April 04, 2012

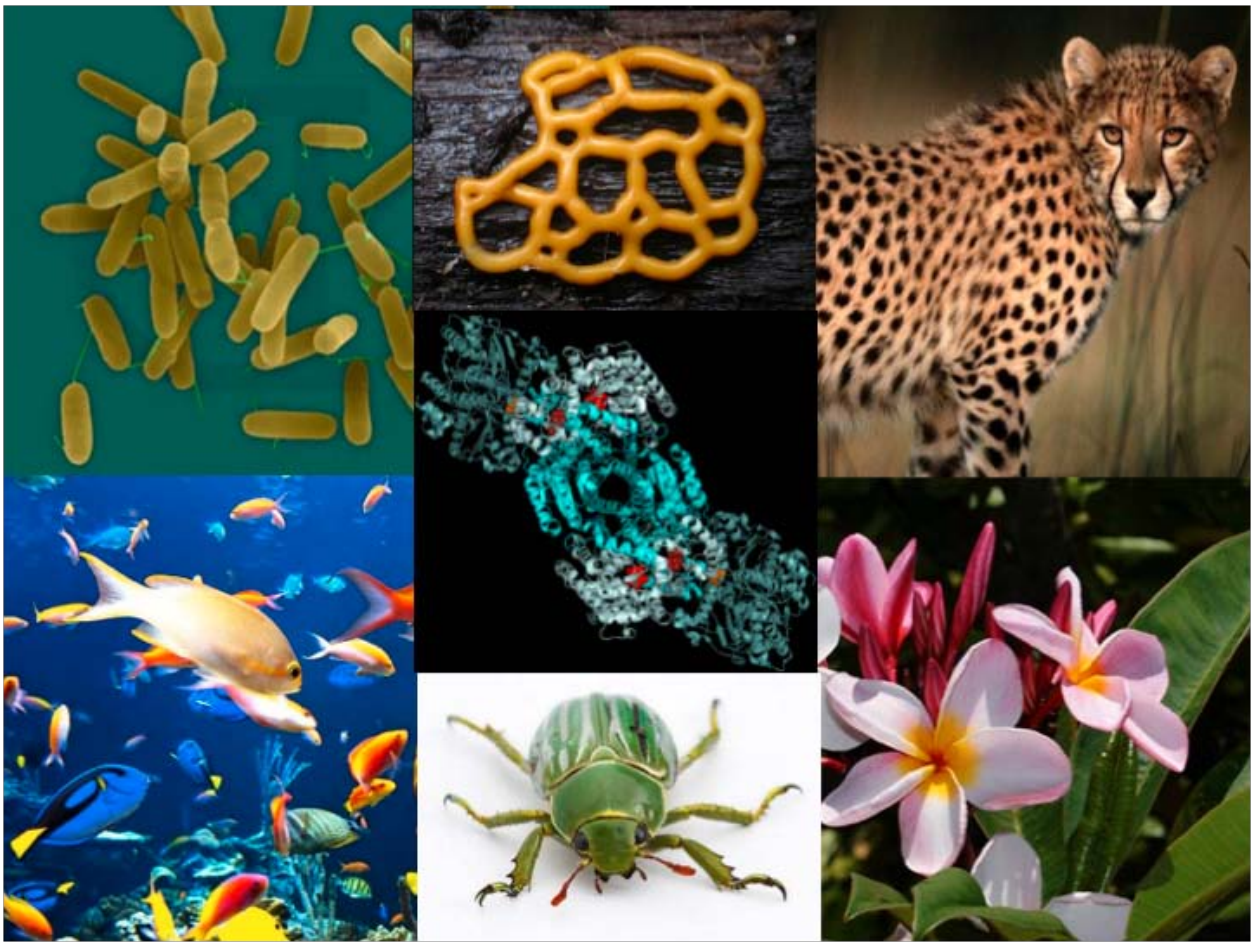
MOTIVATION

1. Biology is the 21st century science.
2. Our world is rapidly changing, and biology is intimately involved.
3. One day you or someone you love will get sick.
4. Biotechnological innovations are raising important ethical questions.

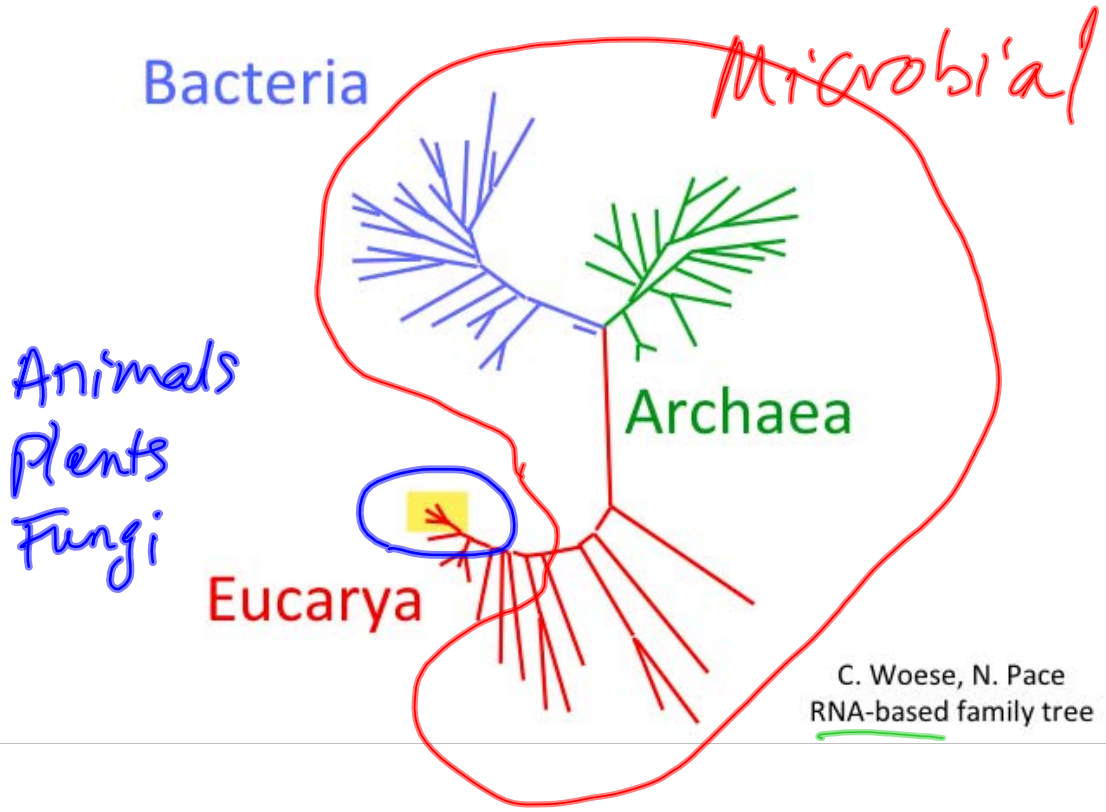
IT IS TIME FOR NEW APPROACH TO TEACHING BI 1

1. Unifying principles – micro to macro
2. Integration with other scientific/engineering fields
3. Experimental emphasis (featuring Caltech research)

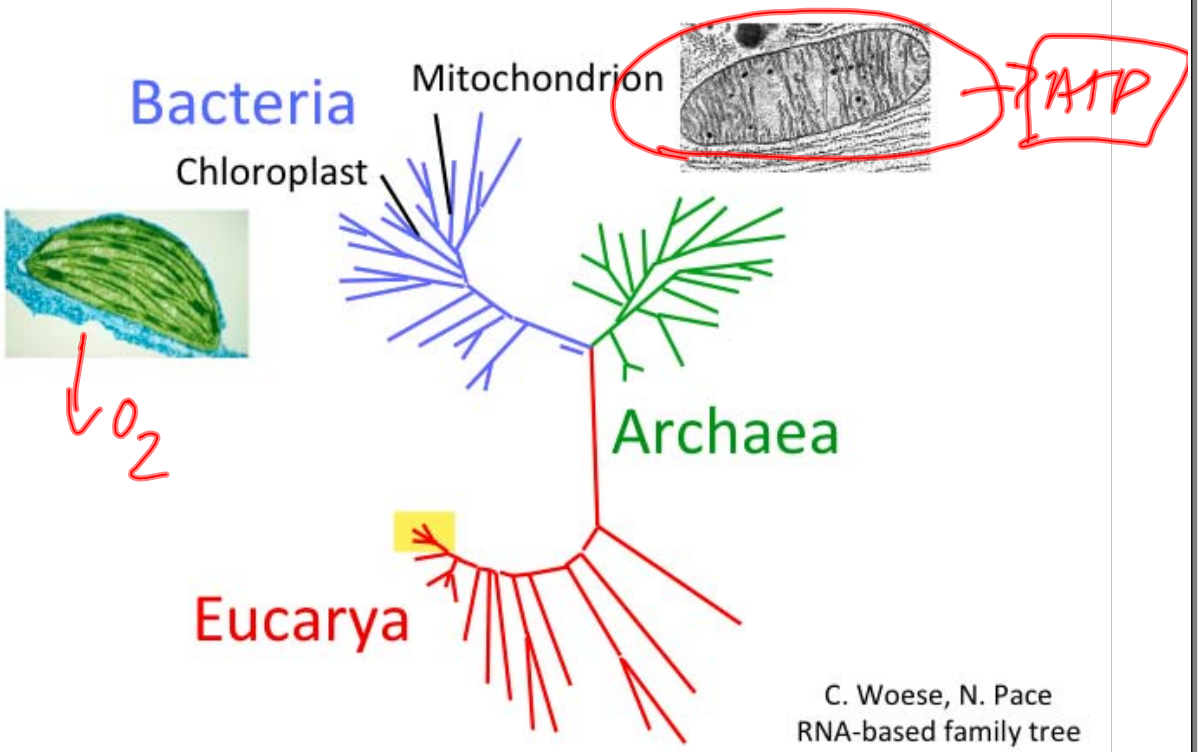
April 04, 2012



The 3 domains of life are predominantly microbial

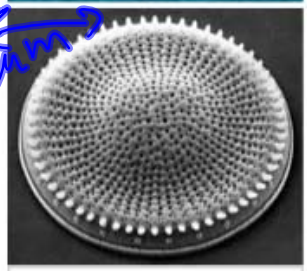


All of life's metabolism is microbial in origin



Microbes collapse the hierarchy of life

Biosphere
Ecosystem

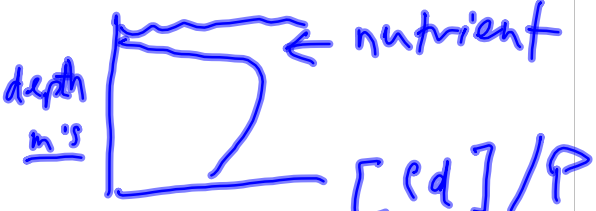


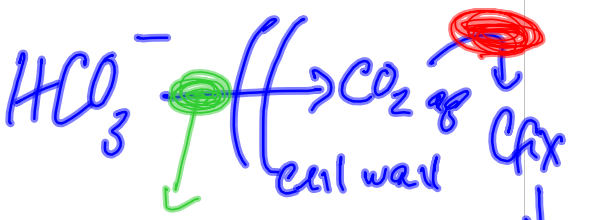
10 μm

Communities
Organisms
Diatoms

Molecular
Atom

Cd





$HCO_3^- + H^+ \leftrightarrow CO_2 + H_2O$

Carbonic anhydrase

Lane, T.W. and F.M.M. Morel. *PNAS*, 97: 4627-4631 **(2000).**

We are not alone!

