Biology 101 – Lecture notes, 14 January 2019

Welcome!

I. Course overview, syllabus and website – as described.

Course website: biosbcc.net/kay

SBCC Student Health and Wellness Center: http://www.sbcc.edu/healthservices/

II. Characteristics of life / living things

Despite the ignorant (!) claim that plants are uninteresting and don't really "do anything", they do a great deal and exhibit all the characteristics of living things: (As in future lecture notes: <u>You need to know all the bolded terms/concepts in these notes for quizzes and exams</u>.)

1) <u>Order</u> – basis of which is cells (*we'll discuss these in our next lecture!!*).
   Living beings are not random arrangements of cells and molecules, but instead have well organized bodies that allow them to survive and reproduce. Such order is typically absent from non-living systems.
2) <u>Regulation</u> – maintain the order (mentioned in #1) – life exists within ranges of temperature, hydration, and concentrations of materials in solution within cells.
3) <u>Exchange matter and energy</u> – organisms require energy to maintain order and to function (see item #1!!). Via photosynthesis, plants convert the energy in sunlight into chemical energy that you, I and, all other non-plants depend upon for our existence – this conversion of light energy to chemical energy drives almost all life on Earth! Feeling peppy? Thank a plant…!!
4) <u>Growth and development</u> – Basis of growth, development, and reproduction is cell division (we'll get to cell division later in the course…).
5) <u>Respond to the environment</u> – environmental stimuli
6) <u>**Reproduction**</u> – Organisms reproduce their own kind (species). Key points for now:
   - **Sexual reproduction** – Creation of genetically unique offspring from two parents (much, much more vocabulary to come later in the class!).
     <u>In nature</u>: sexual reproduction is critical because it generates the genetic variability in populations that is necessary for natural selection – and thus evolution (see below!)
     <u>In plant breeding/agriculture</u>: Sexual reproduction generates genetic variability that can give rise to new varieties of plants, some of which might be commercially important due to desirable features (fruits, flowers, disease resistance, etc…). Plant breeders, like breeders of dogs or other animals, create new "strains" or types of plants via the process of selective breeding. **Selective breeding:** Process by which humans breed male and female plants (or animals) in order to create offspring with desirable traits (e.g., sweeter fruit, faster growth, etc…).
   - **Asexual reproduction** – Creation of offspring from a single parent. Parent and offspring are genetically identical (with rare exceptions…!)
     <u>In nature:</u> Important because plants can't always find a sexual partner! Thus, asexual reproduction helps short- to medium-term persistence of a plant's genes…(but long-term persistence usually requires sex and evolution…)
     <u>In plant breeding/agriculture</u>: Asexual reproduction is critical because plants with a desirable feature (fruit, flower, etc.) can be cloned (literally) and the desirable feature is reliably duplicated in the offspring. Almost all fruit you eat is from cloned trees/plants.

Examples from lecture: Hass avocado and Cavendish banana. The fruits of Hass avocados and Cavendish bananas, as we know them today, were originally "bred into existence" by plant breeders that were cross-breeding (sexually crossing/reproducing) plants. The original plants were then cloned many many thousands of times, such that, in each case, ALL HASS AVOCADO and ALL CAVENDISH BANANA trees are clones (asexually reproduced from) individual mother trees! The downside of this approach: since clones are genetically identical, they are more-or-less uniformly susceptible to disease. That is to say, a single disease has better odds of destroying an entire crop/plantation. For example, the Cavendish may be headed for commercial extinction, or at least a much-reduced place in the banana market, due to a new fungal disease that is lethal to Cavendish clones. Look for new bananas to hit the market in coming years.

- In both sexual and asexual reproduction, inherited information coded for by DNA is passed to offspring
- Plant sex! Plant sexual reproduction is often very novel and interesting…ooooh yeah… - we'll take a closer look at this throughout the semester…

7) **Evolution** –Descent with modification. Change within a species through time as new generations inherit certain characteristics from previous generations (yep – you guessed it - that info is passed along in DNA!)

Species: A group of organisms capable of interbreeding and producing fertile offspring.

III. Evolution, adaptation, and natural selection

Evolution is something that we will revisit in this class frequently. The fact that organisms change through time is a **unifying principle** of botany and biology in general (i.e., it is present in, and fundamental to understanding, all topics and subjects in biology).

At the conceptual core of evolution is another unifying principle: **adaptive trait**

Adaptive trait (aka adaptation): An inherited characteristic that increases an organism's ability to survive and reproduce (the "meaning of life" !!!).

Selective pressure: Any cause that reduces an organisms ability to survive and reproduce (e.g., predators, difficulty securing food/water, disease, drought, freezing, etc…).

