2.3 - Carbon Compounds
Carbon

- has **4 valence electrons** which can bond *covalently* with other atoms
- can bond with other carbon atoms to form long chains
- can form single, double, or triple bonds...
- ...can form a great variety of **giant and complex molecules**
The Chemistry of Carbon
Elements of Life

- 96% of living organisms is made of:
  - carbon (C)
  - oxygen (O)
  - hydrogen (H)
  - nitrogen (N)
Molecules of Life

- Put C, H, O, N together in different ways to build living organisms
- What are bodies made of
  - carbohydrates
  - proteins
  - fats (lipids)
  - nucleic acids
How do we make these molecules?

We build them!
Building large molecules of life

- Chain together smaller molecules called **monomers** *(mono = one, meris = part)*

  ![Monomer structures](image1)

  ![Polymer structures](image2)

  to make bigger molecules called **polymers**
- Small molecules = **building blocks**

- Bond them together = **polymers**
Building important polymers

Carbohydrates = built from sugars

Proteins = built from amino acids
amino acid – amino acid – amino acid – amino acid – amino acid – amino acid

Nucleic acids (DNA) = built from nucleotides
nucleotide – nucleotide – nucleotide – nucleotide – nucleotide
Carbohydrates
Low-Carb vs. Low-Fat
- General formula: $C_n(H_2O)_n$
- Building block molecules = sugars

sugar - sugar - sugar - sugar - sugar - sugar

sugar  sugar  sugar  sugar  sugar  sugar  sugar  sugar  sugar
Building carbohydrates

1 sugar = monosaccharide

2 sugars = disaccharide

- **Glucose**
- **Glucose**
- **Maltose**

**Mono = one**
**Saccharide = sugar**
**Di = two**
1 sugar = monosaccharide

- glucose
- fructose

2 sugars = disaccharide

- sucrose (table sugar)

How sweet it is!
BIG carbohydrates

Polysaccharides

- **Starch** (energy storage in plants)
- **Glycogen** (energy storage in liver and muscles of animals)
- **Cellulose** (structure in plants, cell walls)
- **Chitin** (structure in arthropods and fungi)
Building BIG carbohydrates

glucose + glucose + glucose... = polysaccharide

starch (plant)

energy storage

glycogen (animal)
Polysaccharides

- cost energy to build
- So why build them?
- use as energy reserves (starch in plants, glycogen in animals)

vs.
Cellulose

- Most abundant organic compound on Earth (~100 billion tons/year)
- makes up cell wall in plants, wood, paper...
- Herbivores have evolved a mechanism to digest cellulose. Most carnivores cannot.
Helpful bacteria

- How can cows digest cellulose so well?
- **Bacteria** live in their stomachs and help digest cellulose-rich (grass) meals
Benefits of Cellulose

- Cellulose/fiber stays undigested and keeps material moving in your intestines
- So eat your fiber or else....

or

Dulcolax
LAXATIVE TABLETS
(bisacodyl USP 5mg)

Gentle, predictable overnight relief

Regents Biology
Lipids
Lipids

- are hydrocarbons (made from carbon and hydrogen atoms)
- Include
  - Fats
  - oils
  - waxes
  - hormones (sex hormones)
- **energy storage**
  very concentrated
  twice the energy as carbohydrates!
- **cell membrane**
- **insulates body**
- **cushions organs**
... as cushion

Thank god there's a fat guy to cushion my fall...
Structure of Fat

NOT a chain of monomers (polymer) = just a “big fat molecule”

(b) Fat molecule
- contains a glycerol molecule and 3 fatty acid tails

Regents Biology
**Saturated fats**

- Fatty acid tails contain only **single** C-C bonds
- “saturated” means maximum amount of H’s
- are **solid** at room temperature
- should limit the amount of saturated fat in your diet since it contributes to heart disease, deposits in arteries, etc.
Unsaturated fats

- Fatty acid tails contain at least one C-C double bond (monounsaturated) or multiple double bonds (polyunsaturated)
- are liquid at room temp. since fatty tails don’t stack tightly together
- include plant, vegetable and fish fats
- are healthier choices in your diet
Saturated vs. Unsaturated
Hydrogenated Oil

Hydrogenation of Oleic Acid

\[ \text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{C}-\text{OH} + \text{H}_2 \rightarrow \text{CH}_3(\text{CH}_2)_7\text{CH}_2\text{C}-(\text{CH}_2)_7\text{C}-\text{OH} \]