- We have 10X number of microbes on/within us than human cells
- Gut microbiome encodes >100X human genome!
- Microbial ecology linked to autism, celiac disase, colitis, obesity…

10^{12}/human

Outline for today:

- Principles of biology – key concepts that structure the course
- Diversity of the biosphere
- Evolution – how diversity arose
- Syllabus

Summary of principles – outline of course week(s)

1. Life must EXIST (interface/interact with external environment) 1, 3, 4, 5
2. Life must PERSIST (replicate into next generation +) 6, 7
3. Life achieves #1 and #2 through EVOLUTION 1, 2
4. Life CO-EVOLVES with the natural world 2, 8, 9
5. Life's organizational rules are captured by ECOLOGY 8, 9

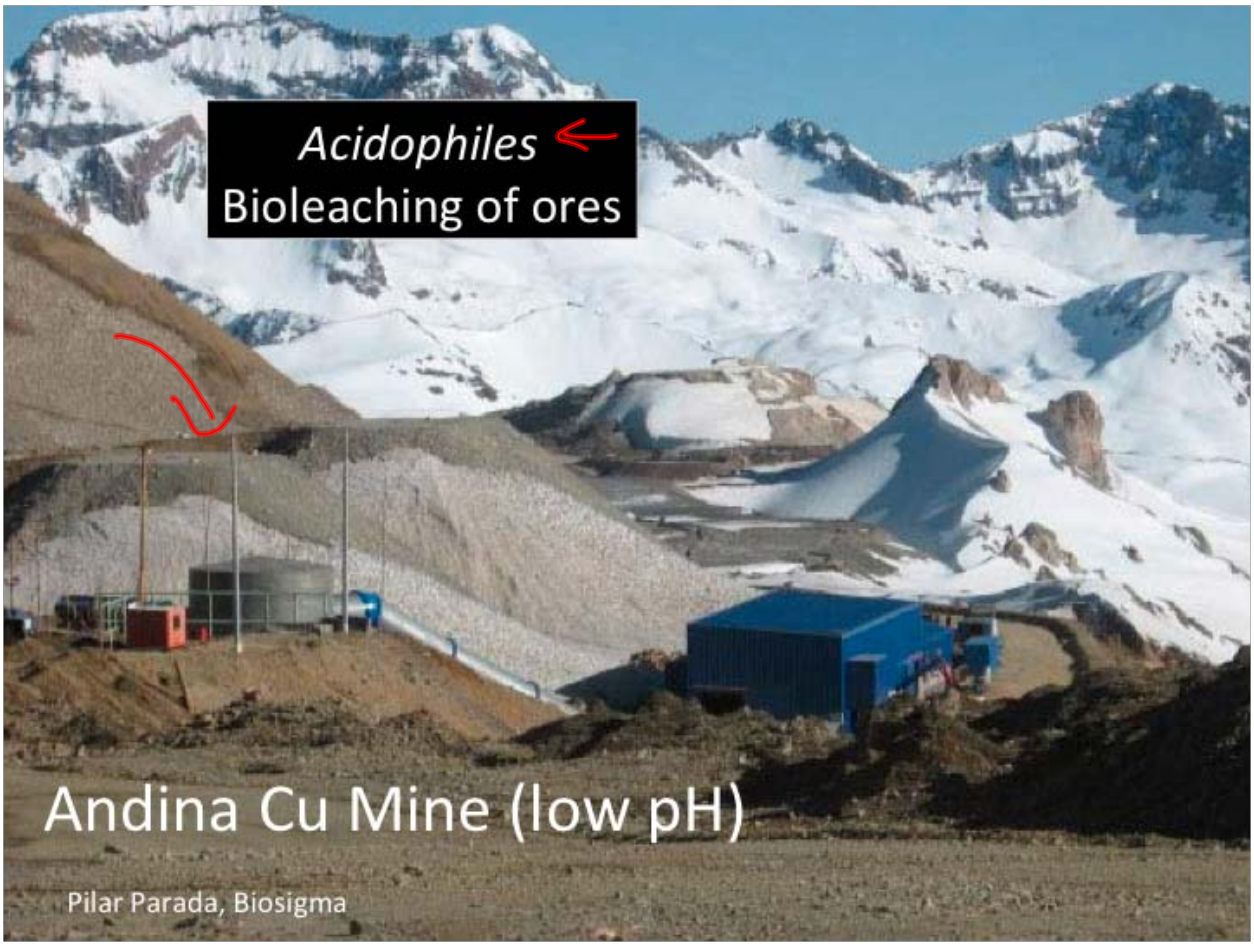
To be an engaged 21st century citizen, you must understand biology 10

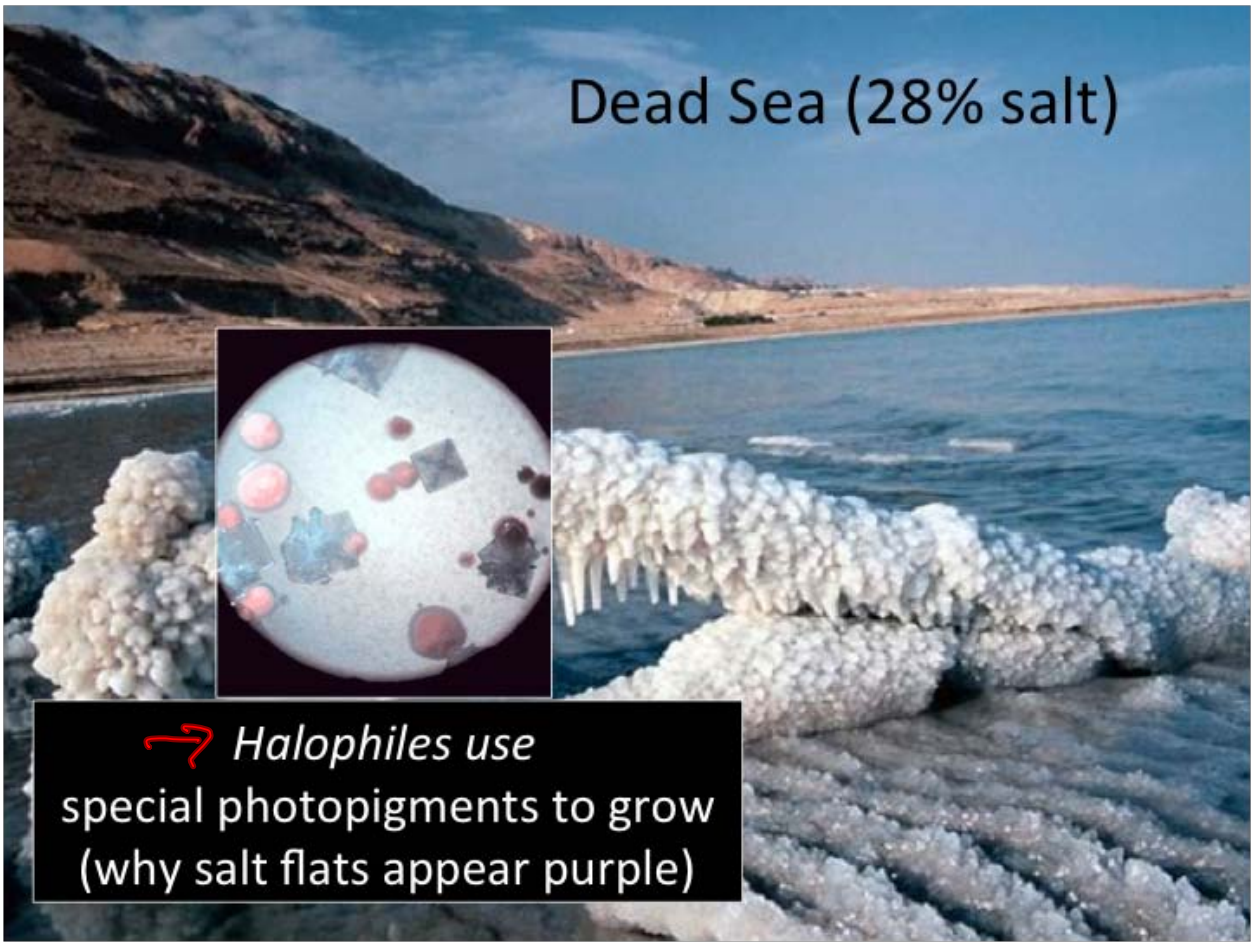
EXIST All organisms must:

