Introduction to Biochemistry for Middle School

Presented by Nancy Sergi-Gott and Alison Gott
SET School of Metrowest in partnership with TEC School

Four Major Groups of Biochemicals

- Proteins – made up of amino acids
- Lipids - made of fatty acids
- Carbohydrates -made of sugars
- Nucleic acids -made of phosphate-sugar groups joined to nitrogenous bases.

Assumptions

- Living things are made of cells.
- The body is made of systems.
- The systems are made of organs.
- Cells in the organs have special functions.

A Cell is Like a City

A city has :	A cell has:
Factories	Ribosomes
Energy plants	Mitochondria
Roads	ER and microtubules
Clean up crews	Enzymes
Police	Protein gates
Truck drivers	Motor proteins
City Hall	Nucleus
Borders	Cell membrane

Overview lesson

- What is biochemistry?

Prefix “bio” means “life”, so biochemistry is the chemistry of living things.

- While “living” is a function of major organ systems, it ultimately comes down to a series of chemical reactions in our cells.

The exquisite dance of chemicals

- Breathing: the absorption of oxygen by hemoglobin
- Digestion: the release of enzymes to break down food
- Growth: the duplication of cell parts prior to division
- Thinking: the release of acetylcholine across a synapse

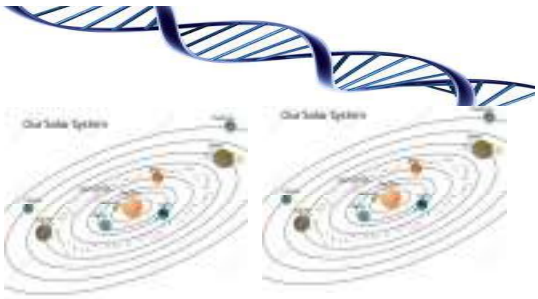
Water is crucial to life

- All chemical reactions in the body take place in water.
- 60-65% of the human body is water.
- The watery environment in our cells is a busy place!

The four major biochemicals

- Hundreds of thousands of biochemicals
- Proteins are the largest group and make up 20%.
- Lipids or fats make up about 15%
- Carbohydrates make up 5%
- DNA from one cell stretches 2 meters or 6 feet!

The DNA of one person would stretch across two solar systems!



Lesson 1 Proteins

Proteins have a wide variety of functions in the body.

For example, they make up the enzymes that help digest our food, and are in hormones that regulate body functions like temperature and growth, and are in antibodies that help protect us from infections.

Proteins: seven major types

1. Contractile proteins – make up muscle fibers (actin, myosin)
2. Antibodies – search out foreign invaders like bacteria and viruses (immunoglobulins)
3. Enzymes – speed up chemical reactions such as digestion (lactase) and DNA repair (polymerase)
4. Hormones - regulate and coordinate body activities like sugar metabolism (insulin)
5. Structural - provide support especially for tendons,ligaments and skin (keratin, collegen, elastin)
6. Storage proteins - store amino acids for later protein synthesis (ovalbumin, casein)
7. Transport proteins - move molecules inside body and in cells (hemoglobin)

More about proteins

Proteins are very large molecules.

They are made up of other smaller molecules called amino acids.

Out of the hundreds of amino acids, only 20 are important in protein synthesis.

Protein synthesis is done at the ribosome, an organelle that is found all throughout the cell.

DNA controls which proteins get made.

Protein synthesis

- The word synthesis comes originally from Greek and simply means “together-putting”.
- The term is used in chemistry to mean creating a compound from simpler chemicals.
- In this case, amino acids are joined together one after the other, like beads on a string, until a much bigger molecule is created.

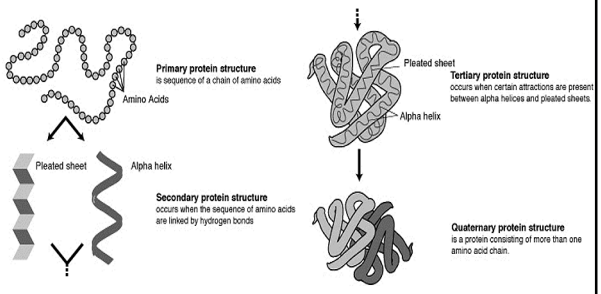
Chart of amino acids

The 20 amino acids

Abbreviation	Amino acid	Abbreviation	Amino acid
Ala	Alanine	Leu	Leucine
Arg	Arginine	Lys	Lysine
Asp	Aspartic acid	Met	Methionine
Asn	Asparagine	Phe	Phenylalanine
Cys	Cysteine	Pro	Proline
Gln	Glutamine	Ser	Serine
Glu	Glutamic acid	Thr	Threonine
Gly	Glycine	Trp	Tryptophan
His	Histidine	Tyr	Tyrosine
Ile	Isoleucine	Val	Valine

Most are synthesized in the cell, but eight of them (phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine) are not made in the cell and must come from the food we eat.

