# evolution, The themes of Biology, and scientific inquiry

Key concepts:

- Study of life reveals common themes (1.1)
- core themes: evolution accounts for unity and diversity of life (1.2)
- hypothesis + observations (1.3)
- science benefits from coop approach + diverse viewpoints (1.4)

## Concept 1.1

5 underlying themes of bio:

- organization
- information
- energy + Matter
- Interactions
- Evolution

## Organization

reductionism: zooming through levels of biological heirarchy. Reduces complex systems into simpler components

### Emergent properties

Emergent properties: New properties that arise w/ each step upwards in the hierarchy of life, owing to the arrangement and interactions of parts as complexity increases

systems biology: exploration of a biological system by analysing the interactions of its parts

### structure and function

Theres lot of corrolation between structure and function

↳ hummingbird's wings rotate at the shoulder → means hummingbirds got the ability to fly backwards or hover in place

### The cell: an organisms basic unit of structure and functions

In structural hierarchy, cell is smallest unit that can preform all activities required for life

levels of biological organization

1. the biosphere: all life on earth and all the places where it exists. Most regions of land, most bodies of water, atmosphere (until altitude of 7km), sediment bellow ocean floor
2. ecosystems: All living things in a particular area (including non living components (soil, water, light, atmospheric gases
3. communities: the array of organisms in an ecosystem. Plants, animals, fungi, microorganisms
4. Population: all the individuals w/in a specific area
5. organism: each individual organism
6. organs: body part made of multiple tissues w/ distinct arrangement and function
7. Tissues: group of cells that work together (specialized function)
8. cells: fundamental unit of structure and function
9. organelles: functional components of the cell
10. Molecules: chemical structure consisting of 2+ atoms

## Information

Within the cell, chromosomes contain the genetic material (DNA)

DNA, the genetic material

before cell divides, DNA's replicated or copied. each chromosome contains 1 very long DNA Molecule w 100k+ genes

DNA molecule is made up of 2 long chains (strands) arranged in a double helix

each chain is made up of a, T, C, G. Cytosine, adenine, Guanine, Thymine. (nucleotides)

nucleotides are a 4 letter alphabet

many genes, its a sequence provides the blueprint for protein synthesis (enzyme, antibodies

Protein synthesis:

Transcription → Translation → Protein folding

DNA → mRNA → chain of AA → Protein

### Geonomics

all the genetic info of organism is called the genome

genomics: The study of a whole set of genes and their interactions w/in a species, as well as genome comparisons between species

Proteome : The entire set of proteins expressed by a given cell or group of cells

Proteomics: The systematic study of the full protein sets (proteomes) encoded by genomes

## Energy and matter

any form of work (moving, growing, reproducing) takes energy

input of energy is usually by the sun

There are producers and consumers. Producers photosynthesize sun and consumers eat them

Energy usually flows through an ecosystem in 1 direction. In as light and out as heat

## Interactions

between components of an ecosystem

### Molecules: interactions within organisms

The key is the ability of many biological processes to self-regulate by a mechanism called feedback

feedback regulation: The regulation of a process by its output or end product

- most common feedback regulation is negative feedback (ex. insulin signaling)
- There is also positive → The end product speeds up the process (ex. platelet production)

### Ecosystems: An organisms interactions w/ other organisms + pysical environment

@ ecosystem level: all organisms react w/ other organisms

interactions among organisms help regulate the functioning of the ecosystem as a whole

organisms also interact w/ physical environment. environment is then affected by the organisms living there

- on a global scale: plants + other photosynthetic organisms generated all the $O_2$ in the atmosphere
- This has also affected climate change {+1°C since 1900}

## Concept 1.2

## Evolution

Evolution: Descent with modification; the idea tha living species are decendents of ancestral species that were different from the present-day ones; also defined more narrowly as the change in the genetic composition of a population from generation to generation

### Classifying the diversity of life

Discovered 1.8 Billion species of organisms

To date: 100,000 fungi

290,000 plants

57,000 vertebrate

1,000,000 insects

### The three domains of life

Bacteria } Prokaryotes
Archaea }

Eukarya : Plantae
Fungi
Anamalia
Protists

Plants: produce their own sugar + food molecules w/ photosynthesis

Fungi: absorb dissolved nutrients from their surroundings

Animals: obtain food by eating + ingesting other organisms

There are the most protists. mostly single celled. There are multiple groups of protists. some are more closly related to [plants, fungi animals] than to other protists

### Charles Darwin and the theory of natural selection

Decent w/ modifications

Natural selection is primary cause

Darwin's 3 observations:

- individuals w/in a population vary; traits are mostly heritable
- population can produce more offspring than can survive to make their own
- Species are adapted to their environment

natural selection: a process in which individuals that have certain inherited traits tend to survive and reproduce at higher rates than other individuals *because* of those traits

### The tree of life

One ancestral organism can give rise to multiple different species

## Concept 1.3

### Form and test hypothesis

Science is a form of inquiry that includes making observations; forming logical, testable explanations, and testing them

### Exploration and observation

recorded observations are called data

there are qualitative and quantitative data. qualitative is description and quantitative is numerical measurements

quantitative data is generally expressed as numerical measurements : tables and graphs

scientists use math called statistics

inductive reasoning: a type of logic in which generalizations are based on large number of scientific observations

Deductive Reasoning: a type of logic in which specific results are predicted from a general premise (if → then)