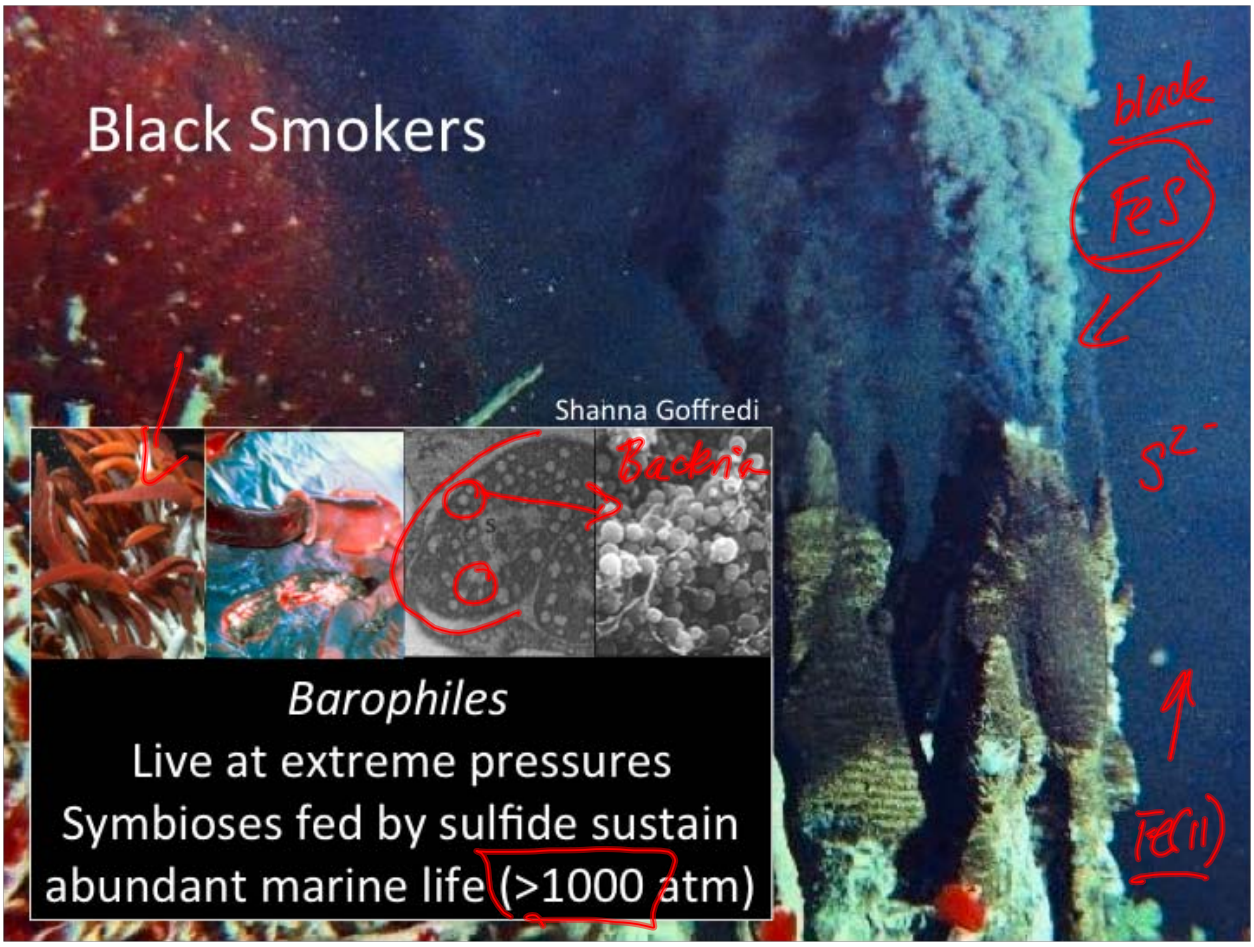
Week

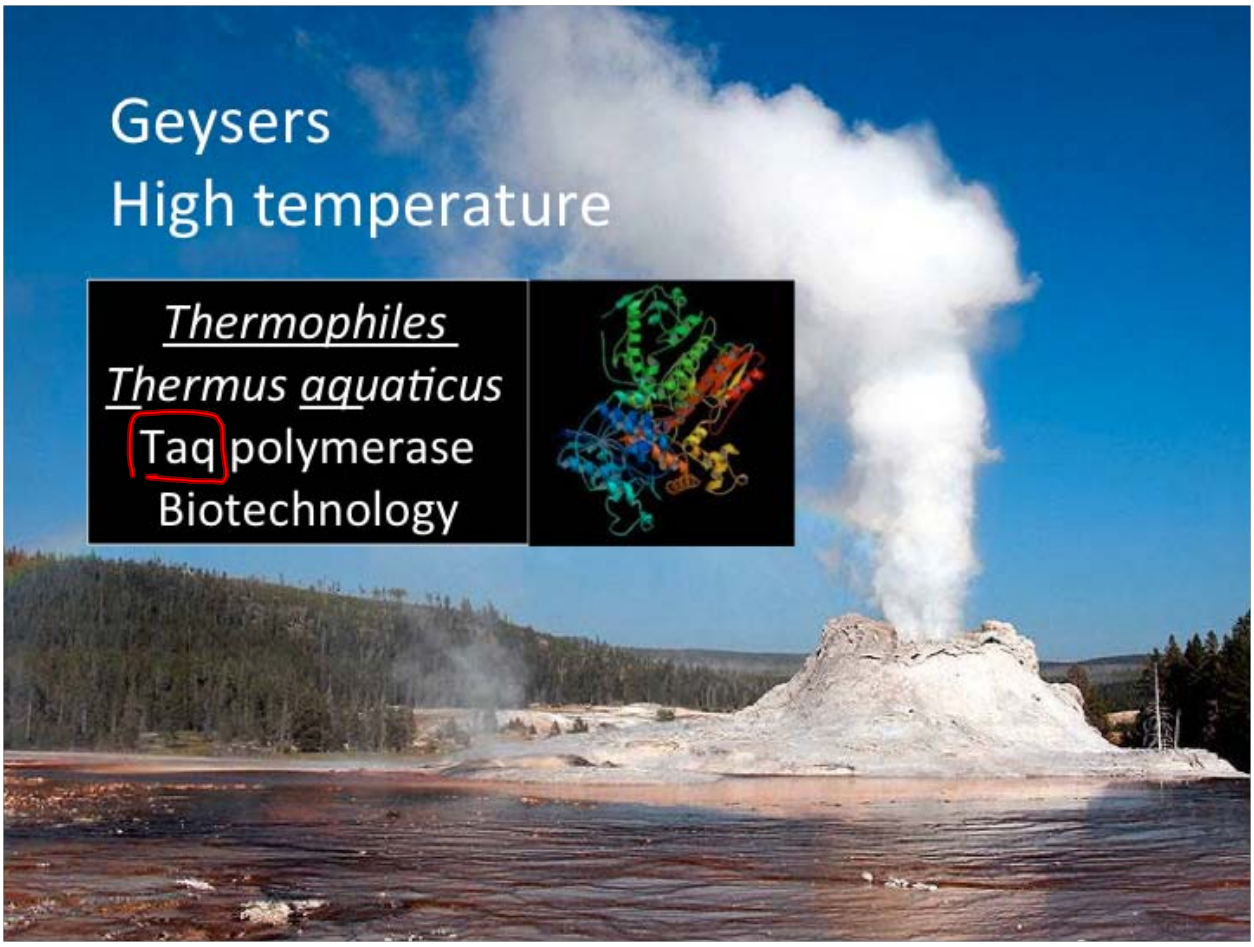
- Define a cell/organismal boundary — 1, 2
- Build it using conserved materials — 1, 2, 6
- Maintain internal environment (homeostasis, repair damage) — 3, 4
- Generate energy (growth, maintence) — 4, 5

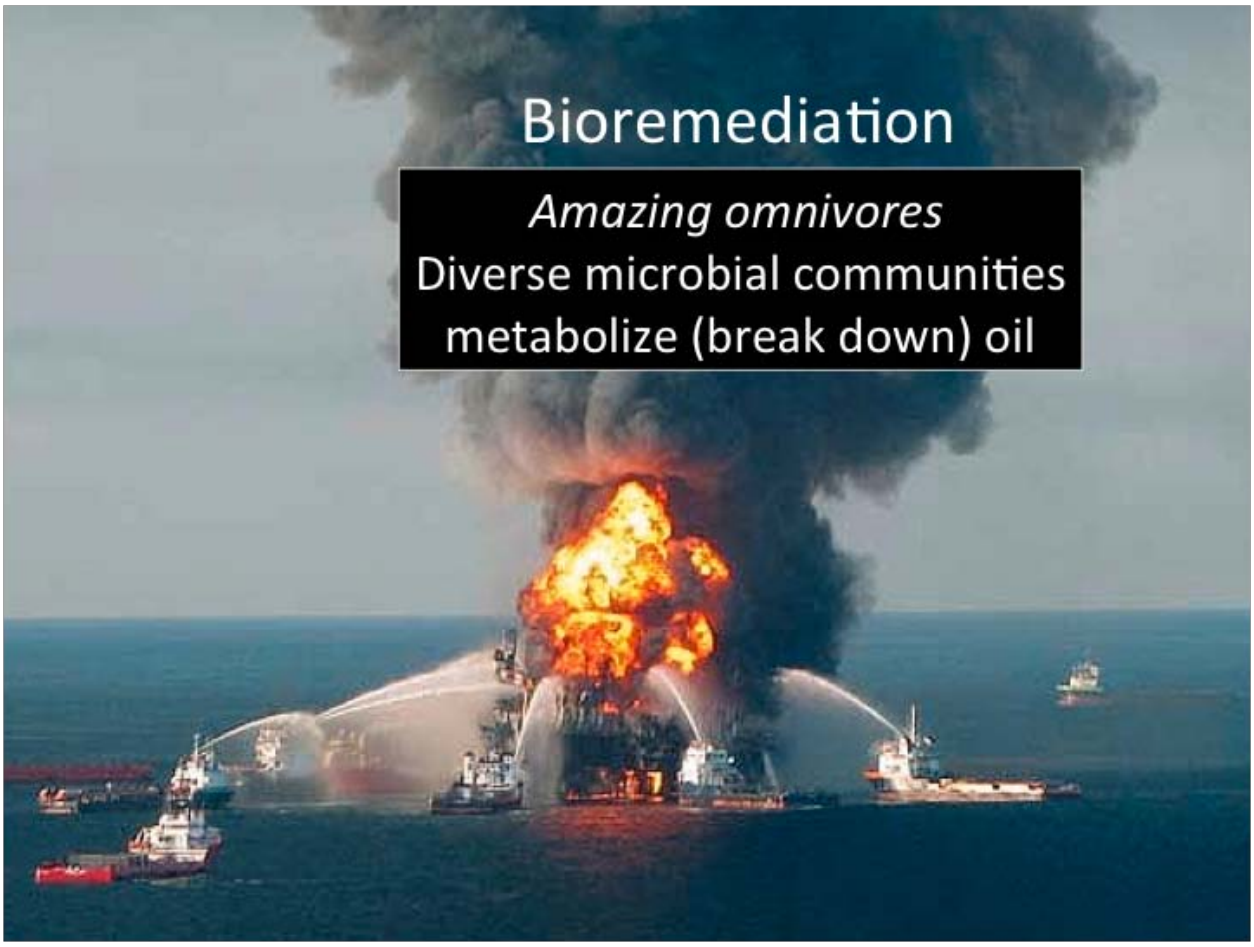
What are the limits to life? (physical? chemical? thermodynamic?)
→ what are the design principles that push against these limits?


