Syllabus:

NanoMachines: The Tiny Biological Gadgets that Animate Life

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Fridays, 9:30 - 11:00 a.m., March 3 through March 24, 2023
Hybrid: Illinois Classroom and Zoom Webinar

Course Description:

Inside all the cells in our bodies, as well as those in bacteria, buttercups and beluga whales, a surprising variety of microscopic macromolecular machines toil away 24/7 keeping life processes humming. Quite a bit is now known about how some of these remarkable mechanisms work, but much remains to be teased out. These devices carry out a wide range of functions, including energy production, manufacturing, motion, pumping, data processing, communication, sensing and others. We will investigate the construction and operation of many of the nanomachines, comparing them with familiar man-made machines carrying out similar activities. No scientific background or knowledge is required, just a lively curiosity.

The Plan:

The course will be presented using PowerPoint materials, as usual, including numerous available computer-generated videos showing the nanoMachines in action. Unfortunately, due to the tiny scale of the gadgets involved, there will be few in-class demonstrations, but we should still have plenty of fun.

There is no obvious natural order to the topics we need to cover, but I have tried to arrange them in an order that introduces the various concepts in a logical order, with later sessions building on earlier ones to some extent. Of all the enormous range of nanoMachines ticking away in living cells, we will try to concentrate on the most amazing ones.

The 4 weeks:

1. Overview of nanoMachines. The building blocks of nanomachines at the atomic level, including the structures of proteins and other biomaterials. Weirdness of life at tiny scales. The key role of energy flow in living organisms. How scientists are able to figure out how the machines work.

2. NanoMachines involved in energy production and distribution in cells. Photosynthetic machines, mitochondria, and respiratory machines. ATP synthesis.

3. Structural beams and girders at the cellular level. Motors, cargo transport and locomotion. Bacterial flagella. The inner workings of muscles.

4. Informatic machines involved in DNA and RNA processing and protein manufacturing. Sensory devices, including light and olfactory sensors.

Reading List:

I have found no good one-stop references covering the content of this course at an appropriate level, but some annotated suggestions follow.

1. Nick Lane Transformer: The Deep Chemistry of Life and Death (Norton 2022)
   This book inspired the course, although the content of the course wound up diverging pretty far from it. Any book by Nick Lane on the subject of the fundamentals of life is worth reading, in my opinion – and he has written quite a few.
2. Nick Lane Life Ascending: The Ten Great Inventions of Evolution (Norton 2009)
   This Nick Lane book, in particular, lies closer to the theme of this course.
3. David Goodsell The Machinery of Life (Copernicus, 2nd Ed 2010)
   Lavishly illustrated, on-topic, and useful. Perhaps a bit pricey, however, for most.
4. Bhanu Jena Cellular Nanomachines: From Discovery to Structure -- Function and Therapeutic Applications (Springer 2020)
   Appears to be excellent and directly relevant, but at $150 out of my reach. I did not check the UI library.
5. Joachim Frank, Editor Molecular Machines in Biology: Workshop of the Cell (Cambridge 2011)
   Too technical for this course. Also, at $150, unaffordable.
6. On-line resources:
   a. Wikipedia Article "Molecular Machine" *A quick read that is partially relevant.*
   b. Numerous YouTube lectures by Ron Vale (UCSF, Howard Hughes Medical Institute)
      Many of Vale's lectures cover materials relevant to this course, and are quite good.
   c. Any YouTube molecular animation videos by **Drew Berry** (Walter & Eliza Hall Medical Institute, Melbourne Australia).
      Along with animations by Harvard BioVisions, I have used many of Berry's videos in this course.