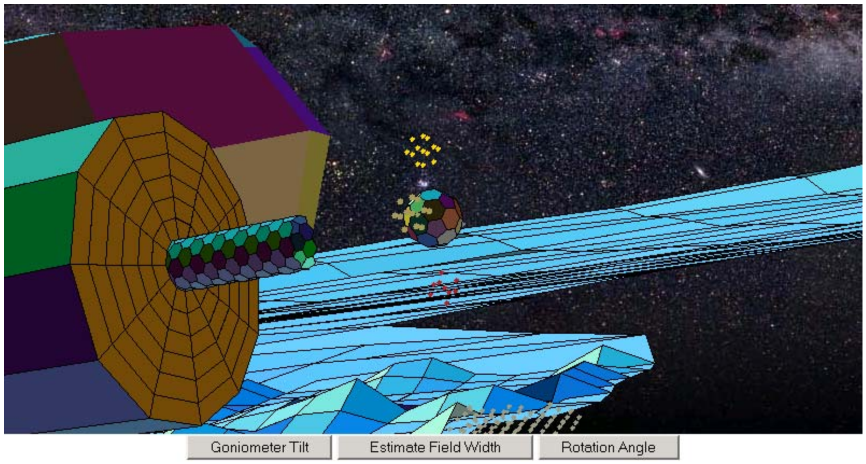
What's next?

- Play with a film 50 atoms thick, and try to figure out how a ferrofluid works.
- Try to make some measurements with a virtual microscope.
- Go over a few local project examples.
- Try another speaker for a while...

Segway to other activities available on the program...

A nanoscale detective trainer may be found on the web at
http://www.umsl.edu/~fraundor/nanowrld/dtemspec.html

A MissOuri NanoAlliance inventory may be found at
http://newton.umsl.edu/~run/mona/default.htm



This last slide illustrates one of our web-based virtual microscopes. These are designed to offer empirical observation exercises to students, patterned after challenges offered by real microscopes on real specimens. Strategies are being developed for their use in homework (lab notebook, scientific report, and peer review), in modeling workshops, through peer instruction, and even on timed in-class exams. Of course, to return to the beginning, this discussion about nanoscience in everyday life does not end with progress. It is also about survival over a variety of time-scales on a planet attempting to preserve, or enhance, its correlation-based complexity even though our per-capita free-energy production peaked at 2.2 kilowatts a quarter century ago, and our half-billion year's accumulation of fossil fuels is about to run out. For this, we're going to need every bit of hard-won ingenuity we can put our hands on, spanning multiple scales of both space and time.