Acidophiles
Bioleaching of ores
Andina Cu Mine (low pH)
Pilar Parada, Biosigma


Dead Sea (28% salt)
Halophiles use
special photopigments to grow
(why salt flats appear purple)


Black Smokers
Shanna Goffredi
Barophiles
Live at extreme pressures
Symbioses fed by sulfide sustain
abundant marine life (>1000 atm)
black
FeS
S^{2-}
Fe(II)


Geysers
High temperature
Thermophiles
Thermus aquaticus
Taq polymerase
Biotechnology


Bioremediation
Amazing omnivores
Diverse microbial communities
metabolize (break down) oil

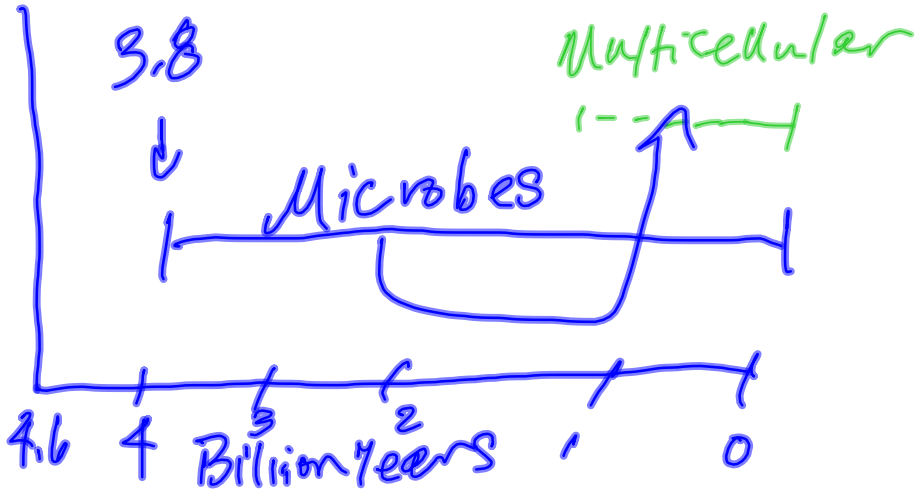
weeks

PERSIST

6,7

- Cells/organisms reproduce
- To do so, must copy
  - ↳ mistakes
    - ↳ drives evolution

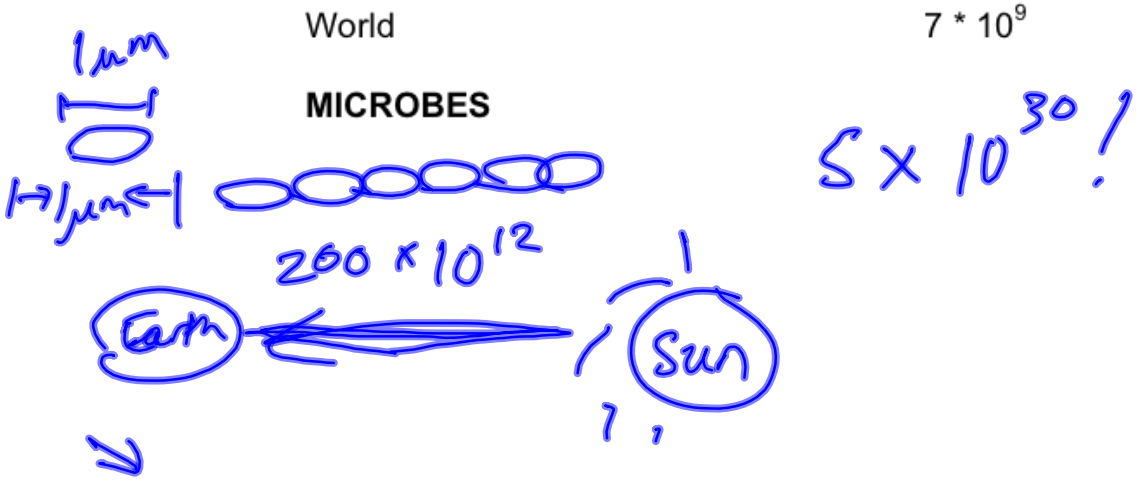
* Microbes have persisted for a LONG time



* Microbes have reproduced a LOT

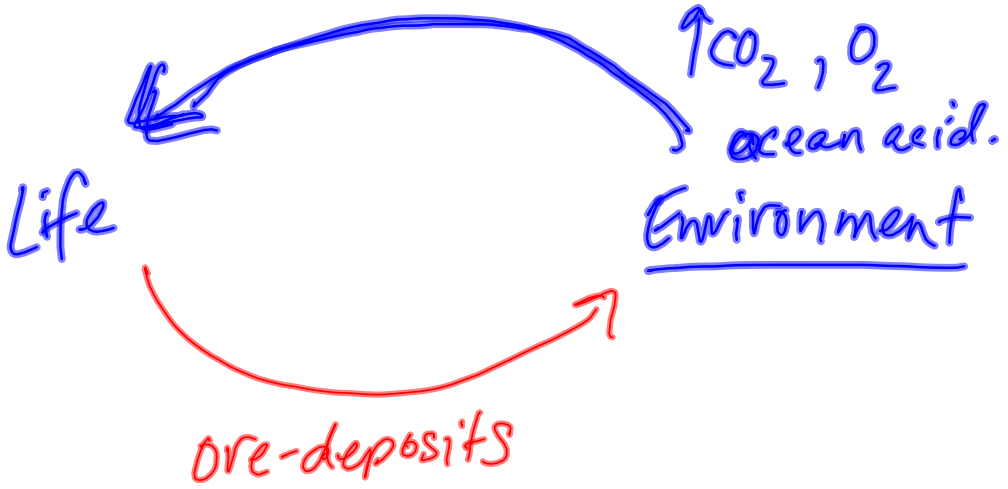
Population of	Los Angeles	~10 * 10^6
	California	38 * 10^6
	United States	~313 * 10^6
	World	7 * 10^9

MICROBES



See "Microbiology by Numbers" in Reader
"Prokaryotes: the Unseen Majority" (Supplemental Reading)

DIALECTIC with Natural World (CO-EVOLUTION)



ECOLOGY: Organizational principles that hold living things together

What makes an ecological systems robust? stable?
- John Doyle (CDS, EE, Bio Eng) – internet design

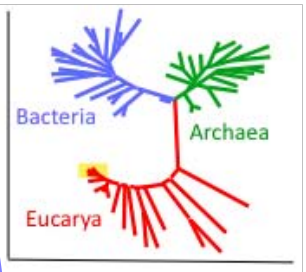
Part 2:

Key concepts for today

1. DIVERSITY
   - HIERARCHY
   - EMERGENT PROPERTIES
   - ORDER / RELATIONSHIPS ← NO DESIGN
2. EVOLUTION (& ENGINEERING)
   - FITNESS

LIFE'S HIERARCHY

biosphere



BACTERIA/ARCHAEA

EUKARYA

ecosystem

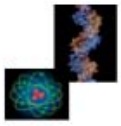
community

population

organism [cell]

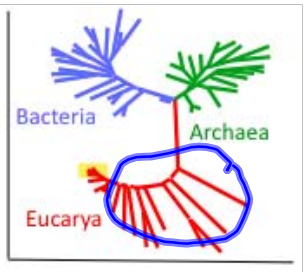
molecule

atom



LIFE'S HIERARCHY

biosphere



BACTERIA/ARCHAEA

EUKARYA

single-celled

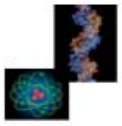
ecosystem

community

population

organism [cell]

