What did we get from the last lecture?

What is a plant? A living organism that is usually photosynthetic, usually immobile to the naked eye and has a cellulose cell wall.

**Plants do things fundamentally differently than animals**

Plants exhibit **indeterminate growth**: they grow without having a genetically preprogrammed shape, size or often lifespan (contrast with animals)

- Plants can live to extremely ancient ages
- Plants can be huge

Plants are **tremendously productive**: 90% of world’s biomass is plant material
- Cellulose found in the cell wall of plants is the most abundant polymer
- Rubisco is the most abundant protein

**Plant productivity enables plants to replace and repair injuries**

Plants are **essential for life**: Produce oxygen and capture solar energy.

**Plants have shaped human history**

- Important role in both Agricultural and Industrial revolution
- Plants changed world history

**Plants do all the things all living things need to do**: Obtain food and water, grow and develop, reproduce (both sexually and asexually), disperse their offspring, sense and respond to the environment and environmental changes and over time, plant populations have adapted and evolved.

**Plants have adaptations that enabled them to invade land:**

- Waxy cuticle to prevent water loss, stomata (pores) in the surface to permit gas exchange, vascular tissue, pollen and seeds, support tissue, roots for uptake of water and nutrients, specialized organs.

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Plants: highly organized organisms with regulated metabolism (the reactions in the cells), like other living things, composed of organic molecules.

**Elements of life**: the bulk of living material is comprised of only a few elements:

- C, H, O, P, K, N, S, Ca, Fe, Mg, Cl, Mn, B, I, Cu, Zn - Carbon, hydrogen, oxygen, phosphorous, potassium (K), nitrogen, sulfur, calcium, iron (Fe), magnesium, chlorine, manganese, boron, iodine, copper, and zinc.

- C. Hopkins, Cafe Manager. Closed Monday but I see you (Cu) soon.

The most **abundant compounds** are listed first: carbon, hydrogen, oxygen, nitrogen and phosphorous make up the bulk of living tissue:

- Most = water and the rest is mostly organic (carbon based) compounds.

**Main classes of organic compounds**:

Four main classes of **primary compounds**:

- **Carbohydrates** for energy, energy storage and structure
- **Proteins** for doing things (enzymes), regulating processes and storage
- **Lipids** for storage, protection, structure, hormones and membranes,
- **Nucleic acids** as a set of instructions for making what you need.

Plants have a far number of **secondary metabolites** as well: Secondary metabolites or compounds are compounds that are not essential for life but are produced in small to large amounts by the plant.

- Often, though to have protective function, often function is unknown.
Carbohydrates: “Sugars and complex carbohydrates” -
Plant can churn these out at an astounding rate: main product of photosynthesis is a carbohydrate (glucose, a sugar and plants make tons of it).

Plants use carbohydrates:
- **As an energy source** (burn some of the sugar they make for energy for metabolic work)
- **As energy storage**: store the carbohydrates as **starch** - we use this as humans as the main source of calories in the worldwide diet, and also use starch as a **sizing agent** (to make materials like cloth and paper) stiff and smooth, and as a **hydrogel** - “water modifying agent” - a thickener for mixtures.
- **As structure**: **cellulose** in cell walls - similar chemistry as starch but not readily digested by most organisms

Proteins: chains of **amino acids** (amino acid = small molecule with nitrogen containing amino group)
Proteins are made up of **20 different amino acids** linked together in chains in various sequences

Plants use proteins:
- **As enzymes**: every chemical reaction in the cell is catalyzed by an enzyme that speeds up the rate of the reaction.
  - **In order to build all the molecules in a cell, you need protein**: Every step in the process of making carbohydrates in photosynthesis is helped by an enzyme, every step in the production of lipids is catalyzed by an enzyme, to modify any compound in a cell, you need an enzyme.
  - **Central dogma** (*editorial note: in lecture, I believe I changed the order here so your notes might not match up): DNA in the nucleus is read and transcribed as RNA that is decoded and translated into protein.
  - Need those enzymes to control the chemical reactions of the cell - **gotta have enzymes to do all the tasks you need to do**.

Plants are able to make all the amino acids they need but humans and other animals cannot:
- Humans must consume protein in diet as they can make 11 of the amino acids that make up protein but cannot make 9 of them: we eat the protein in our diets, it is digested and broken down into amino acids that we use to build new protein.

Other functions of proteins include: regulating cell process, transporting material in and out of cells, as signal molecules, storage but not structure.