### Questions that can and cannot be adressed by science

a scientific hypothesis must be testable (observation + expirament)

not all hypotheses meet criteria of science

### Experimental variables + controls

controlled experiment: an experiment in which an experimental group is compared w/ a control group that varies only in the factor being tested

variables: a factor that varies in an experiment or other test

dependent variables: a variable whos value is measured during an experiment / test to see whether it is influenced by changes in other variables

independent variables: a variable whose value is manipulated or changed during an expirament / test to reveal possible effects on another variables

researchers usually control unwanted variables not by eliminating them through environmental regulation, but by cancelling out their effects by using control groups

### Theories in science

scientific theories are much broader in scope

theories are general enough that its possible to have multiple hypotheses about it

theory is supported by more evidence

## Concept 1.4

### Cooperative approach and diverse viewpoints

### Science and technology

Goal of science is to understand natural phenomena, while technology is to apply scientific knowledge for a specific purpose

question is more "should we do it?" not "can we do it?"

ethical questions have to do w/ : politics, religion, economy, cultures

### Value of a diverse viewpoint

diff cultures ignight new ideas

women and minority groups are still underrepresented

# The chemical context of life

Key concepts:

- Matter consists of chemical elements in pure form and in combinations called compounds (2.1)
- an elements properties depend on the structure of its atoms (2.2)
- The formation and function of molecules depends on chem bonding btw atoms (2.3)
- Chem reactions make / break chem bonds (2.4)

## Concept 2.1

matter: anything that takes up space and has a mass. exists in many forms

elements: cannot be broken down into any other substance by chemical reactions

compound: a substance made up of 2+ elements combined in a fixed ratio. (ex: NaCl). a compound has characteristics different than its elements

### The elements of life

20-25% of elements are essential elements. These are necessary for organisms to live and reproduce.

Oxygen, nitrogen, Hydrogen, and carbon make up of 96% of living matter

Trace elements: required by organism in trace quantities

Table 2.1: Elements of the human body

| Element | Symbol | Percent of Body mass (w/ $H_2O$) |
|---|---|---|
| Oxygen | O | 65% |
| Carbon | C | 18.5% |
| Hydrogen | H | 9.5% |
| Nitrogen | N | 3.3% |
| Calcium | Ca | 1.5% |
| Phosphorus | P | 1.0% |
| Potassium | K | 0.4% |
| Sulphur | S | 0.3% |
| Sodium | Na | 0.2% |
| Chlorine | Cl | 0.2% |
| Magnesium | Mg | 0.1% |

## Concept 2.2

Atom: is the smallest unit of matter that still retains its property of the element

### Subatomic particles

There are more than 100 types

3 matter:

- neutron
- electron
- proton

neutron: electrically neutral, has no charge

proton: positivly charged. same size as neutron

electron: negativly charged. smaller than proton + neutron

proton + neutron are packed together in nuclear core (atomic nucleus)

we use daltons to measure atoms + subatomic particles

Dalton: A measure of mass for atoms and subatomic particles; the same as the atomic mass unit (AMU)

neutrons + protons have ~1 AMU. electron is 1/2000$^{th}$ of the weight (ignore it when calculating mass of atom)

### Isotopes

Isotope: one of several atomic forms of an element, each w/ the same number of protons but a different number of neutrons (thus differing in atomic mass

some isotopes are stable isotopes, meaning that their nuclei do not have a tenancy to lose subatomic particles (decay). ex. $^{12}C$ or $^{13}C$

some isotopes ($^{14}C$) are not stable (radioactive)

radioactive isotope: An isotope (an atomic form of a chemical element) that is unstable; the nucleus decays spontaneously, giving off detectable particles + energy

If the radioactive decay leads to a change in proton, the element changes. $^{14}C$ decays, it loses a proton, becoming an atom of $^{14}N$

Radioactive tracers

useful in medicine. Radioactive isotopes incorporated into biologically active molecules, which are used as tracers to track atoms during metabolism. also good for diagnosing/discovering diseases. Also used w/ tech (PET scans) to monitor growth + metabolism of cancers

Radiometric dating

measuring radioactive decay of fossils/relics. Parent isotope decays into daughter isotope at fixed rate (expressed as the half-life of the isotope: time it takes for 50% of parent isotopes to decay). each radioactive isotope has a characteristic half-life not affected by temp, pressure, or other env. variable. Radiometric dating calculates how many half lives since

## The energy level of electrons

atoms are mostly empty space. only electrons are involved in chem reactions

Energy: The capacity to cause change, especially to do work (move matter against an opposing force)

Potential energy: the energy that matter posesses as a result of its location or spatial arangement (structure)

matter has natural tendancy to go towards lowest state of potential energy

An electron's energy level is corrolated with its average distance from the nucleus

electrons found in diff electron shells. further from nucleus, more potential energy. when electron absorbs energy it moves shell further. when it loses energy, it moves shell closer

Chemical behaviour of atom depends on outer shell. outer electrons are called valence electrons. outermost shell: valence shell