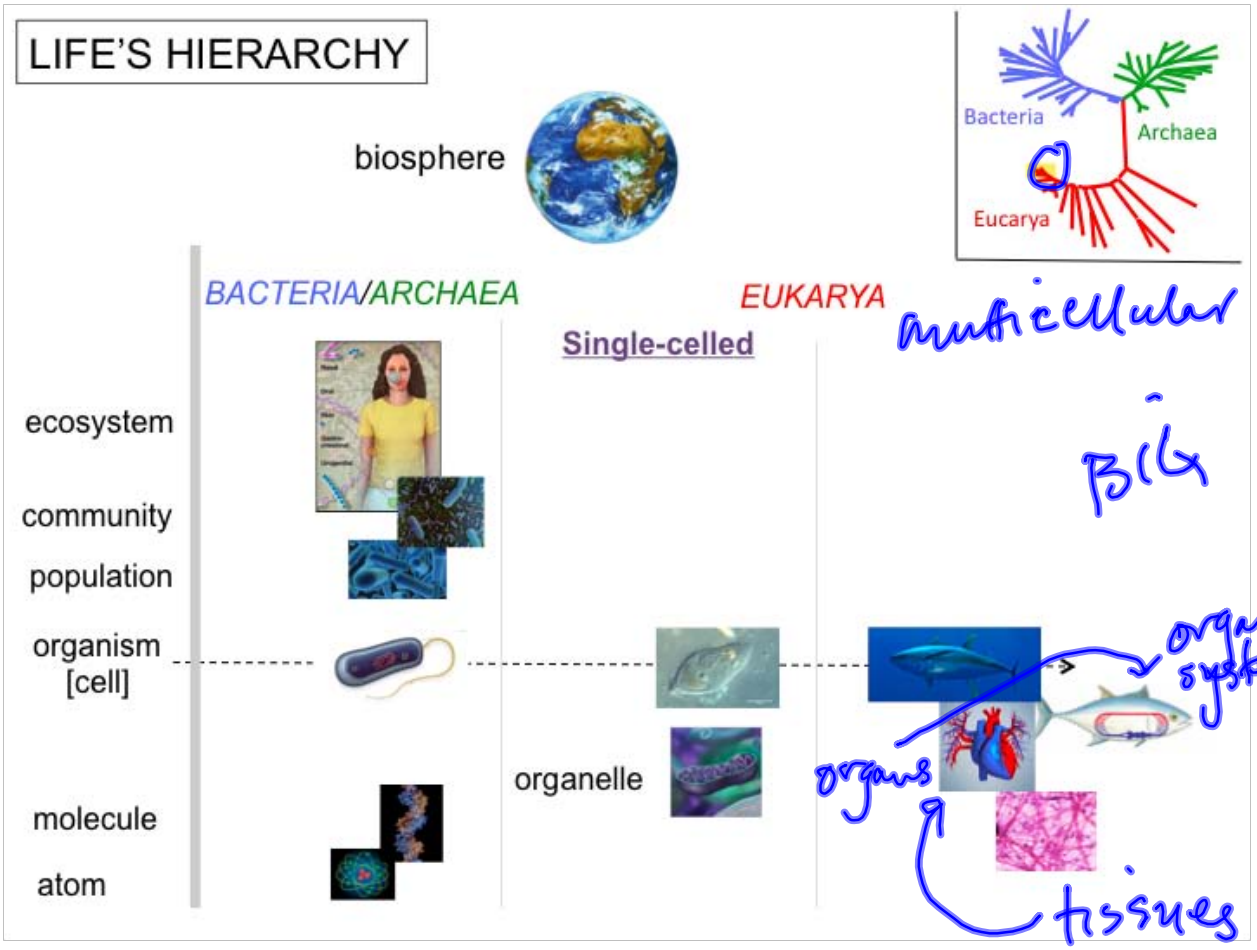
molecule

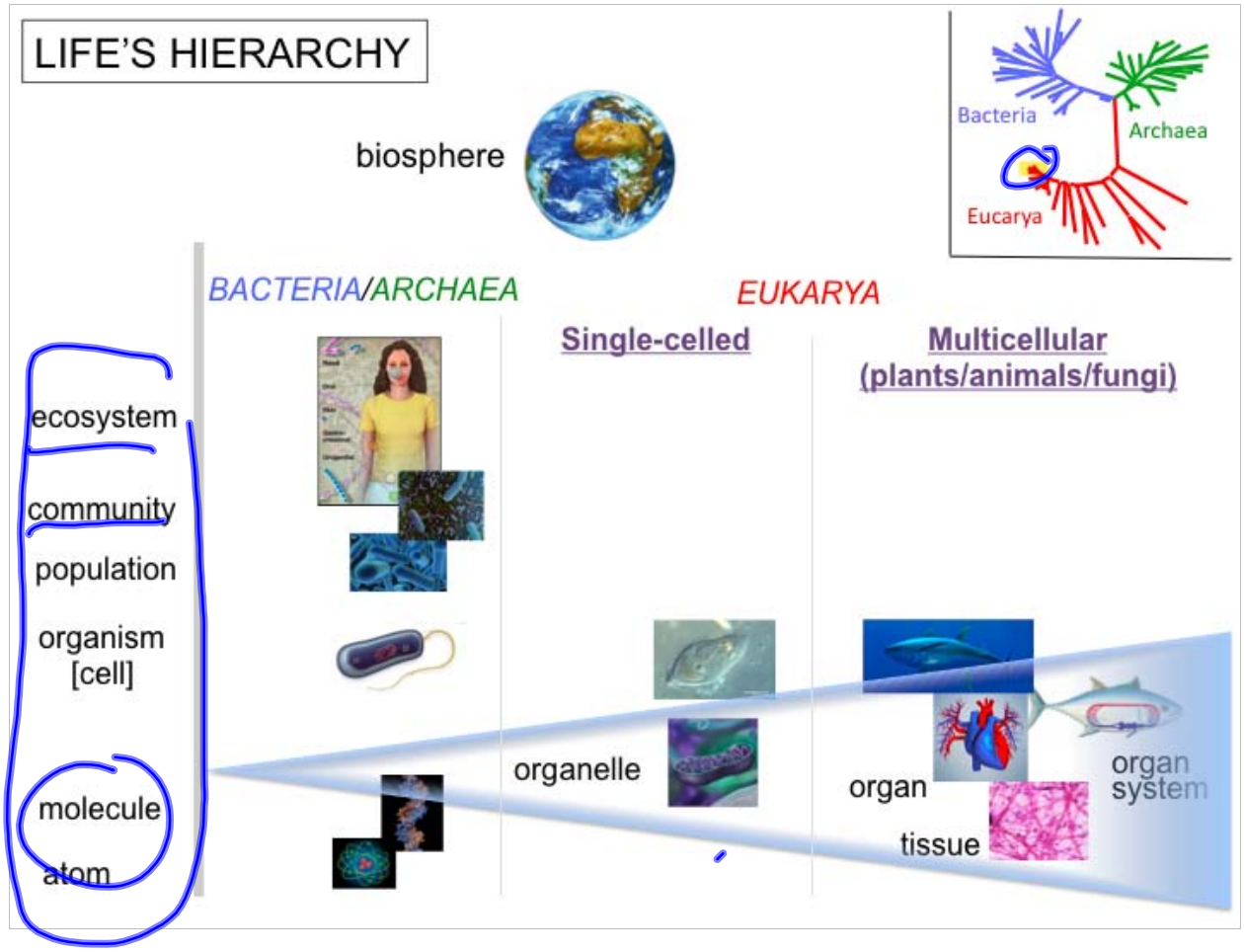


atom

organelles

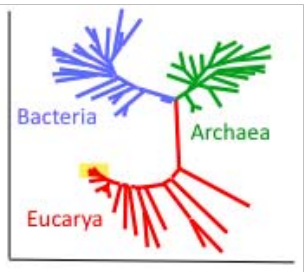
DNA


LIFE'S HIERARCHY
biosphere
Bacteria
Archaea
Eucarya
BACTERIA/ARCHAEA
EUKARYA
Single-celled
multicellular
big
ecosystem
community
population
organism
[cell]
organelle
molecule
atom
organ systems
organs
tissues


LIFE'S HIERARCHY
biosphere
Bacteria
Archaea
Eucarya
BACTERIA/ARCHAEA
EUKARYA
Single-celled
Multicellular
(plants/animals/fungi)
ecosystem
community
population
organism
[cell]
molecule
atom
organelle
organ
tissue
organ
system

LIFE'S HIERARCHY

biosphere



ecosystem

community

population

organism [cell]

molecule

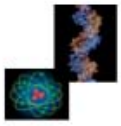
atom

BACTERIA/ARCHAEA

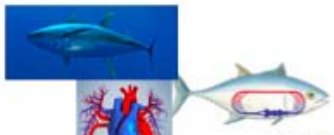
EUKARYA

Single-celled

Multicellular (plants/animals/fungi)



organelle



organ

organ system

tissue

NESTED

organism

ecosystem

EMERGENT PROPERTIES - whole > sum

- biosphere
- ecosystem
- community
- population
- organ system
- organ
- tissue
- cell
- organelle
- molecule
- atom

DNA 200 bp > 1000

In your readings:
Cohen (your reader) Math & Biology
Davies (PDF, Bi1 Website] Emergent biological principles and the computational properties of the universe.

Emergent Properties

BACTERIAL COMMUNITY AFFECT HOST HEALTH

HOST'S BODY SELECTS FOR SPECIFIC MICROBES

RELATIONSHIPS

Limits of RESOLUTION

SEEING

- BC – EYES
  ANIMALS / PLANTS
- LATE 1700's
  MAGNIFYING LENSES
  A/P / MICROBES
- BETTER LENSES (TEM)
  1960
  ANIMLS / PLANTS / FUNGI / PROTISTS / MONERA
  SEQUENCING RNA
  pre 2000

Humbington

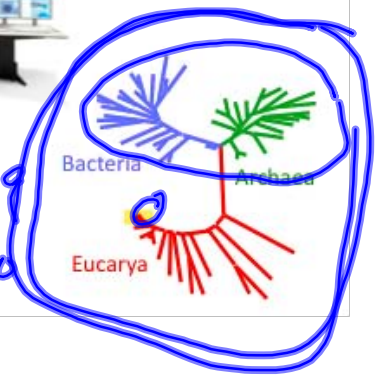
Aristotle

Anton van Leeuwenhoek

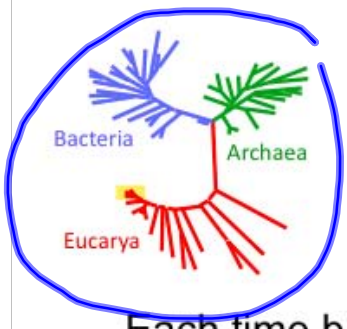
Transmission Electron Microscope

1979

1990



Are we done? – Maybe not

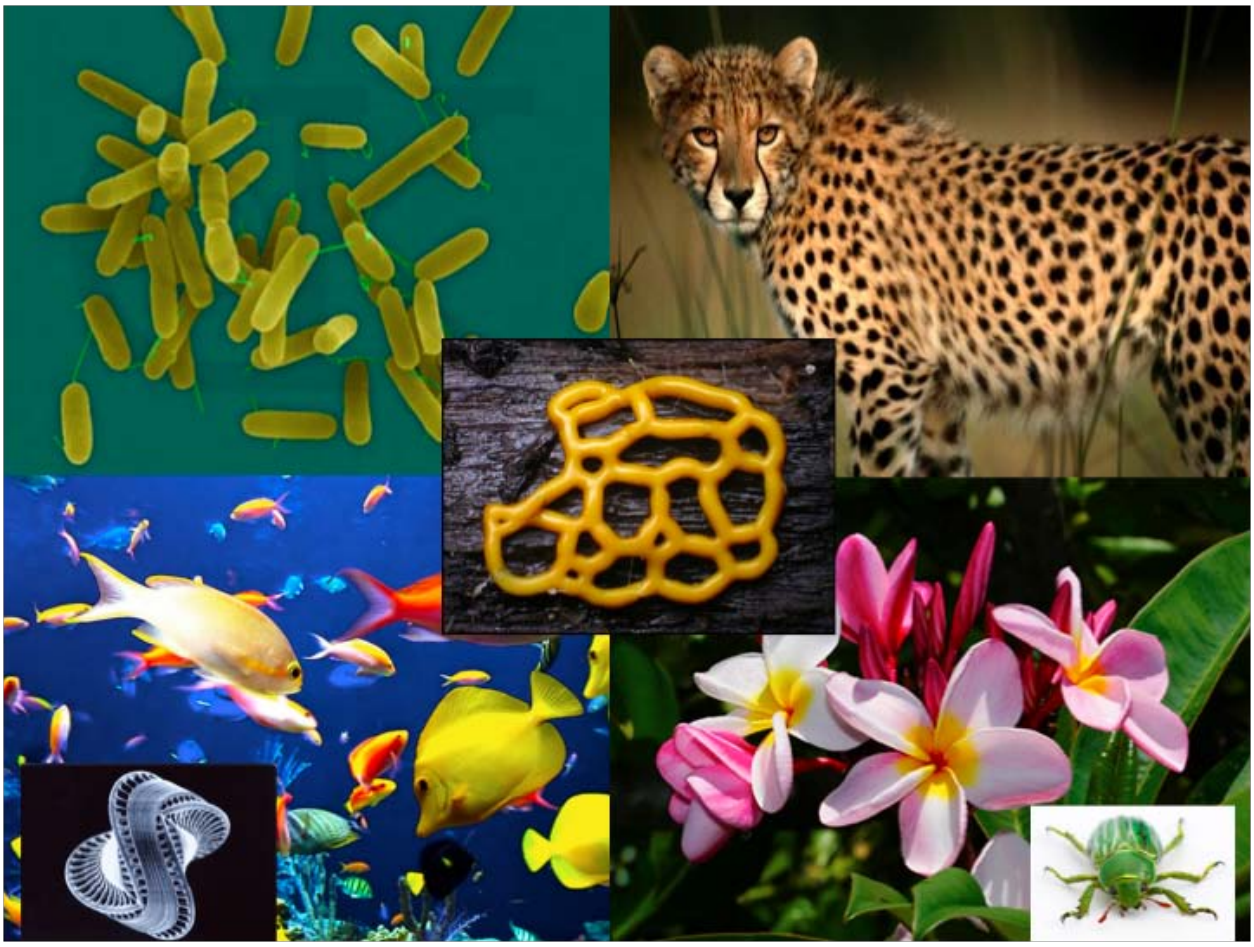


Each time biologists are sure they had the final picture

THE DNA IS NOT STATIC!

