Jan 16 lecture notes – Cell theory, structure, and diversity

Cell: A basic unit of living matter separated from its environment by a plasma membrane; the fundamental structural unit of life

1665: The term 'cell' was first coined by Robert Hooke in 1665 as he peered through his microscope at a sample of cork (bark material from the cork oak *Quercus suber* – a specimen of this species is on SBCC campus near the barrel cacti we examined during lab in week 1). The individuals spaces, or "cells", reminded Hooke monastic cells (the small cells in which monks dwell ad ponder), hence the name.

1674: Antonie van Leeuwenhoek is first human to record observations of live single celled organisms (the alga *Spirogyra* sp.) under a microscope.

Cell sizes: generally 1-10µm (bacteria/archaea); 10-100 µm (plant and animal cells)
(1meter = 1000mm; 1mm = 1000 µm [micrometer or 'micron']; 1 µm = 1000nm [nanometer])
(by the way, 1 meter = 1 ten millionth of the distance from the equator to the north pole – you don't need to know this….!!!)

(FYI: notably large (and common) single cells are <u>unfertilized</u> eggs of birds such as chickens and ostriches (the latter is one of the largest single cells in known to biology).

Mid 1800's – cell theory developed and formalized (a joint effort building upon the observations of Hooke, van Leeuwenhoek and many others). Cell theory posited by: Mathias Schleiden (German botanist, 1804-1881), Theodor Schwann (German physiologist, 1810-1881), and Rudolf Virchow (German physician, 1821-1902)

Cell Theory (three important premises):

1) **Cells are the fundamental unit of structure and function in all organisms.**
2) **All living things are composed of cells**
3) **All cells are derived from other cells**

Cell theory may seem obvious now, but at the time of its discovery/synthesis it elevated scientific thinking about a number of fundamental biological concepts. Examples we discussed in lecture:

1) Spontaneous generation – with cell theory the fallacy of spontaneous generation is apparent. Recall the important experiment of Redi and Pasteur – were you present and do you recall them?!
2) Cancer – we read a passage from The Emperor of all Maladies (pp. 14-15) in which Virchow comes to understand cancer as uncontrolled cell division (pathological hyperplasia, for you pre-med students…).

<u>**Major categories of life on Earth**</u>

All living organisms are placed into categories that are based upon cell structure. The two broadest categories are:

I. Prokaryotes – Single-celled organisms that lack a nucleus ("*pro*-:before + *karyon*:kernel"). Two groups:

1. Domain Bacteria (many kingdoms in this domain)
2. Domain Archaea (many kingdoms in this domain)

Prokaryotes are unicellular, and consequently they are structurally simple.

II. Eukaryotes (Domain Eukarya) – Organisms whose cells have a nucleus ("*Eu*-:good + *karyon*:kernel") and other membrane-bound organelles (plastids, mitochondria). There are four groups of eukaryotes:

1. Kingdom Plantae (four groups, which we will study in detail later in the semester but you do not need to know now: mosses, ferns and allies, gymnosperms, angiosperms)
2. Kingdom Animalia
3. Kingdom Fungi
4. "Kingdom" Protista (actually many "subkingdoms" – see below)

Many eukaryotes are multicellular, and consequently they can form complex tissues/structures because individual cells can specialize and perform different tasks for the organism.

Any single species of eukaryote is categorized as being plant, animal, fungus, or protist based in part upon cell structure. You do not need to know detailed differences in cell structure, but I do want you to know the following important differences among the four groups:

<u>**Kingdom Animalia**</u> (animals) - multicellular, no cell wall, heterotrophic, internal digestion
<u>**Kingdom Fungi**</u> (fungi) - multicellular (yeasts = unicellular), cell wall (chitin), heterotrophic, external digestion (we will discuss fungi at great length later in the semester)
<u>**Kingdom Plantae**</u> (plants) – multicellular, cell wall (cellulose), photoautotrophic**,** *Plants* make sugars via photosynthesis in chloroplasts, and have many other plastids (see below).
<u>**Kingdom Protista**</u> **(actually many kingdoms…)** (protists) – Uni- or multicellular, autotrophic, heterotrophic, and mixotrophic (!!).
An extremely diverse group, protists are **any eukaryotes that are not plants, fungi, or animals**.