## Electron orbitals

Orbital: The 3D space where an electron is found 90% of the time

no more than 2 electrons @ 1 orbital

## concept 2.3

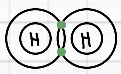
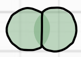
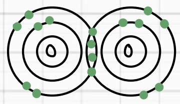
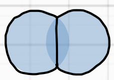
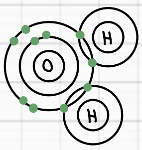
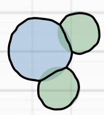
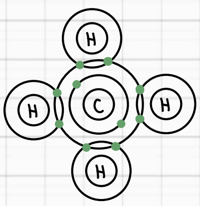
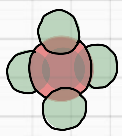
Interactions usually result in atoms staying close, this is called a chemical bond. Strongest bonds are: covalent bonds, and ionic bonds in dry ionic compound

## covalent bond

covalent bonds: a type of strong chemical bond in which two atoms share one or more pairs of valence electrons

Two+ molecules held together by a covalent bond form molecule ($H_2$) can be written as H – H; shows its a single bond. O=O is double bond

Figure 2.0 covalent bonding

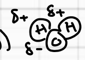
| name of molecular formula | Electron distribution diagram | lewis dot structure/structural formula | space filling molecule |
|---|---|---|---|
| Hydrogen ($H_2$) |  | H : H<br>H – H |  |
| oxygen ($O_2$) |  | Ö :: Ö<br>O=O |  |
| water ($H_2O$) |  | :Ö : H<br>H<br>O – H<br>\|<br>H |  |
| Methane ($CH_4$) |  | H<br>H : C : H<br>H<br>H<br>\|<br>H – C – H<br>\|<br>H |  |

bonding capacity is called valence, is usually number of unpaired electrons in outershell (left to complete)

once 3rd row of periodic table, some have multiple valence (phosphorus usually 3 unpaired electrons, but sometimes forms 3 single bonds + 1 double bond (valence of 5)

the attraction of a particular atom for electron of covalent bond is called electronegativity. The more electrons, the stronger it pulls electrons towards itself

covalent bond w/ 2 same element, attraction = 0, called non polar covalent bond.

when 1 atom stronger than other (more negative) polar covalent bond ($H_2O$) 

electrons go towards oxygen more. These bonds vary in polarity.

oxygen is one of the most electronegative elements (water is very polar)

written as δ (delta) δ- (delta minus: negative charge: more electrons), δ+ (delta plus: more positive: less electrons

electronegativity of: O: 3.44, N: 3.04, C: 2.55, H: 2.20

useful when identifying behaviour of amino acids

## Ionic bonds

ionic bond: a chemical bond resulting from the attraction between oppositly charged ions

cation: positivly charged ion

anion: negativly charged ion

[Na] + [Cl] → NaCl ($[Na]^{+}$ + $[Cl]^{-}$)

sodium "gave" an electron to chlorine. Na has charge of 1+, Cl has charge of 1-

compounds formed by ions are called ionic compounds (or salts).

salts often found in nature as crystals

unlike covalent bonds, whic consist of molecules having a definite size + number of atoms, an ionic compound does not consist of molecules. Formula for ionic compounds (NaCl), indicate only the ratio of elements in the crystal of salt

not always equal number of cations + anions ($MgCl_2$) → $[Mg^{2+}] + 2[Cl^{1-}]$

ion also applies to entire molecules that are electrically charged ($NH_4Cl$) → $[Cl^{-}] + [NH_4^{+}]$

environment effects strength of ionic bond

weak chemical interactions

### Hydrogen bonds:

A type of weak chemical bond that is formed when the slightly positive hydrogen atom of a polar covalent bond ($H_2O$) in one molecule is attracted to the slightly negative atom of a polar covalent bond in another molecule ($H_2O$), or in another region of the same molecule (some amino acids)

### Van der Waals interactions:

weak attractions between molecules, or parts of molecules that result from transient local partial charges

- molecule regions change intensity + area of -/+ charges, when accumulated, areas are more polar. this allows atoms/molecules to stick together. van der waals interactions only occur when atoms/molecules are very close together.
- when occuring symoultaneously, can be powerfu (allow gecko to walk straight up a wall)

## Molecular shape and function

a molecule has characteristic size + shape, key to function of living cell

molecule w/ 2 atoms is always linear ($O_2$, $H_2$)

shape determined by position of orbitals

molecular shape is crutial: Determines how bio molecules recognize + respond to one another w/ specificity. Bio molecules often bind temporarily to each other by forming weak bonds, can only happen if shapes are complimentary.

## concept 2.4

chemical reactions: The making and breaking of chemical bonds, leading to change in the composition of matter

in chemical reactions, there is reactants and products. all reactants must be accounted for in the products

chemical equilibrium: in a chemical reaction, the state in which the rate of the forward reaction equals the rate of the reverse reaction, so that the relative concentration of the reactants/product doesn't change over time

# water and life

key concepts

- Polar covalent bonds in water result in hydrogen bonding (3.1)
- Four emergent properties of water contribute to earth's suitability for life (3.2)
- Acidic + Basic conditions affect living organisms (3.3)

## concept 3.1

water molecules form a V shape : H-O-H , connected by single covalent bonds , the oxygen is more electronegative : O = δ- , H = δ+ .
this makes a polar covalent bond

property of water : attraction to other water molecules

## concept 3.2

four emergent properties of water

cohesive behaviour

ability to moderate tempurature

expansion upon freezing

versatility as solvent

## cohesive of water molecules

water molecules stay close due to hydrogen bonds

collectivly , hydrogen bonds hold drink together by phenomenon : cohesion

cohesion contributes to transport of nutrients against gravity in plants

adhesion : The clinging of one substance to another (water to plant cell walls) by means of hydrogen bonds

surface tension : A measure of how difficult it is to stretch / break the surface of a liquid . Water has high surface tension because of the hydrogen bonding of surface molecules