[END OF Bi1 – Myles Jackson, NYU – ethics in modern biology

April 04, 2012




HOW DOES DIVERSITY ARISE?
EVOLUTION

April 04, 2012

Charles Darwin

1809 – 1882

galapagos Islands

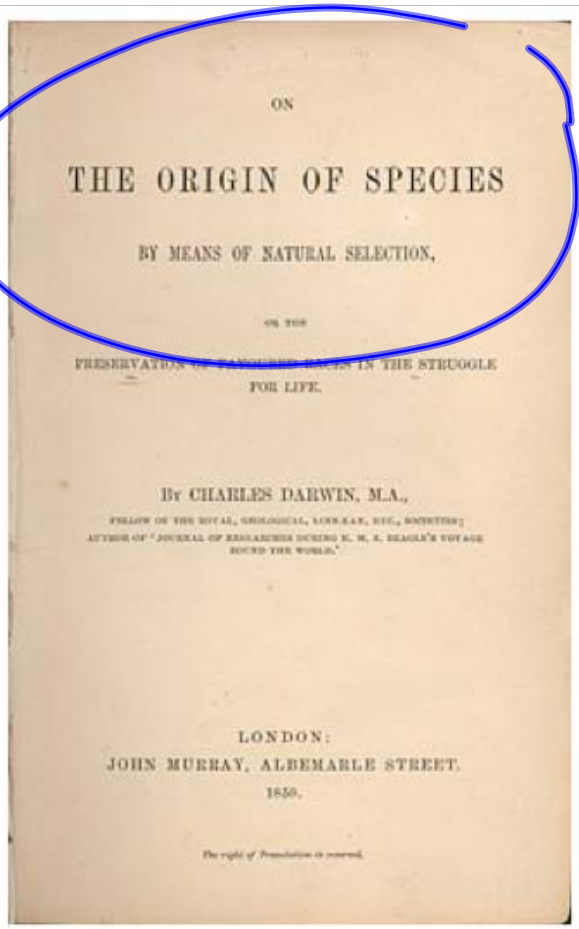
Beagle

Divergence
Galapagos
finches

UTube video – possible idea for your writing assignment:

http://www.youtube.com/watch?v=_UZ5u5sN1WQ

Nov 1859



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;

AUTHOR OF "JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD."

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1859.

How did the diversity of the biological world arise?

Evolution:

Δ in genetic makeup (DNA) OF A POPULATION OVER GENERATIONS

BASIS - GENETIC VARIATION

& FITNESS

Fitness w = Capacity of a particular genetic make up (= genotype) to leave offspring to the next generation

$$w_{ABS} = \frac{N_{AFTER}}{N_{BEFORE}}$$

$w > 1$, genotype ↑ in population

$w < 1$ " ↓

How did the diversity of the biological world arise?

MECHANISMS:

1. Change in the genome
   e.g., genetic drift - changes
   horizontal gene transfer
   (ig pieces of DNA) *
2. NATURAL SELECTION - INDIVIDUALS W/ MORE FIT

* [not acquired w/in a generation]

Change in the genome

Frequency of changes in DNA:

1 in 50×10^6

Error rate in DNA replicate ~~in DNA~~

DNA damage > 1000 lesions/cell

HGT - variable

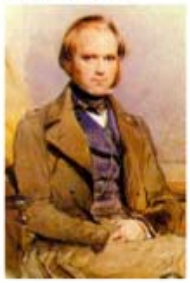
Evolution through laboratory experiment
DESIGN

Frances Arnold
Chemical Engineering

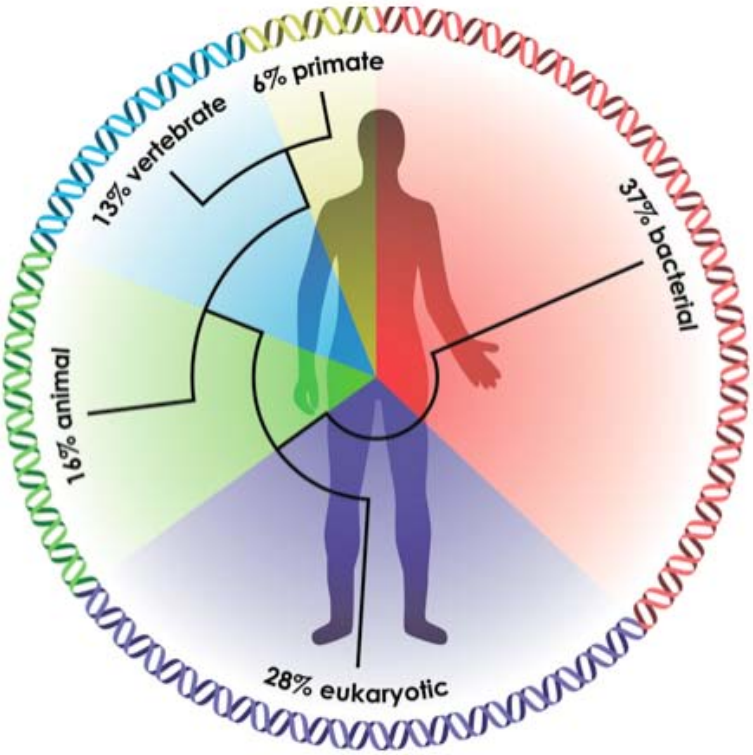
Darwin was all about natural selection

His precepts:

1. Life had a common beginning

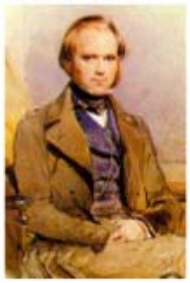


~ 23,700



Graphics by N Glasser

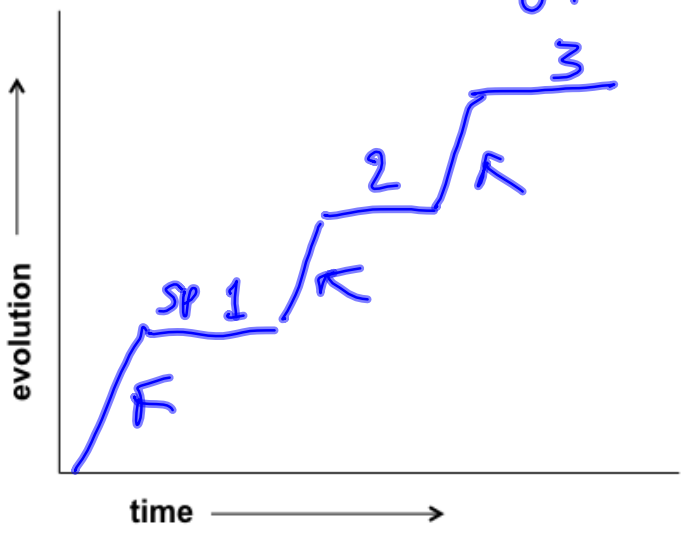
Darwin was all about natural selection



His precepts:

1. Life had a common beginning.
2. Random variation
3. Environment selects
4. Accumulate
5. Gradual change

PUNCTUATED EQUILIBRIUM - STEVEN GOULD - long periods of stability + short episodes of change

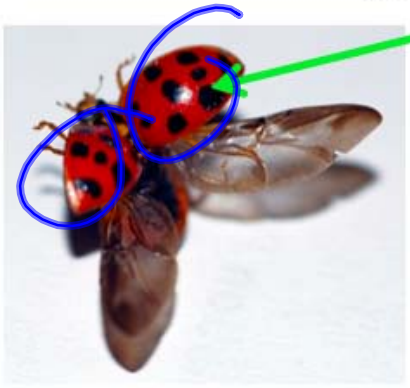


KEY INNOVATION –

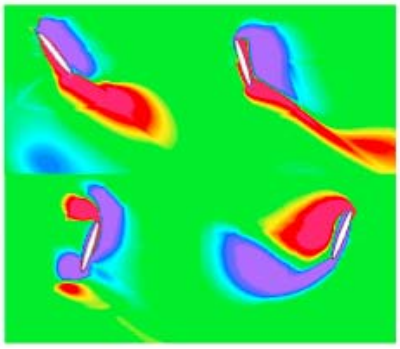
TRAIT THAT ENABLES A GROUP TO DIVERSIFY

e.g.

KEY INNOVATION – e.g., hardened forewings (elytra) of beetles



Vortex field contour during one cycle of hind wing flapping



Le et al. (2010) Numerical investigation of the aerodynamic characteristics of a hovering Coleopteran [beetle] insect.

Key concepts for today:

Principles of biology – Key concepts that structure the course

Diversity of the biosphere

Evolution – how diversity arose

Syllabus

Bi 1
Micro- to Macro-Biology: Integrating Basic Principles Across the Life Sciences
Spring 2012

COURSE INFORMATION

Instructors:
Dianne Newman: dkn@caltech.edu (302 Braun; x3543); Office Hours: Tues, Thurs 3-4pm or by appointment
Margaret McFall-Ngai: mmn@caltech.edu (423 Beckman Institute; x4839); Office Hours: Tues, Thurs 3-4 pm or by appointment

Administrator:
Patricia Mindorff: mindorff@caltech.edu (216 Beckman Labs)

Lead Coordinators:
Dr. Nora Sullivan: nls@caltech.edu (Expertise: Microbiology) Office Hour: Thurs. 12-1 PM North Mudd 210;
Molly Phillips: mphilli5@caltech.edu (Expertise: Marine Biology); Office Hour: Thurs. 4-5 PM 210 North Mudd

Teaching Assistant Teams
Writing TA: *Elisa Walsh*: eclaire@caltech.edu (Undergraduate, Biology) Office Hour: Wed. 2-3 PM at Red Door Cafe
Section 1: Wednesdays 1-2 PM; Room: 024 KRK
-*Hima Hassenruck-Gudipati*: hhassenr@caltech.edu (Undergraduate, Mech E) Office Hour: Sun. 9-10 PM in Dining Room of Blacker
-*Dr. Janet G Yang*: jgy@caltech.edu (Postdoc in D. Rees lab, Molecular Motors) Office Hour: Wed. 9-10 AM in Broad 3rd Floor Kitchen Area
Section 2: Wednesdays 1-2 PM; Room: 101 KRK
-*Catherine Xie*: catherinebxie@caltech.edu (Undergraduate, Bioengineering) Office Hour: Fri. 3-4 PM in SFL room 2-2
-*Nate Glasser*: nglasser@caltech.edu (BMB Graduate, Biochemistry, Synthetic Biology) Office Hour: Mon. 3-4 PM in 370 Braun
Section 3: Wednesdays 1-2PM; Room: 3 BBB
-*Katja Luxem*: kluxem@caltech.edu (Undergraduate, Chem E) Office Hour: Fri. 1-2 PM in SFL room 2-1
-*Jessica Ricci*: jricci@caltech.edu (BIO Graduate, Microbial Ecology) Office Hour: Mon. 2-3 PM in Braun 370
Section 4: Wednesdays 7-8PM; Room: 024 KRK
-*Pei Yin Shih*: pshih@caltech.edu (BIO Graduate, Molecular Biology) Office Hour: Fri. 9-10 AM in 151 Braun
-*Michael Dieterle*: mgdieterle@gmail.com (Undergraduate, Biology) Office Hour: Sun. 8-9 PM in SFL Room 2-2.
Section 5: Wednesdays 7-8PM; Room: 101 KRK
-*Prakriti Gaba*: prakritigaba@gmail.com (Undergraduate, Biology & BEM) Office Hour: Sun. 12-1 PM in Fleming House Lounge
-*Dr. Caj Neubauer*; 123caj@gmail.com (Postdoc in D. Newman lab, Structural Biology) Office Hour: Mon. 9-10 AM in 370 Braun
Section 6: Thursdays 4-5PM; Room: 101 KRK
-*Greg Donaldson*: gregpd8@gmail.com (BIO Graduate, Bacterial Genetics) Office Hour: Tues. 2:35-3:35 PM in 370 Braun
-*Giulio Rottaro*: rottaro@caltech.edu (Undergraduate, Physics) Office Hour: Mon. 9-10 PM in Ruddock House Lounge
Section 7: Thursdays 7-8PM; Room: 024 KRK
-*Katie Schretter*: cschrett@caltech.edu (BIO Graduate, Development & Behavior/Environmental Response) Office Hour: Sun. 7-8 PM in SFL Room 328.
-*Stone Jiang*: ssjiang@caltech.edu (Undergraduate, Chemistry) Office Hour: Mon 8-9 PM in SFL Room 2-2
Section 8: Thursdays 7-8PM; Room 3 BBB
-*Josie Kishi*: jkishi@caltech.edu (Undergraduate, Computer Science) Office Hour: Sun. 10-11 PM in Blacker Lounge
-*Naomi Kreamer*: nkreamer@gmail.com (BMB Graduate, Enzymes & Regulatory Networks) Office Hour: Thurs. 2:35-3:35PM at the Red Door Cafe