Organisms traditionally ID'd as protists include single celled animal-like organisms called **protozoans** such as ciliates and amoebas. A recent addition to the protists are all **algae** (even giant kelp off of our coast!). <u>Algae are the only protists you will be tested on in this course – but not until later!</u>
Protist taxonomy is a complete MESS that you will do well to avoid!!! (We will study algae in detail later this semester – you won't be asked about them in detail on Midterms 1 or 2.)
In case you are irrepressibly curious – here is a definition for algae
Algae: (This definition from <u>http://www.oilgae.com/algae/algae.html</u>): In general algae can be referred to as <u>plant-like organisms that are usually photosynthetic and aquatic, but (unlike plants) do not have true roots, stems, leaves, vascular tissue and have simple reproductive structures</u>. They are distributed worldwide in the sea, in freshwater and in wastewater. Most are microscopic, but some are quite large, e.g. some marine seaweeds that can exceed 50 m in length.

Autotroph ("auto:*self* + trophic*:nutrition")***:** An organism that makes its own food (e.g., by photosynthesis) and can sustain itself without eating other organisms. Also known as a "producer"

Heterotroph: ("hetero:*another* + trophic*:nutrition")*: An organism that cannot make its own food and must eat other organisms. Also known as a "consumer"

Mixotroph: An organism capable of heterotrophy and autotrophy (Ex: the protist Euglena)

SOME OF THE FOLLOWING ASPECTS OF PLANT CELL STRUCTURE WERE NOT COVERED IN DETAIL IN LECTURE, BUT WE WILL COVER IT MORE IN LAB DURING WK 2, AND YOU NEED TO KNOW THE MATERIAL PRESENT HERE FOR LECTURE ASSESSMENTS (MIDTERMS AND FINAL)

PLANT CELL STRUCTURE

Plant cells have the following structures (that you need to know for this class, LOTS of other cell structures exist but are not included here. You're welcome…).

- **Plasma membrane** - lipid bilayer that separates the inside of the cell from the outside environment, thereby allowing the cell to maintain conditions (e.g., solute concentrations) that differ from the environment.
- **Cytoplasm/cytosol (…and protoplasm)**

  Cytoplasm – everything inside the plasma membrane, minus the nucleus (if you're dealing with a eukaryote!) and vacuole(s).

  Cytosol - The liquid portion of the cytoplasm

  Protoplasm – all the contents of a plant cell inside the cell wall (i.e., not including the cell wall). (When referring to a single cell, we often call the protoplasm the "protoplast.") I will NOT ask you the terms "protoplasm/protoplast" on exams…but you might encounter them elsewhere…
- **Chromosomes** - contain the genetic information (DNA), contained in nucleus
- **Nucleus** – membrane bound structure that contains the cell's DNA (when a cell is not undergoing division, DNA exists in a diffuse mass called chromatin. During cell division, DNA bundles into **chromosomes).** *You do not need to know about chromatin!*
- **Mitochondria** – powerhouse of the cell - produce ATP which provides energy for all cell functions.
- **Plastids** – Sites of manufacture and storage of chemical compounds.
  - **Chloroplasts** – organelles where photosynthesis occurs (also present in some Protista)
  - **Amyloplasts** – storage of sugars (starch). Especially abundant in seeds and storage organs such as tubers. (Light levels can cause conversion from amyloplasts <-> chloroplasts)
  - **Chromoplasts*** – contain fat-soluble pigments called carotenoids (yellow and orange hues).
  - **Proplastid** – The simple precursor of all plastids above! (not unlike a stem cell…)
  - *(Leucoplast) – a descriptive term for any colorless plastid (including amyloplasts); some leucoplasts are site of fat/lipid synthesis. Do NOT need to know!*
  - *(Etioplast)- a chloroplast that is colorless (leucoplast) due to lack of light. Do NOT need to know!*
- **Vacuoles**: Very important! Several roles (FYI – prominent in plants; present in few other cells):
  1) Turgor pressure: the pressure exerted by water on the inside of a cell or vacuole. (Think water balloon…). This maintains the shape of plants cells (the cell wall helps too – a big reason it's there!) and soft tissues such as leaves, stems, flower petals.
  2) Rapid growth of plant cells b/c they (vacuoles) swell with water (think of a flower opening, or a fern fiddlehead unfurling – this is all driven by cell division or cell expansion (which can be accelerated by swelling of vacuoles). Young cells can have many vacuoles, and they typically coalesce into a large central vacuole in mature cells.
  3) Water storage. This is important b/c plants must endure dry/drought periods
     {VIDEO – Planet Earth, "Deserts" 18:00-19:50} -- VIEWED IN LAB WEEK 1
  4) Waste storage. Plants do not have an excretory system – weird eh? So, many wastes get stored in the vacuole. Many plants have evolved to benefit from this arrangement by making nasty wastes/toxins that serve as chemical defenses.
  5) Pigment storage*. Anthocyanins are water soluble pigments stored in vacuoles.