## moderation of tempurature by water

moderates temp by absorbing heat from air + releasing when air is cooler

temp / Heat

everything that moves has kinetic energy

kinetic energy : The energy asociated w/ the relative motion of objects moving matter can perform work by imparting motion to other matter

The faster a molecule , the more kinetic energy

kinetic energy acosiated w/ the random movement of molecules is called thermal energy

Thermal energy : kinetic energy due to the random motion of atoms/molecules . energy in its most random form (heat)

Temp : average kinetic energy of the molecules in a body of matter

Although temp of hot water is higher than a pool , pool has higher kinetic energy

Heat : thermal energy in transfer from 1 body of matter to another . Measured in Jouls (J)

Kilocalorie (kcal) : 1000 cal , amount of energy needed to raise 1kg of water by 1°C .

1 cal : 4.184 J

1 Joule : 0.238 cal

water's high specific heat

specific heat : amount of heat that must be absorbed / lost for 1g of the substance to change its temp by (+/-) 1°C . How well substance resists change

specific heat of water : 4.18 J/(g · °C) . water has unusually high specific heat

because of high specific heat , it changes less temp when absorbing / releasing heat

water that covers earth keeps temps fluctuating w/in limits that permit life

evaporative cooling

even when water temps are low , there are still molecules that escape (vapourize / evaporate)

heat of vapourization : The quantity of heat a liquid must absorb for 1g of it to be converted from liquid to gas

water heat of vapourization : 1g water at 25°C needs 2427 J

helps regulate earth's climate

evaporative cooling : The process in which the surface of an object becomes cooler during evaporation , a result of the molecules w/ greatest kinetic energy changing forms (liquid to gas)

## Floating of ice on liquid water

less dence as solid

above 4°C, water behaves like other liquids

btw 0°C - 4°C : starts to freeze

below 0°C : freezes. each water molecule w/ 4 molecules. Hydrogen keeps distance, making it 10% less dense

## Water: the solvent of life

solution : a liquid that is a homogenous mixture of the 2 substances

solvent: the disolving agent of a solution. waters most versatile

solute : a substance thats dissolved in a solution

aqueous solution: one where the the solute is water

hydration shell: the spher of water molecules around a disolved

### Hydrophillic / hydrophobic substances

Hydrophilic : Affinity to water (likes water) usually polar. sometimes dont disolve

Hydrophobic : Dont like water

### Solute concentration in aqueous solutions

molecular mass: The sum of all the atoms in a molecule, sometimes called molecular weight

when figuring out concentration, need to know molecular mass

- ex: molecular mass of sucrose ($C_{12}H_{22}O_{11}$)
  - C : 12
  - H : 1
  - O : 16
  - $(12 \times 12) + (1 \times 22) + (16 \times 11)$
  - $144 + 22 + 176 = 342$ daltons

moles : $6.02 \times 10^{23}$ (Avagadro's number). theres $6.02 \times 10^{23}$ daltons in 1g

342 g to represent $6.02 \times 10^{23}$

1 mol sucrose = 342g

- How to make 1L solution of 1 mol sucrose?
- measure 342g sucrose
- add 1L water
- 1M solution of sucrose

Molarity : common measure of solute concentration, reffering to the number of moles of solute per litre of solution

## Concept 3.3

Acidic and basic conditions effect living organisms

sometimes a hydrogen atom participating in a hydrogen bond btw 2 water molecules shifts from 1 to the other. Hydrogen leaves behind its electron, and hydrogen ion [$H^+$] is whats transfered (single ion w/ charge 1+). water molecule is now hydrogen oxide [$OH^-$] (charge of 1-). Proton binds to another water molecule making it a hydronium ion [$H_3O^+$]

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

water $\rightleftharpoons$ Hydronium ion + Hydroxide ion

$H^+$ does not exist on its own in an aqueous solution (always associated w/ $H_2O$ molecule in form of $H_3O^+$

in pure $H_2O$; 1 molecule / 554 million is dissociated (25°C). 60 000 million / L of pure $H_2O$

concentration of $H^+$ and $OH^-$ are equal in pure water, but change w/ addition of acids and bases

## Acids / Bases

when acids disolve, they donate $H^+$

acid : A substance that increases the hydrogen ion concentration of a solution. ex: HCl (hydrocloric acid). $HCl \rightarrow H^+ + Cl^-$

when bases disolve, they reduce $H^+$ by accepting it, or by adding hydroxide ions.