Oleic Acid - Unsaturated

Stearic Acid - Saturated

(a) Saturated fat and fatty acid

C. Ophardt, c. 2003
**Twinkies**

**Ingredients:** Enriched bleached wheat flour [flour, ferrous sulfate, “B” vitamins (niacin, thiamine mononitrate (B1), riboflavin (B2), folic acid)], sugar, corn syrup, water, high fructose corn syrup, partially hydrogenated vegetable shortening (contains one or more of: soybean, canola or palm oil), dextrose, whole eggs. Contains 2% or less of: modified corn starch, cellulose gum, whey, leavenings (sodium acid pyrophosphate, baking soda, monocalcium phosphate), salt, cornstarch, corn flour, corn dextrins, mono and diglycerides, polysorbate 60, soy lecithin, natural and artificial flavors, soy protein isolate, sodium stearoyl lactylate, sodium and calcium caseinate, calcium sulfate, sorbic acid (to retain freshness), color added (yellow 5, red 40). May contain peanuts or traces of peanuts.
1. Don't eat anything your great grandmother wouldn't recognize as food. "When you pick up that box of portable yogurt tubes, or eat something with 15 ingredients you can't pronounce, ask yourself, "What are those things doing there?" Pollan says.

2. Don't eat anything with more than five ingredients, or ingredients you can't pronounce.

3. Stay out of the middle of the supermarket; shop on the perimeter of the store. Real food tends to be on the outer edge of the store near the loading docks, where it can be replaced with fresh foods when it goes bad.

4. Don't eat anything that won't eventually rot. "There are exceptions -- honey -- but as a rule, things like Twinkies that never go bad aren't food," Pollan says.
Yum, yum, yum... and hydrogenated fat!
Trans Fat

Linoleic Acid

All Cis

Trans, Cis

All trans

C. Ophardt, c. 2003
California Bans Trans Fat
Other lipids in biology

- Cell membranes are made out of lipids
- forms a barrier between the cell and the outside
Proteins
Proteins

- muscle
- skin, hair, fingernails, claws
- **Pepsin** (digestive enzyme in stomach)
- **Insulin** (hormone that controls blood sugar levels)
**Functions**

- many, many functions
- **enzymes**
  - help to speed up chemical reactions
    
  *Ex: protease in detergents*
- **hormones**
  - signals from one body system to another (insulin)
- **movement**
  - muscle
- **immune system**
  - protect against germs
Building block = **amino acids**

There’s 20 of us... like 20 different letters in an alphabet! Can make lots of different words.

---

**amino acid – amino acid – amino acid – amino acid – amino acid**
Amino acids

- **Structure**
  - central carbon
  - **amino group**
  - **carboxyl group** (acid)
  - **R group** (side chain)
    - variable group
    - different for each amino acid
    - confers unique chemical properties to each amino acid (like 20 different letters of the alphabet)

![Amino acid structure](image)

Oh, I get it!

*amino = NH₂*

*acid = COOH*
Effect of different R groups:

Nonpolar amino acids

- nonpolar and hydrophobic

Why are these nonpolar and hydrophobic?
Effect of different R groups: Polar amino acids

- polar or charged and hydrophilic

<table>
<thead>
<tr>
<th>Polar</th>
<th>Acidic</th>
<th>Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serine (Ser)</td>
<td>Aspartic acid (Asp)</td>
<td>Lysine (Lys)</td>
</tr>
<tr>
<td>Threonine (Thr)</td>
<td>Glutamic acid (Glu)</td>
<td>Arginine (Arg)</td>
</tr>
<tr>
<td>Cysteine (Cys)</td>
<td></td>
<td>Histidine (His)</td>
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<td>Tyrosine (Tyr)</td>
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</tr>
<tr>
<td>Asparagine (Asn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glutamine (Gln)</td>
<td></td>
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</tr>
</tbody>
</table>

Why are these polar and hydrophilic?
Amino acid chains

- **Proteins** = **amino acids** chained into a **polymer**

- Each amino acid is different
  - some “like” water and dissolve in it
  - some “fear” water and separate from it
For Proteins: SHAPE matters!

- Proteins fold and twist into 3-D shape
- Different shapes = different jobs

growth hormone

pepsin

hemoglobin
It’s SHAPE that matters!

- Proteins’ SHAPE determines their JOB

- Unfolding – denaturing – a protein destroys its shape, often prevents it from doing its job

- Protein denaturation can occur due to changes in:
  - temperature
  - pH (acidity)
Any Questions?

Penguins gone bad!