- Adaptive traits, in essence, are inherited characteristics that allow organisms to overcome selective pressures.
- It is conceptually accurate, therefore, to think of adaptive traits as evolutionary "solutions" to selective pressures. Throughout the semester, we will think about the selective pressures and adaptations present in plants – this mindset is foundational and a fun element of botany and biology!

Natural selection: A process in which individuals with certain inherited traits (i.e., adaptive traits) are more likely to survive and reproduce than individuals without those traits (in biology, survival and reproduction is the "meaning of life"!!!).

- Organisms with adaptive traits survive reproduce at a higher rate, and thus the inherited adaptive traits that are passed on to their offspring become more common in the general population – thereby driving evolutionary change.
- Natural selection is the mechanism that drives evolution. Charles Darwin's greatest (but not his only!) contribution to science.

For natural selection to work, a few conditions must be present:

1) Genetic (i.e., coded in DNA) variation among individuals in a population
   Q: Where does this genetic variation come from?
   A: 1) Sexual reproduction (this is why sex is important!); 2) random mutations to DNA
2) Struggle for existence (life is hard and not everybody is able to survive!) due to **selective pressures** that exist
3) Differential survival and reproduction based upon genetic differences (adaptive traits are present in some individuals, but not all, and those that possess them have a higher rate of survival and reproduction…such that the traits become more common in the species or population over time!)

Natural selection and the Survival of the Fittest

Because the individuals with adaptive traits survive and reproduce at the highest rate, natural selection is often referred to as ***survival of the fittest***. (This term is conceptually accurate, and it used frequently, but for some evolutionary biologists it is an awkward term – we won't get into why but feel free to ask me in lab or in office hours…!)

Adaptations increase an organism's ability to survive and reproduce by providing some important service or function. Often, the function or service that a particular adaptation provides is evident in its form (e.g., shape, size, color, etc). This gives rise to the expression: **"Form equals function"**.

The concept that "form equals function" is another anchor point for this course – and we will examine the function and evolutionary context for a great number of adaptations that range in size from large (flowers on trees) to small (molecules).

Most importantly, the principles of evolution via natural selection, as well as adaptive traits provide a necessary and critical context for any biological science. ALL subjects, structures, and processes in biology are meaningful only when considered in their evolutionary context.

Examples from lecture: giraffe necks, tongues. *Acacia* spines.

{Video: desert pocket mouse and natural selection:
http://www.hhmi.org/biointeractive/making-fittest-natural-selection-and-adaptation
0:00 – 3:20} (note: We might have viewed this in LAB!)

The following material might have been covered IN LAB (i.e., we ran out of time in lecture). Unless otherwise noted, you DO need to know this material for lecture quizzes and exams.

Darwinian natural selection vs. Lamarckism

Lamarckism: traits acquired during an organism's life can be passed along to offspring (e.g., a giraffe's neck stretches and elongates in an effort to reach tall branches – and this longer neck is then passed along to offspring. We know this to be false, of course….)

Darwin: adaptive traits are inherited from parents. Organisms with adaptive traits have a higher rate of survival and reproduction.

Key points about natural selection:
1) Adaptive traits are inherited, not acquired during life of an organism (latter = Lamarckism!).
2) A single individual does not evolve.
3) Evolution via natural selection is an incremental process that occurs over many generations and often over long time periods (shocking exceptions of rapid evolution exist, such as bacterial resistance to antibiotics, but bacterial generation times are very short and the change still occurs over many generations.)

EVIDENCE FOR EVOLUTION (and natural selection)

We briefly mentioned four lines of evidence for evolution via natural selection. *(There are many other lines of evidence, but you should know these four and at least understand the examples when reminded of them. I won't ask you to define these on exams, but I might mention them for context.*

1) **Fossil record**. The fossil record contains a long (over 3 billion years!) and detailed history of species that have evolved and gone extinct over evolutionary time. In addition to the appearance and extinction of species over time in the fossil record, exquisite evidence of evolution is contained in individual fossils or species. Two examples that we viewed, which you don't need to know for exams were: 1) Archaeopteryx, and; 2) the progressively larger claws and marine crabs and the thickening of shells in the snails that they eat.

2) **Vestigial structures.** Vestigial structures are structures in an organism that have no or very little utility, but are remnants of important structures that were present in an ancestral species (a species from which the current organism evolved). The example we viewed, again from the animal kingdom, was the presence of hip bones in whales and dolphins. Marine mammals (whales, dolphins, and others) evolved from wolf-like terrestrial ancestors, and the pelvis appears to no longer serve an important role but is explained by the terrestrial ancestry. Another example is found in the wings of flightless birds. Human examples include the tail bone (coccyx) and wisdom teeth.

3) **Recapitulation** (the presence of earlier/ancestral structures in embryos/early developmental stages of organisms). Examples we discussed included teeth in the jaws of baleen whale fetuses (remember, the ancestor of whales and dolphin was wolf-like…and I've never seen a wolf with baleen!).