Base : A substance that reduces the hydrogen ion concentration of a solution. Ex: $NH_3$ (Amonia). $NH_3 + H^+ \rightleftharpoons NH_4^+$ (Ammonium ion)

- Ex: NaOH (sodium hydroxide) $NaOH \rightarrow Na^+ + OH^-$

double arrow reaction indicate weak acid/base

ex: $H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

carbonic acid, Bicarbonate ion, Hydrogen ion

## The pH scale

in any aqueous solution at 25°C, product of $H^+$ + $OH^-$ concentration is constant at $10^{-14}$

$[H^+] + [OH^-] = 10^{-14}$

neutral : $[H^+] = 10^{-7}$ , $[OH^-] = 10^{-7}$ $(10^{-14})$

acidic : $[H^+] = 10^{-5}$ + $[OH^-] = 10^{-9}$ $(10^{-14})$

pH : pH of a solution is the negative log (base 10) of the hydrogen ion concentration. $pH = -\log[H^+]$

neutral = $-\log[10^{-7}] = -(-7) = 7$

## Buffers

human blood is pH 7.4 (cant survive at 7.0 or 7.8)

0.01 mol strong acid to 1L water : 7.0 → 2.0

0.01 mol strong acid to 1L blood : 7.4 → 7.3

Buffer: substance that minimizes changes in concentration of $H^+$ / $OH^-$ in a solution. accepts $H^+$ when in excess, and donating them when not enough

### Acidification : A threat to our oceans

25% of fossil fuel burned $CO_2$ is absorbed by the ocean

too much absorption is harmful to oceans

when $CO_2$ dissolves in seawater, it reacts to cause carbonic acid (lowers the ocean's pH levels). called ocean acidification

ocean pH is 0.1 pH units lower now than past 420 000 years

drop 0.3-0.5 pH units by end of century

$CO_2 + H_2O \longrightarrow H_2CO_3$ — 1. carbon dioxide dissolves in water to form carbonic acid

$H_2CO_3 \longrightarrow H^+ + HCO_3^-$ — 2. carbonic acid dissociates to hydrogen ion and bicarbonate ions

$H^+ + CO_3^{2-} \longrightarrow HCO_3^-$ — 3. added $H^+$ combines w/ carbonate ions, forming more $HCO_3^-$

$CO_3^{2-} + Ca^{2+} \longrightarrow CaCO_3$ — 4. less $CO_3^{2-}$ available for calcification (formation of calcium carbonate) by marine org. (corals)

ocean acidification will cause carbonate ions to decrease 40% by 2100

# carbon and the molecular diversity of life

key concepts
- organic chemistry is the study of carbon compounds (4.1)
- carbon atoms can form diverse molecules by bonding to 4 other atoms (4.2)
- A few chemical groups are key to molecular function (4.3)

carbon : The backbone of life

concept 4.1

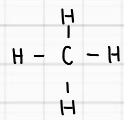
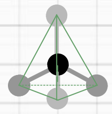
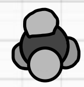
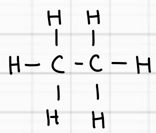
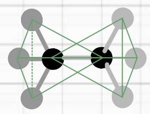
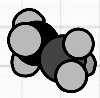
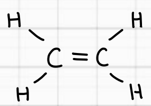
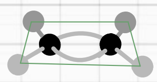
organic chemistry : The study of carbon compounds (organic compounds

organic molecules and origin of life on earth

overall % of the major elements (C, H, O, N, S, P) are uniform in all organisms
diff org have diff combinations of the elements

concept 4.2

carbon atoms form diverse molecules by bonding to 4 atoms

| molecule /molecule shape | Molecular formula | Structural formula | Ball+stick model | Space filling model |
|---|---|---|---|---|
| methane: when C atom has 4 single bonds w/ other atoms, shape is tetrahedral | $CH_4$ |  |  |  |
| Ethane: A molecule may have more than 1 tetrahedral group of single bonded atom (2 of these in ethane) | $C_2H_6$ |  |  |  |
| Ethene (ethylene): when 2 or more C are joined w/ double bond, all atoms attached to the C are in the same plane, and molecule is flat | $C_2H_4$ |  |  |  |

in organic molecules, C forms double or single bonds
valence : the bonding capacity of a given atom; usually equals no. of unpaired electrons required to complete atoms outermost shell

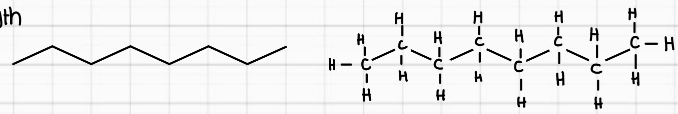
Molecular diversity arising from variation in carbon skeleton

can be straight, branched, ring . can be double / single bond

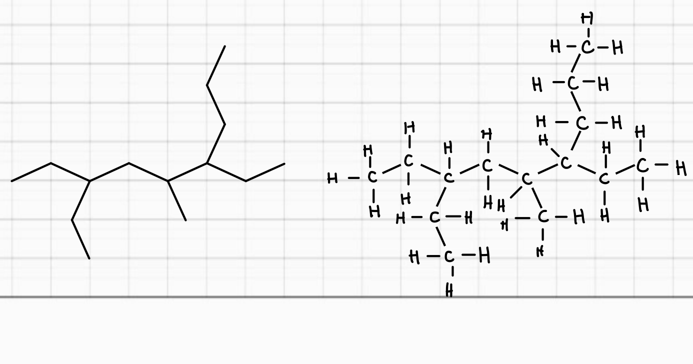
hydrocarbons

hydrocarbon: An organic molecule consisting only of carbons and hydrogens
not prevelant in most org, many cell's org molecules have regions of only H+C (fats)
ways carbon chains differ