Section 9: **Fridays 1-2PM; Room 101 KRK**
-*Katie Schaefer*: schaefer@caltech.edu (CCE Graduate, Cell biology, Biochemistry, DNA-protein interactions) Office Hour: Mon. 1-2 PM outside of Chandler
-*Alicia Rogers*: arogers@caltech.edu (BIO Graduate, Bioinformatics) Office Hour: Fri 2-3PM in 370 Braun
Section 10: **Fridays 3-4PM; Room 3 BBB**
-*Yang Hu*: yhu@caltech.edu (Undergraduate, Biology) Office Hour: Fri. 4-5PM in 3 BBB
-*Yunji Wu*: wuy@caltech.edu (Graduate, Structural Biology) Office Hour: Thurs. 11-12PM in 351 Broad

***Meeting times*:**
Lecture: 1 – 2:30, T,Th; recitation sessions, as registered.

Course reader (required): An introductory biology text that integrates across all domains of life to teach fundamental biological principles does not exist. A reader has been created specifically for this class.

Synopsis:
The last 10 years of biological research have demonstrated that microbes have dominated the biosphere throughout Earth's history. Microbes play major roles in such broad processes as maintenance of human health and ecosystems. Concomitant with this growing awareness of microbial centrality, advances in technology have given us the ability to now articulate basic biological principles in much the same way as was done in physics and chemistry decades ago. The fundamental assumption that guides this course is that the biology of microbes provides a unique opportunity to present these unifying principles. Therefore, for each topic, our point of departure will be the microbial world. With this foundation, we will explore how other life forms, such as animals and plants, have diversified in form and function, abstracting from the basic 'rules' provided by the microbial world.

***Lectures and Quizzes*:**
Most classes will include the following components: (1) Lectures by Prof. Newman and Prof. McFall-Ngai to cover the micro- and macrobiological worlds, respectively. You are welcome to record the lectures, but recordings will not be made available on the website. Only audio recordings are allowed. Course notes, however, will be posted as PDFs after each class. (2) At some point to be determined during the class, an iClicker quiz will be given. Each quiz will have two multiple-choice questions: one question will cover material that is presented that day; the other will concern material from any previous lecture or reading assignment to encourage you to continuously review what you are learning. These questions may be asked at the same time or separately. You will receive full credit for the quiz if you get either answer correct, half credit for completing it whether your answers are right or not, and zero credit if you do not take the quiz. The correct responses will be given to you afterwards. We encourage you to ask a question during class at any time if you are confused about the material being presented.

Recitation section:
Because the recitation sections will build upon the material that is being presented that week and will give you the background information necessary to complete your homework assignment, it is vital that you show up on time weekly to your assigned recitation section. In addition, your active participation in these sections will factor into your course grade (see below). For this reason, you must always attend the same section unless you make arrangements with your assigned TAs to attend another section because of an exceptional circumstance. If you need to change your recitation section permanently because of a time conflict you must contact the TAs of your registered section and Molly Phillips. Permanent changes are not allowed after the first week. Each week's recitation section will be different but will generally consist of:

- A brief review of the weekly lecture material (10-15 min)
- A 30 min teaching module to complement that week's topic. These modules will introduce you to a variety of state-of-the art biological methods and experiments, among other things.
- An introduction to that week's homework assignment, to be handed in at the beginning lecture the following Tuesday.
- On occasion, there will be a "mini lab" built into the recitation section. You will be expected to actively participate in this activity.
- Your recitation grade will derive from both from your participation in section as well as your homeworks.

iClickers

1. Cover material from that day
2. Any other preceding

Grading:

- This class may only be taken for a grade
- Writing Assignment (see below for details): 15%
- Lecture Quizzes (two questions per lecture, see above): 20%
- In Class Exam 1: 15% - Thursday, May 3
- In Class Exam 2: 15% - Thursday, June 7
- Final Exam: 20% - A 30 minute oral exam upon arrangement (for seniors, on June 8; for everyone else June 13 or 14). During the course there will be ~40 lecture quiz questions. If you get 75% or more correct, you will not have to take the oral final exam and will receive 100% credit for it. Note that this is different from getting 100% credit for the quizzes (see above).
- Homework and Section Participation: 15% - There will be 8 homework sets throughout the course. We will drop your lowest score from your grade to allow for emergencies. Active participation in recitation discussions and mini labs will also be taken into account when assigning your grade.

Honor code:
We take plagiarism and other forms of cheating extremely seriously and do not tolerate it. We reserve the right to give a "D" grade as the highest possible passing grade to any student who violates the honor code in any way, regardless of how well the student has done on other parts of the course where cheating has not been observed.

BoC

Course policies:

- **Attendance.** We expect everyone to attend each lecture and recitation section; you will not be able to pass the course otherwise.
- **Electronic devices**. Please leave your cell phone and computer outside the lecture hall. As helpful as these devices can be, they can also be a major distraction to you, your fellow students, and your professors. Paying attention in class is important to get the full benefit from the course. In addition, we may call on you to answer questions in class from time-to-time.
- **iClickers.** You will need to purchase an iClicker to participate in the lecture quizes. This will be the only expense for the course, and we are subsidizing the cost (we will buy the device back from you for a fraction of its cost during finals week, to be credited to your Bursar's account). You can purchase your iClicker online, either from the company directly (www.iClicker.com) or Amazon (NOTE: purchase iClicker, *not* iClicker 2). If your iClicker malfunctions in class, you will be able to write your answers down on a piece of paper to turn into Molly Phillips or Nora Sullivan in class. You will need to register your iClicker online ASAP so you can use it in class on April 5. Go to http://www.iclicker.com/registration. Note that the remote ID number is found on the back of your iClicker beneath the barcode. Take care to complete the registration without typos. You must bring your iClicker to class on April 5 to complete the registration and use it for the first quiz. From this point forward, it will be your responsibility to bring the iClicker with you to every class. A significant portion of your grade has the potential to eminate from the in class quizzes, so do your best not to lose your iClicker. If you do, you will be responsible to pay the full cost for a replacement. It is obviously an honor code violation to use another student's iClicker in any way. To discourage wandering eyes, please conceal your response to the quiz questions by shielding your iClicker response.
- **Collaboration**. Studying together is encouraged, and you may discuss homework problems together, but the writeup of the homework assignments must be in your own words and by your own hands. Lecture quizzes and in class exams will be taken on the honor code.
- **Late work.** Homework assignments will be handed out in recitation section and are due at the beginning of class the following Tuesday. If you cannot complete your homework on time for a legitimate reason, you must have either a dean's note or a health center note to justify why it is late and you will need to let your recitation TAs know that it will be late before it is due. The final written assignment will be due Tuesday May 29 at the beginning of lecture.

Bring Thursday! or Pen & Paper if you haven't received it

LECTURE SYLLABUS

Lectures will be held Tuesdays and Thursdays, 1:00 – 2:30 pm in Kerckhoff 119

Week 1 – Life from 30,000 feet – basics about biotic systems
Lecture 1 (Apr 3) - Orientation to the course/life's organization/evolution as the unifying principle
Lecture 2 (Apr 5) – The structure of life forms: The cell as the unit of life/the eukaryotic cell/ the patterns and consequences of multicellularity
Reading assignments: Editorial (2011) Microbiology by numbers. *Nat Rev Microbiol* 9:628., Cohen, JE (2004) Mathematics is biology's new microscope… *PLoS Biol* 2:e439., and Finkel, SE and R Kolter (1999) Evolution of microbial diversity during prolonged starvation, *Proc Natl Acad Sci USA* 96:4023.

Week 2 – History of the biosphere and forces shaping its trajectory
Lecture 1 (Apr 10) – Origins
Lecture 2 (Apr 12) – Mechanisms underlying continuing evolution of the biosphere/patterns of radiation
Reading assignment: Pace, NR *et al.* (2012) Phylogeny and beyond… *Proc Natl Acad Sci USA* 109:1011.

Week 3 – Sensing the environment, integrating the information, and responding
Lecture 1 (Apr 17) - Sensing, integrating and responding to the environment
Lecture 2 (Apr 19) – Consequences – Effects on population/community dynamics and behavior
Guest lecturer: Prof. Kenneth Nealson, USC
Reading assignment: Alon, U (2007) Robustness of protein circuits: The example of bacterial chemotaxis. In: *An Introduction to Systems Biology*, Chapman & Hall/CRC.

Week 4 – Resisting perturbation and damage from the environment/energy acquisition
Lecture 1 (April 24) - Exchange with the environment: Protecting the home front
Guest lecturer: Prof. Ann Hirsch, UCLA
Lecture 2 (Apr 26) – Overview of metabolism and nutrient acquisition
Reading assignment: Stipp, D (2012) Aging: A new path to longevity. *Sci Amer*, January:33-39.

Week 5 - Metabolism
Lecture 1 (May 1) – Mechanisms of energy acquisition
Guest lecturer: Dr. Nicky Caiazza, Synthetic Genomics, Inc., http://www.syntheticgenomics.com
In class EXAM I (May 3) Reading assignment: none

Week 6 - Mechanisms underlying persistence of life forms: The molecular basis for growth and reproduction
Lecture 1 (May 8) – Mechanisms underlying the central dogma
Lecture 2 (May 10) – Mechanisms of gene exchange/cell division/cell cycle
Reading assignment: Collins, J (2012) Synthetic Biology: bits and pieces come to life. *Nature* 483:S8-10.