4) **Direct observation** (e.g., herbicide-resistant "superweeds", antibiotic-resistant bacteria, pepper moths in England in the 1800s), Peter and Rosemary Grant's work (read The Beak of the Finch).

So, is it true that plants don't "do anything?". Well, In addition to "doing" all the "things" discussed above, plants provide many services for Earthlings, including humans: photosynthesis, food production, timber products, and medicine, to name a few. We'll study all this and more!

[video: *Plants(0:10-3:55)*, from the BBC series *Life* with David Attenborough]

IV. EVOLUTION VIA NATURAL SELECTION EXPLAINS THE ORIGIN OF SPECIES

Among the most fundamental questions for humanity is: "how did we get here?" That is to say; how do we humans find ourselves, in our current form, here on this planet? This question pertains not only to humans, but extends to all other species with which we share the Earth (though they probably invest less time than we do pondering this existential riddle!).

For most of human history, answers to this question were the domain of religion and other mythologies that explain, usually in colorful detail, how humans and all other species were created. Such explanations are called **creation myths**.

Creation myth: symbolic narrative of a culture, tradition or people that describes their earliest beginnings, how the world they know began and how they first came into it.

<u>All creation myths share two general features</u>:

1) A creator is responsible for the appearance of all the different types of living things (or **species**) on Earth.
2) The appearance of these species is in the image of divine power and does not change – <u>Earth is immutable.</u>

These creationist perspectives – that species do not change through time and are the product of a divine creator – have historically been a fundamental element in western intellectual thought, and this was no different for natural scientists…in fact, Charles Darwin was enrolled in the clergy prior to setting sail on his now famous journey of discovery.

Darwin formulated his theory of natural selection while on a cruise around the world on the HMS Beagle. We now know that creation myths explaining human origins are not supported by scientific evidence. Natural selection explains how species evolve. Natural selection and evolution are supported by overwhelming body of evidence. They are not articles of faith.

<u>**History of Darwin's Discovery, you do not need to know for exams.**</u>

<u>Mid 1700's</u> – geology and fossil record indicate change in natural world – this is a paradigm shift from creationist perspective

<u>1798</u> – Thomas Malthus: *An Essay on the Principal of Population*

<u>1809</u> – Lamarckism (Lamarck's *Philosophie Zoologique*)

<u>1830</u> – Lyell's "Principles of Geology" (Darwin took and read a copy during his journey on the HMS Beagle!!)

<u>1831-1836</u> – Voyage of the HMS Beagle: Circumnavigates the globe; Very influential stop in Galapagos!! Darwin processes his observations and synthesizes previous ideas of others

<u>1858</u> – Sir Alfred Wallace sends Darwin a manuscript for his opinion, Darwin discovers many of his ideas discovered independently by Wallace.

<u>1859</u> – Darwin publishes *On the Origin of Species by Means of Natural Selection*

V. BOTANY, SCIENCE, AND THE SCIENTIFIC METHOD

Due their amazing function, diversity, ecological importance, and benefit to humanity, plants are important organisms that have our full attention, and there are many fields of botany.

Botany: the science of plant life.

Science: an objective process of inquiry based upon observations and testable hypotheses (guaranteed exam question!!!)

Look again at the definition of science, read it carefully. There are three elements that separate science from dogma (e.g., creation myths and other beliefs that are not open to being questioned) and which allow us to understand natural phenomena and invent useful technologies such as medicine and your cell phone (did I say "useful"…?). These three elements are:

1) Objectivity: We do not bias our interpretation of experiments or observation based upon our faith or our desire for a particular answer. (Think of the example of Galileo and Copernicus being punished for suggesting a heliocentric model of the solar system).
2) Observation and testable hypotheses: Scientific conclusions are based upon the transparent collection of data through repeatable experiments and objective observation. (Consider the Chumash mythology of the rainbow bridge and fallen people people becoming dolphins. Do you suppose there was there ever an observation or experiment to support this idea? Were those experiments repeatable?).
3) Process: We do not get to decide how something works without exploring it and gathering evidence. We do this via the **scientific method**!

Scientific method: A way of 'doing' science by making observations and testing hypotheses. We define the Sci. method as having 5 steps:

Five steps:
1. Initial observation 2. Hypothesis 3. Prediction 4. Experiment
5. Interpret results – accept/reject hypothesis. Form new hypotheses?
(Items 3-5 are hypothesis testing)

Experimental control (aka control experiment): experiments or features in an experiment that account for alternative explanations of experimental results.

Concluding thoughts:
As you embark upon your professional journey as a scientist, you have an obligation to practice your craft responsibly. Often times, this is easier said than done. We'll discuss modern examples in lecture. Always consider alternative explanations for your observations. Can you explain them? If not, your need to control for them! Otherwise, you might fall off of a rainbow and become a dolphin.