**Animals have structural proteins** like keratin that waterproofs our skin, etc. but plants do not have any major structural components that are made of protein

**Plants do store proteins (humans cannot)** - have to consume some every day
- Plant storage proteins are **abundant in seeds**: Wheat gluten = the storage protein of wheat seeds.
- **Legumes** (beans, peas and other related plants) can have seeds that have up to 40% of their seed reserves as protein (stored in the seed for growth during germination of the seed).

**Plants do store proteins have a different amino acid composition from animal protein**: most plant proteins are incomplete (they lack sufficient quantities of one or more of the 9 essential amino acids) so that plant proteins often need to be consumed as pairs (or more) of complementary proteins (more later).

**Some plant storage proteins are toxic**: One of the storage proteins of plants acts as an inhibitor of one of the human enzymes that digests protein (won’t kill you but does block digestion of some of the soybeans protein). Castor bean (a plant that is not really a bean) has seeds that contain ricin, a highly toxic and deadly storage protein (ricin blocks protein synthesis and thus blocks all metabolic activity in the cell, i.e. it can kill you).
Lipids: a “mish-mash” of compounds>

Lipids are a class of organic compounds that are comprised of mostly carbon and hydrogen and that do not readily dissolve in water. Very broad definition that fits several different classes of compounds, primarily:

**Fatty acid based lipids**: fats and oils (glycerides), waxes, and phospholipids

**Sterols**: complex carbon ring based structures

**The fats and oils**: storage of energy

- **Animals**: tend to have glycerides that can be called fats - they are solid at room temperature, they are compact and they are easy to move. The structure of the fatty acids of animal fats tends to be long straight chains with every carbon in the chain saturated with hydrogen (hence, saturated fats).

- **Plants**: do not move. Most of the storage lipid of plants = oils - they are liquid at room temperature. **Plant “fat” (oils)** contains both saturated and **unsaturated fatty acids**. An unsaturated fatty acid has a kink in it - it has at least one double bond in the chain and thus at least one of the carbons is not completely saturated with hydrogens. **Linoleic acid** is one such fatty acid that is also an essential fatty acid - must have in diet.

There are some exceptions to this animal fat/plant oil rule of thumb:

- Palm and coconut “oil” are actually more like animal fat
  - **Palm oil** is extracted from the fruit of the oil palm and was historically used for soap and candle making as well as for cooking.
  - **Coconut oil** is extracted from the seed of the coconut palm. It was used to make one of the first margarines and formally used in nondairy creamers and baked good (popularity has dropped off) Still used extensively in cosmetic products.

**Waxes**: fatty acids without the glyceride. The cuticle of plants = cutin (mixture of waxes.)

- Waxes can be found in all plant parts (except roots).
- **Carnauba wax** is a leaf wax that is used in car and floor waxes
- **Bayberry wax** is a surface wax from fruit used in candle making
- **Jojoba is a very funky seed wax**: An “oil” (even though chemically a wax, it is liquid so often called an oil). Initially hoped to be an industrial lubricant that could be used in place of sperm whale oil (it is stable under high heat) but the yields are too low. Still used extensively in cosmetics.

**Sterols**: complex ring structures, the most famous of which is **cholesterol** (that stabilizes the membrane of animal cells and helps insulate the nerve cells) that is **NOT found in plant products** (all plant products by their very nature are cholesterol free).

- **Sterol-based hormones** are found both in plants and animals: one of the most recent classes of plant hormones, the brassinosteroids, are sterol-based compounds.

**Nucleic acids**: last class of organic macromolecules: chains of nucleotides, storage of genetic information

- **DNA**: deoxyribonucleic acid = permanent genetic record of cell
- **RNA**: ribonucleic acid = workhorse - involved in protein synthesis.

Plants also produce abundant secondary metabolites as well: the function of which is not fully understood.

Secondary metabolite is defined as a compound that is not essential for basic metabolism but is still produced by the plant: apparently, some how useful to the plant.

- **Often, thought to be a protective compound - anti-herbivore compounds**
- **Secondary metabolites** include a variety of **alcohols, sterols, alkaloids** (nitrogen containing compound) and **aromatic compounds**.
- **Steroidal glycosides**: sterol plus a sugar side chain - like those produced by milkweed and foxglove are cardiac glycosides (slow and strengthen the heartbeat).

Vine yams (not sweet potatoes) produce tubers that are a good source of saponins that can be used as precursors for synthetic hormones (the first birth control pill was produced using this plant source). These compounds are also used to make cortisone and hydrocortisone.