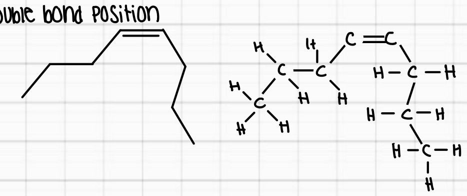
1. length



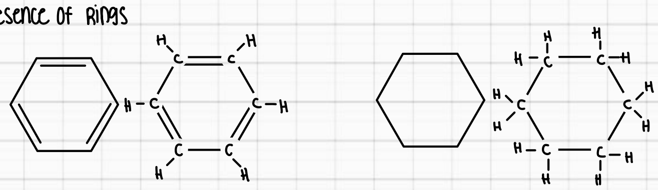
2. Branching



3. Double bond position



4. Presence of Rings



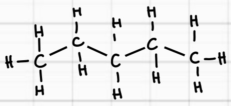
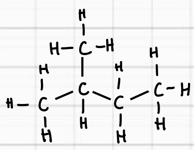
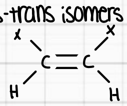
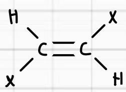
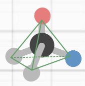
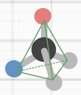
isomers

isomers: one of several compounds w/ the same molecular formula but diff structures + therefore diff properties. The 3 types of isomers are structural isomers, cis-trans isomers, and enantiomer

Structural isomers: one of several compounds that have same molecular formula but differ in covalent arrangement of their atoms

Cis-trans isomers: one of several compounds w/ same molecular formula and covalent bonds between atoms but differ in spacial arrangements of atoms owing to the flexibility of double bonds (geometric isomers)

Enantiomers: isomers that are mirror images of each other due to an asymmetrical carbon (they differ in shape)

| 3 types of isomers | |
|---|---|
| Structural isomers  |  |
| Cis-trans isomers  x are on the same side |  X on the other side |
| Enantiomers: mirror images  L isomer |  D isomer |

Concept 4.3

The chemical groups most important to the process of life

Functional groups: a specific configuration of atoms more commonly attached to the carbon skeleton of an organic molecule, and involved in chemical reactions

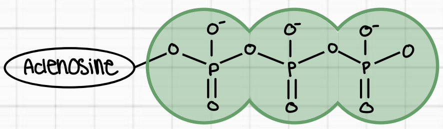
7 most important functional groups:

- hydroxyl ★★
- carbonyl ★★
- carboxyl ★★
- Amino ★★
- sulfhydryl ★
- Phosphate ★★
- methyl ★

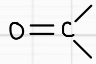
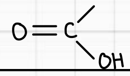
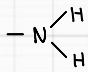
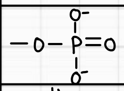
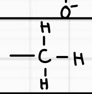
★ chemically reactive
★ hydrophilic

ATP: important source of energy for cellular process

complex organic phosphate: Adenosine triphosphate (ATP



Biologically important chemical groups

| Chemical group | Written | Drawn | Properties | Compound name |
|---|---|---|---|---|
| Hydroxyl group | ( $-OH$ / $HO-$ ) | $—OH$ | Polar electroneg O.H bonds w/ $H_2O$. help disolve compounds | Alcohol (specific names end in "-ol" |
| carbonyl group | ( $>C=O$ ) |  | sugars w/ ketone groups : ketoses. w/ aldehydes called aldoses | ketone (w/in C skeleton) aldehyde (end of C skeleton) |
| carboxyl group | ( $—COOH$ ) |  | acid (donate $H^+$) → covalent bond btw O + H is polar | carboxyl acid or organic acid |
| Amino group | ( $—NH_2$ ) |  | base (pickup $H^+$ from solution (water + living organisms) | Amine |
| Sulfhydryl group | ( $—SH$ ) | $—SH$ | 2 'SH' groups react : cross link stableize protein | Thiol |
| Phosphate group | ( $—OPO_3^{2-}$ ) |  | 1 (-) charge in chain. 2 (-) end. reacts w/ $H_2O$ : release energy | organic phosphate |
| methyl group | ( $—CH_3$ ) |  | gene expression when on DNA change shape + funct. of sex hormon | Methylated compound |

# The structure and function of large biological molecules

key concepts

- macromolecules are polymers, built from monomers (5.1)
- carbohydrates serve as fuel and building material (5.2)
- lipids are a diverse group of hydrophobic molecules (5.3)
- proteins include a diversity of structures, resulting in a wide range of functions (5.4)
- Nucleic acids store, transmit, and help express hereditary information (5.5)
- Genomics + Proteomics have transformed biological inquiry + application (5.6)

## The molecules of life

macromolecules : a giant molecule formed by joining of smaller molecules, usually by a dehydration reaction. Polysaccharides, proteins + nucleic acids are macromolecules

## concept 5.1

- carbohydrates *      * polymers
- proteins *
- nucleic acid *
- Lipids

## synthesis + Breakdown of polymers

polymers : A long molecule consisting of many similar/identical monomers linked together by covalent bonds

monomers : The subunit that serves as the building block of a polymer

enzymes: A macromolecule serving as a catalyst, a chemical agent that increases the rate of reaction w/out being consumed by the reaction. Most enzyme are proteins

dehydration reaction: a chemical reaction in which 2 molecules become covalently bonded to each other w/ the removal of a $H_2O$ molecule

hydrolysis: a chemical reaction that breaks the bonds btw 2 molecules by the addition of water; functions in disassembly of polymers to monomers

in a dehydration reaction, one monomer provides a hydroxyl group (–OH) and the other provides a hydrogen group (–H). This continues creating a polymer (polymerization)