6) General storage and recycling location. The vacuole is a logical location to store materials and to chemically break apart and recycle cellular materials, because the vacuole is isolated from the cytoplasm by the single membrane that surrounds it (the tonoplast)

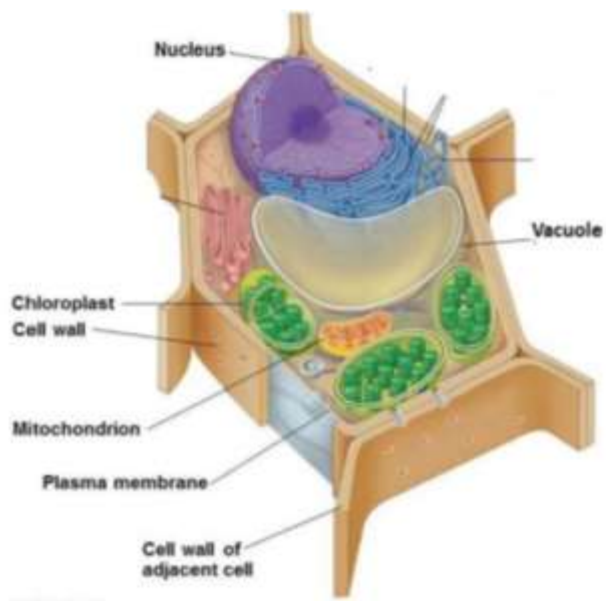
- **Plasmodesmata:** tiny strands of cytoplasm (not protoplasm! Why not? – see the distinction and need for this vocabulary?!!) that extend through small holes in cell walls and connect plant cells.

Other features of eukaryotic cells (you do NOT need to know this stuff for this class!)

- **Endoplasmic reticulum (ER)** – site of protein and lipid manufacture. Ribosomes are embedded in the *rough* ER, while the *smooth* ER does not have ribosomes attached. (The large organelle immediately surrounding the nucleus.)
- **Golgi apparatus** – (do not need to know for exams) - site where cell products (proteins etc) are sorted, packaged, and shipped.
- ***(Lysosomes* -** do not need to know for exams) – contain digestive enzymes for breakdown of large food molecules and recycled cell parts (e.g., other damaged organelles)

*Note the difference in pigments found in vacuoles vs. chromoplasts.
Vacuoles contain anthocyanins (red/purple/blue colors), which are water soluble (dissolve in water).
Chromoplasts contain carotenoids (yellow/orange/red colors), which aren't water soluble.

In structures like flowers, there is a wide diversity of colors because plants can have variable concentrations and combinations of different pigments, and in some cases "overlap" anthocyanins and carotenoids to yield 'new' colors (colors not attainable with a single pigment type (anthocyanin or carotenoid). Patterns are formed by allocating pigments in chromoplasts/vacuoles in cells that from the distinct patterns. We discussed this in lecture and in lab – I think it is interesting…which means it will probably be on an exam!
We will discuss many, many (!) other features of plant cells throughout the semester – but let's wait until we encounter the appropriate context. For now, the list above provides us with a solid foundation.



At right is a generalized plant cell. On future exams and quizzes you will be responsible for identifying the structures indicated here and for knowing their general function in the cell (1 sentence descriptions will be adequate…assuming they are accurate!!). We'll discuss the function of most organelles in future lectures. Not labeled here are the plasmodesmata (the little holes that connect the cytoplasm of adjacent cells). Not pictured here are other plastids.