Week 7 – Patterns of development
Lecture 1 (May 15) – Cell determination and differentiation
Lecture 2 (May 17) – The ecological and evolutionary mechanisms underlying developmental patterns
Reading assignment: Sultan, SE (2007) Development in context. *Trends Ecol Evol* 22: 575-582.

Week 8 – Living with others - populations and communities
Lecture 1 – (May 22) Patterns of diversity – predator/prey dynamics/competition for resources
Lecture 2 – (May 24) Syntrophy and other forms of symbiosis
Reading assignment: Fuhrman, JA (2009) Microbial community structure… *Nature* 459:193-9.

Week 9 – Ecosystems biology – global issues
Lecture 1 – (May 29) Biogeochemical cycling/sustainability/Gaia
Lecture 2 – Our imperiled planet – the effects of climate change/feasibility of proposed solutions (e.g., geoengineering)/conservation biology
Reading assignment: Hardt, MJ and C Safina (2010) Threatening ocean life from the inside out. *Sci Amer* August:66-73.

Week 10 - Horizons in biology and the associated ethics
Lecture 1 - (June 5) Ethics and biology/synthetic biology and other fun topics
Guest lecturer: Myles Jackson, New York U
In class EXAM 2 (June 7)
Reading assignment: Lunshof, JE, et al. (2008) From genetic privacy to open consent. *Nat Rev Genetics 9*: 406-411.
FINAL ORAL EXAM (June 8, 13 or 14)

RECITATION SYLLABUS

Read / Skim

Bring it to section

Week 1 – How to read an article from the primary literature
Assignment for recitation: Read Finkel and Kolter and prepare to discuss
Homework: Komeili et al., (2006) Magnetosomes are cell membrane invaginations organized by the actin-like protein MamK. *Science*. 311: 242-245 and homework questions due April 10

Week 2 – Scientific revolutions
Homework: David and Alm (2011) Rapid evolutionary innovation during an Archaean genetic expansion. *Nature*. 469:93-96 and homework questions due April 17

Week 3 – Networks and circuits: how biology can inform engineering challenges
Homework: Berdoy et al., (2000) Fatal attraction in rats infected with *Toxoplasma gondii*. *Proc. R. Soc. Lond.* B. 267: 1591-1594 and homework questions due April 24

Week 4 – Assessing the metabolic potential of Caltech's microbial community (part I)
Homework: Warnecke et al. (2007) Metagenomic and functional analysis of hindgut microbiota of a wood-feeding higher termite. *Nature*. 450:560-565+ and homework quesitons due May 1
"mini-lab": sample bacteria from Beckman Behavioral and Baxter Ponds

Week 5 - Assessing the metabolic potential of Caltech's microbial community (part II)
Homework: no homework this week
"mini-lab": metabolic microarrays of communities and isolates from Beckman and Baxter Ponds

Week 6 – The central dogma and beyond
Homework: Meselson and Stahl, (1958) The replication of DNA in Escherichia coli. *PNAS*. 44:671-82 and homework questions due May 15

Week 7 –Reproduction and the advantages of fluorescent microscopy
Homework: Hamamura et al., (2011) Live-cell imaging reveals the dynamics of two sperm cells during double fertilization in *Arabidopsis thaliana*. *Cur Biol*. 21:497-502 and homework questions due May 22

Week 8 – Who's in our backyard?: 16S rRNA phylogeny of Caltech's microbial community
Homework: Dekas et al., (2009) Deep sea archaea fix and share nitrogen in methane-consuming microbial consortia. *Science* 326:422-426 and Commentary by R.W. Fulweiler and homework questions due May 29
"mini-lab": Phylogenetic analysis of the16S rRNA sequences from the ponds

Week 9 – Global warming and the effect on the biosphere
Homework: Chen et al., (2011) Rapid range shifts of species associated with high levels of climate warming. *Science* 333:1024-1026. due June 5

Week 10 – Pandemics and Ethics

Thurs. Volta Flame Experiment 7pm – BBB Baxter

WRITING ASSIGNMENT

Motivation: regardless of what field of science or engineering you ultimately pursue, being able to articulate your ideas cogently is crucial for professional success. To help you build the skills needed to achieve this, we have designed a progressive writing assignment. You will have the opportunity to develop an original research proposal in consulation with the Bi1 staff. This proposal is limited to 4 pages, double spaced (font Arial 11 points, 1 inch borders) not including figures or references.

We encourage you to write about any biological problem that interests you, as long as you can formulate a hypothesis and a reasonable means to test it. One way to take advantage of being at Caltech is to propose something that relates to the research of one of our faculty. You are welcome to write about any of the following 5 topics (and associated hypotheses); alternatively, you can develop one of your own. For the topics/hypotheses given below, we have provided the names and websites of the Caltech faculty doing research in these areas to guide your search for information.

TOPIC: BIOMECHANICS
Hypothesis: Significant savings to the operational costs of running a submarine can come from applying design principles from aquatic organisms.

Prof. John Dabiri (MechE): http://dabiri.caltech.edu/
Prof. Mory Gharib (MechE): http://www.gharib.caltech.edu/
Prof. Rob Phillips (App Phys and Biology): http://www.rpgroup.caltech.edu/

TOPIC: ENERGY
Hypothesis: Viable alternate energy solutions can be found by mining the enzymatic potential of biological systems in an engineered context.

Prof. Frances Arnold (ChemE): http://cheme.che.caltech.edu/groups/fha/
Prof. Harry Gray (Chemistry): http://www.bilrc.caltech.edu/index.php?module=webpage&id=22
Prof. Jared Leadbetter (Env. Eng): http://www.its.caltech.edu/~jaredl/
Prof. Nate Lewis (Chemistry): http://nsl.caltech.edu/research
Prof. Jonas Peters (Chemistry): http://jcpgroup.caltech.edu/research.html

TOPIC: NETWORK DESIGN
Hypothesis: Feedback networks in biological systems provide important mechanisms for providing robustness, but also introduce fragilities.

Prof. Michael Elowitz (Biology & BioEng): http://elowitz.caltech.edu/
Prof. John Doyle (CDS): http://www.cds.caltech.edu/~doyle/wiki/index.php?title=Main_Page
Prof. Richard Murrary (CDS and BioEng): http://www.cds.caltech.edu/~murray/wiki/Main_Page

Hypothesis: Networks of biomolecular reactions can be used to implement computations and functions that provide insight into biological systems and new approaches to nanoscale engineering.

Prof. Richard Murray (CDS and BioEng): http://www.cds.caltech.edu/~murray/wiki/Main_Page
Prof. Niles Pierce (BioEng and App. Math): http://piercelab.caltech.edu/
Prof. Paul Rothemund (CDS and BioEng): http://www.dna.caltech.edu/~pwkr/
Prof. Eric Winfree (CDS and BioEng): http://www.dna.caltech.edu/~winfree/

TOPIC: ECOLOGY/MICROBIOME
Hypothesis: Carriage of specific microbes alters the complexity of the immune system.

Prof. Sarkis Mazmanian: http://biology.caltech.edu/Members/Mazmanian
Prof. Margaret McFall-Ngai: http://www.medmicro.wisc.edu/labs/mcfall-ngai/index.html

TOPIC: EVOLUTION
Hypothesis: Microbial metabolisms directly changed the geological landscape of the early Earth.

Prof. Woody Fischer (GPS): http://www.gps.caltech.edu/~wfischer/
Prof. Joe Kirschvink (GPS): http://www.gps.caltech.edu/~jkirschvink/
Prof. Dianne Newman (BIO and GPS): http://dknlab.caltech.edu/Newman_Lab.html
Prof. Victoria Orphan (GPS): http://www.gps.caltech.edu/people/vorphan/profile
Prof. Alex Sessions (GPS): http://www.gps.caltech.edu/~als/

To provide each of you with effective feedback on your writing assignment, we will be collecting and reviewing each stage of your progress. ***These assignments are due at the begining of Tuesday lecture and should be typewritten***. The steps, due dates and the grading scheme are listed below. Note that your final grade will be derived from the three major assignments in bold (Weeks 4, 6 and 8), so it is important to stay on track throughout the term. More details about our expecations for each step will be provided during the introduction to the assignment in the first week of class.

Week 1: Introduction to assignment (no work due this week)
Week 2: Define interests (multiple ideas) due April 10
Week 3: Refine ideas due April 17
Week 4: Hypotheses/aims (ONE idea) due April 24 -- worth 20% of writing assignment total
Week 5: Methodology/Approach due May 1
Week 6: Rough draft due May 8 -- worth 30%
Week 7: Revision of corrected rough draft (no work due this week)
Week 8: Final draft due May 22 -- worth 50%

CALENDAR


Sun
Mon
Tue
Wed
Thu
Fri
Sat
Define
Homework 1
Homework 2
Refine Ideas
Homework 3
Hypotheses
Homework 4
Methodology
EXAM 1
Rough Draft
Homework 5
Final Draft
Homework 6
Homework 7
Homework 8
EXAM 2
SENIOR FINAL
ORAL FINAL
ORAL FINAL

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http://www.nature.com/nrmicro/journal/v9/n9/pdf/nrmicro2644.pdf

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http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0020439

Finkel, SE and R Kolter (1999) Evolution of microbial diversity during prolonged starvation, *Proc Natl Acad Sci USA* 96:4023.
http://www.pnas.org/content/96/7/4023.full.pdf+html

Pace, NR *et al.* (2012) Phylogeny and beyond… *Proc Natl Acad Sci USA* 109:1011.
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Alon, U (2007) Robustness of protein circuits: The example of bacterial chemotaxis. In: *An Introduction to Systems Biology*, Chapman & Hall/CRC.
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Stipp, D (2012) Aging: A new path to longevity. *Sci Amer*, January:33-39.
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Collins, J (2012) Bits and pieces come to life. *Nature* 483:S8-S10.
http://www.nature.com/nature/journal/v483/n7387_supp/pdf/483S8a.pdf

Sultan, SE (2007) Development in context. *Trends Ecol Evol* 22: 575-582.
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Fuhrman, JA (2009) Microbial community structure… *Nature* 459:193-9.
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David and Alm (2011) Rapid evolutionary innovation during an Archaean genetic expansion. *Nature*. 469:93-96
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Dekas et al., (2009) Deep sea archaea fix and share nitrogen in methane-consuming microbial consortia. *Science* 326:422-426 and Commentary by R.W. Fulweiler
http://www.sciencemag.org/content/326/5951/422.full.pdf
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Chen et al., (2011) Rapid range shifts of species associated with high levels of climate warming. *Science* 333:1024-1026.
http://www.sciencemag.org/content/333/6045/1024.full.pdf