## The diversity of polymers

polymers made of common 40-50 monomers

## concept 5.2

carbohydrates : sugars + polymers of sugars

## sugars

monosaccharides : have molecular formula of some multiple of $CH_2O$ ($C_xH_{2x}O_x$)

most common monosaccharid is $C_6H_{12}O_6$ (Glucose)

either aldehyde sugar or ketone aldehyde

Glucose is an aldose

Fructose (isomer) is a ketose

other classification for sugar is: number of carbons (3-7)

hexose: 6 carbons

Triose: 3 carbons

Pentose: 5 carbons

spacial arangement of parts around asymetrical carbon

- Glucose + Galactose

sugars used for cellular respiration. energy source, carbons, (H+O) used for building

Disaccharids: A double sugar, consisting of 2 monosaccharids joined by glycosidic linkage formed by a dehydration reaction

glycosidic linkage: A covalent bond formed btw 2 monosaccharids by a dehydration reaction

Lactose is a disaccharide

## Polysaccharids

Polysaccharids: A polymer of many monosaccharids, formed by dehydration reaction
serve as building material for structures that protect cell or whole organis

### Storage polysaccharides

both plant + animals use
Plants store starch (glucose monomers). 1-4 linkage
- simplest form is amylose (unbranched)
- Amylopectin is more complex (branched w/ 1-6 linkage)

Animals store glycogen (polymer of glucose) [like amylopectin but much more brancea
- mainly in liver + muscle cells
- usually lasts 1-2 days. low carb diets: cause weakness + fatigue

### Structural polysaccharides

cellulose: major components of cell walls
Globally plants produce ~$10^{14}$ kg of cellulose / year
- most abundant organic molecule on earth

1-4 linkage of cellulose is like starch. Diff is 2 slightly diff rings for glucose. Attached to $C^1$ either above or bellow
- starch is α configuration
- cellulose is β configuration

cellulose is straight + never branched
some hydroxyl groups are free to H bond w/ hydroxyl of other cellulose molecules
in plant cell wall, parallel cellulose grouped into units called microfibrils
we need cellulos but cant digest it. cows can. insoluble fiber is usually cellulose
chitin: carb used by arthropods (insects, spiders, taceans) to build exoskeleton. exoskeleton: chitin + protein. also found in fungi
chitin has β linkage. glucose monomer of chitin has a nitrogen-containing attachment

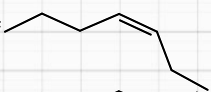
## Concept 5.3

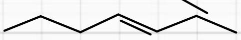
Lipids: mix poorly (if at all) w/ water
Hydrophobic based on molecular structure
mostly have hydrocarbon regions (have traits)

## Fats

not a polymer (but large molecule from small molecule by dehydration reaction
Fats: A lipid consisting of 3-fatty acids linked to 1 glycerol molecule, also called a triglyceride/triglycerol
Fatty acid: A lipit consisting of 3 fatty acids linked to 1 other molecule; also called a triacylglycero/trilyceride
- usually 16-18 C long

Triglycerol: a glycerol + 3 fatty acids
Saturated fat: single bonds
Unsaturated fats: Double bonds

cis fats:


trans fats:


most animal fat is saturated. called fats
most plant fat is unsaturated (and fish). called oils
major function of fat is energy storage

concept 5.4
~~·AA monomer~~
~~·polypeptide (AA polymers)~~
~~·proteins~~
~~structure + funct.~~
concept 5.5
~~·Role of Nucleic~~
·acid
~~·components of Nucleic acid~~
~~·Nucleotide polymer~~
~~structure of DNA~~
~~+RNA molecule~~
concept 5.6
·DNA proteins as tape measure
evolution

## Phospholipids

Phospholipid: A lipid made up of glycerol joined to 2 fatty acids and a phosphate group. The hydrocarbon chains of the fatty acids act as a nonpolar, hydrophobic tails, while the rest of the molecule acts as a polar, hydrophobic head. Phospholipids form bilayers that function as biological membranes

## Steroids

Steroids: A type of lipid characterized by a carbon skeleton consisting of 4 fused rings w/ various chemical groups attached
cholesterol: Type of steroid essential in animals
- in vertabrates, cholesterol is synthesized in the liver

concept 5.4

Proteins include diversity of structures, resulting resulting in a wide range of functions

Proteins are ~50% of dry mass of cell

Roles:

- Speed up chemical reactions
- defence
- Storage
- transport
- Cellular communication
- movement
- Structural support

Catalyst: A chemical agent that selectively increases the rate of a reaction w/out being consumed by the reaction

Human has 10,000 different proteins

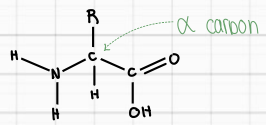
Bond between amino acid is called : peptide bond

Polypeptide: Polymer of amino acid

Protein: biologically functional molecule made up of 1+ polypeptides, each folded + coiled into a specific 3D structure

Amino Acid monomers

Amino acid: an organic molecule possesing both a carboxyl group and an amino group. amino acids serve as the monomer of polypeptides




the Pysical + Chemical properties of a side chain determine the characteristics of a particular amino acid

Grouped : nonpolar : hydrophobic

Polar : hydrophilic

electrically Charged : hydrophilic

Polypeptides

Peptide bond: the covalent bond btw the carboxyl group of 1 amino acid and the amino acid of another, formed by a dehydration reaction

Polypeptides range from a few to ~1000+

one end always has free amino group, one side free carboxyl group

Protein Structure + functions

When cells synthesise a polypeptide, the chain may fold spontaneously

Proteins may be spherical (globular proteins) or long fiber (fibrous proteins)