THE FOLLOWING INFORMATION ON BINOMIAL NOMENCLATURE MIGHT HAVE BEEN COVERED IN LAB DURING WEEK 1 OR 2. YOU MUST KNOW THIS FOR EXAMS AND MIDTERMS

Binomial nomenclature: a formal system of naming individual species with names comprised of two Latin words (sometimes borrowing roots from other languages such as Greek). (These names are often referred to as "*Latin names*" or "*scientific names*".) Developed by Carl Linneus (1707-1778).

In a scientific name, the first Latin word is the genus name, and the second is the species epithet:

Example (from lab):

Ceanothus *megacarpus*
(genus name) (species epithet)

Proper reporting of scientific names:

- First letter of the genus name is capitalized
- Species epithet is not capitalized
- Both are italicized (or, underlined if written by hand)

Correct:

- *Nicotiana glauca*

Incorrect (can you see why?):

- nicotiana glauca
- *nicotiana glauca*
- NICOTIANA GLAUCA
- *NICOTIANA GLAUCA*
- Nicotiana Glauca
- Nicotiana glauca
- Nicotiana *glauca*
- *ETC…*

Plant Families

Finally, similar genera (and thus, the species each genus contains) are organized into families. There are ~415 families of flowering plants (and about 250,000 - 400,000 known species), and ~ 14 families of gymnosperms (conifers and allies – don't worry if you don't know what this means – you soon will!) – we will discuss a small number of these during Bot 100. Some families contain tens of thousands of plants (e.g., the orchid family Orchidaceae has ~22,000 species!), others contain very few.

The value of binomial nomenclature:

1) Efficient – species names before Linnaeus tended to be lengthy descriptions
2) Universal – Latin is not unique to any country or people, therefore "fair"
3) Stable – Latin is a "dead" language and is therefore not changing
4) Uniqueness and clarity – A single common name (nickname) can be used for different species in regions vary from country to country (Example of robins in Europe and US; crayfish in Australia vs USA). Similarly, regionally different names can exist for a single species (Example mahi-mahi / dorado / dolphin fish)

http://fliiby.com/file/914884/c6incxgf4b.html episode "freeze frame" (road runner cartoon with latin names)
http://fliiby.com/file/19330/neihpct0uv.html episode: "soup or sonic" (another rr cartoon with latin names)

OK, regarding the following material on classification…did we squeeze it in? Perhaps not. I wrote these notes prior to lecture and lab this week.
You are going to get a healthy dose of this in Biology 102. We might skip it in Bio101, which seems like a shame. Stay alert and let's check in prior to the midterm! Perhaps we'll cover this in lab?

Taxonomy: is the science of identifying and naming species, and arranging them into a classification (category)

For centuries, humans had attempted to name and classify (categorize) the vast number of species on Earth.
Carl Linnaeus (1707-1778) revolutionized efforts with two main contributions:

1) **Binomial nomenclature**
2) **Classification - A hierarchical classification scheme**

Binomial nomenclature: explained on the previous page!
Classification: A grouping of organisms based upon biological similarity (and presumably, evolutionary relatedness).

In addition to assigning names to individual species, Linneaus classified (grouped) them into larger groups based upon biological similarity. His classification scheme is **hierarchical.**

Hierarchy: an arrangement of items as being above, below, or at the same level as each other. There are two general types:

Exclusion hierarchy: Items at a given level do not "belong" to any other levels (Example: student/teacher status: junior high, high school, college undergraduate, graduate student, professor, etc…each level has unique privileges).
Inclusion hierarchy: Items above other levels contain items in the lower level, items below "belong" to the upper level hierarchical units (Example: Russian dolls).

Properties of Linneaus' classification hierarchy:

1) Linneaus' classification hierarchy is an **inclusion hierarchy**.
2) Seven levels in the hierarchy (now 8, including Domains):
   Domain
   Kingdom
   Phylum
   Class
   Order
   Family
   Genus
   Species
3) Each level is called a "**taxon**", or "**taxonomic group**" – and is defined by a biological characteristic shared by all members in the taxonomic group.

As one proceeds from the domain level down to species, the characteristics that define each group become more specific and pertain to a smaller number of organisms. BUT- the features of broader taxonomic groups are possessed by all the narrower groups that it contains.