4 levels of protein structures

Primary structure : The level of protein structure refering to the specific linear sequence of amino acid

Secondary structure: Regions of coiling / folding of the polypeptide backbone of a protein due to hydrogen bonding between constitutes of the backbone (not side chains)

tertiary structure : The overall shape of a protein molecule due to interactions of amino acid side chains, including hydrophobic interactions, iconic bonds, hydrogen bonds, and disputable bridges

Quaternary structure: The particular shape of a complex, aggregate protein defined by the characteristic 3D arrangement of its constitutional subunits, each a polypeptide

Secondary structures have α-helixes and β sheets

hydrophobic interactions: A type of weak chemical interaction caused when molecules that do not mix w/ water coalesce to exclude water

disulfide bridges: form when 2 cystine monomers, which have sulfydryl groups (—SH) on their side chains, are brought close together by the folding of the protein. disulfide bridge (—S—S—) rivets part of protein together.

What determines protein structure?

denaturation: in proteins, a process in which a protein loses its native shape due to disruption of weak chem bonds + interactions, thereby becoming bio inactive, in DNA, the separation of the 2 strands of the double helix. denaturation occurs under extreme conditions (PH, salt, temp)

concept 5.5

nucleic acid store, transmit, and help express hereditary info

gene: A discrete unit of hereditary information consisting of a specific nucleotide sequence in DNA (or RNA in some viruses)

nucleic acid: A polymer (polynucleotide) consisting of many nucleotide monomers; serves as a blueprint for proteins and, through the actions of proteins, for all cellular activities. The two types of DNA + RNA

## The Role of nucleic acid

2 types: Deoxyribonucleic acid (DNA)
ribonucleic acid (DNA)

Gene expression: The process by which information encoded in DNA directs the synthesis of proteins (or in some cases RNA) that are not translated into proteins and instead functions as RNAs

each chromosome contains 1 long DNA molecule (carrying 100+ genes)

Each gene along a DNA molecule directs synthesis of a type of RNA called messenger RNA (mRNA). The mRNA molecule interacts w/ the cells protein-synthesizing macheinery to direct production of a polypeptide (which folds into all/part of a protein

DNA Resides in the nucleus

## The components of nucleic acids

nucleic acids are macromolecules that exists as polymers called polynucleotides. each polynucleotide consists of nucleotides.

nucleotide composed of 3 parts: nitrogenous Base (nitrogen base), a 5-carbon sugar (pentose), and 1 or more phosphate group

portion of a nucleotide w/out a phosphate group: nucleoside

each nitrogenous base has 1-2 rings that include nitrogen atoms.
called nitrogenous bases because nitrogen atoms tend to take up $H^+$ from solution

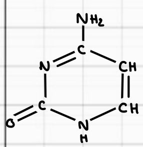
2 families of nitrogenous bases: pyrimidines and purines

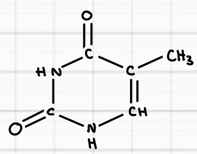
Pyrimidines: one of 2 types of nitrogenous bases found in nucleotides, characterized by a 6-membraned ring. cytosine, thymine, and uracil

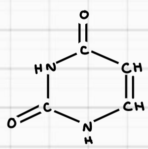
Purine: one of 2 types of nitrogenous bases found in nucleotiats, characterized by a 6-membrane attached to a 5-membrane ring
Adenine and guanine

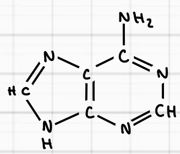
the sugar in DNA is Deoxyribose. in RNA is Ribose. DNA (lacks oxygen atom on the 2nd carbon ring

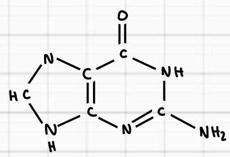
attach phosphate group to the 5' carbon


Cytosine (C)


Thymine (T)


Uracil (U)


Adenine (A)


Guanine (G)

## Nucleotide polymers

linkage of nucleotides into polynucleotide involves a dehydration reaction

sugar-phosphate backbone. Nitrogenous bases are not part of the backbone

Phosphate group attached to 5'-C end and hydroxyl group on 3'-C end

sequence of bases along DNA unique

## Structure of DNA + RNA molecules

DNA molecules have 2 polynucleotides (strands) forming a double helix

The two sugar-phosphate backbones run in opposite directions (antiparallel)

Sugar phosphate backbone is on outside of double helix

2 strands held together by hydrogen bonds

2 strands are complementary

base pairs w/in RNA allow it to take on 3D shape needed for its function: ex) tRNA (transfer RNA)

RNA C—G, A—U

DNA: C—G, A—T

RNA: usually single strand, probably preceded DNA as carrier of genetic info in early forms of life

concept 5.6

Genomics and proteomics have transformed biological inquiry and application

first techniques for DNA sequencing developed in the 1970's

Human genome project:

- 1980-2000s
- Rapid developement/less expensive methods of sequencing
  - cost of sequencing 1M base pairs: 2001 $5000

    2016: $0.02

bioinformatics: the use of computers, software, and mathmatic models to process and integrate biological info from large data sets

Geonomics: The study of whole sets of genes and their interactions w/in a species, as well as geneome comparisons btw species

Proteomics: The systematic study of the full protein sets (proteomes) encoded by genomes