Protein Structure



Demonstration: Protein Structures

- Make a long strip of paper and color it in sections. The colors represent the individual amino acids in the primary sequence
- Stretch it out, then twist it and pleat it (secondary structure).
- Bunch it up into a ball shape (tertiary shape).
- Add another bunch (quaternary structure)

Make a Protein Activity

Students can work in pairs or alone.

Each gets a bowl of beads, a pipe-cleaner, and a chart of amino acids.

They choose 10-15 beads that they like and put them on the chart, the bead will represent that amino acid in the chain.

Choose distinct beads, no two should be the same.

Protein Set-up

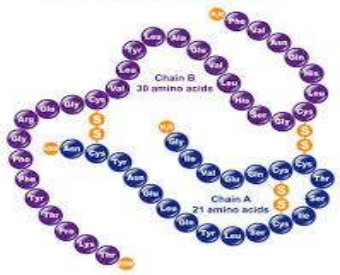
Write down the sequence first, then thread the beads one by one. This is the primary sequence

Coil it around a pencil.
This is the secondary structure

Fold it back and squish it gently into a loose ball. This is the tertiary shape

As an extension they can research a protein and then try to make it.

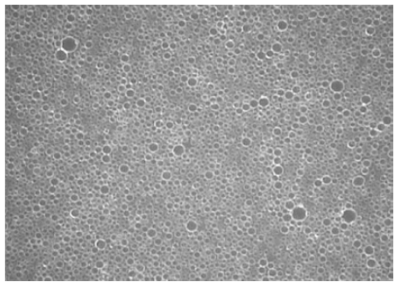
Human Insulin



Lesson 2 Lipids

- Lipids are known by their common names, fats and oils. Examples are butter, olive oil and lard.
- Lipids also occur as waxes, steroids, cholesterol and some types of vitamins.
- Lipids are not soluble in water.

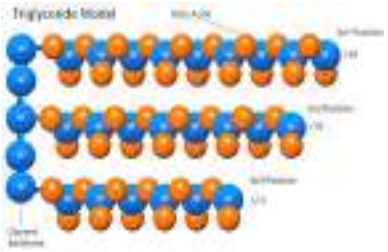
This is milk at 800X magnification.
The dark circles are tiny droplets of fat, the white edges are the protein molecules of casein



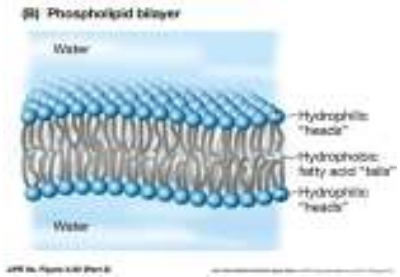
Uses of lipids in the body

- Energy storage – fat stored in the liver and adipose or fatty tissue is converted to energy as needed.
- Signaling – steroids and hormones control body functions, like growth.
- Cell membranes - fat is the main component in the form of phospholipids.
- Protection – fats insulate and form a protective layer over neurons and internal organs.

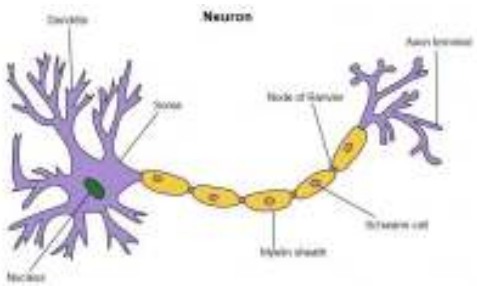
The main component of lipids are fatty acids. They occur most commonly in the form of triglycerides.



Cell membranes are mainly composed of phospholipids. Each has a hydrophilic phosphate "head" and two hydrophobic fatty acid "tails".



Fats are part of the myelin sheath that insulates the long axons of nerves and helps them transmit impulses better.



Activity: Making Butter

Students smash fat droplets together until they form butter

Pour a cup of heavy cream into a 2 cup plastic jar. Add a metal marble and secure the lid tightly.

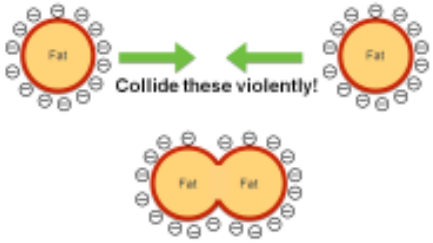
Shake the jar vigorously for several minutes.

When jar is full of white stuff and the marble banging sound is muffled, stop to check. The jar should be full of whipped cream.

Return to shaking and very soon a thick yellow substance and a watery fluid appears.

What happened?

The fats globules in the cream were forced together into larger ones until they separated from the watery part.



What are carbohydrates?

They are made of sugars called saccharides, from the Greek word for sugar.

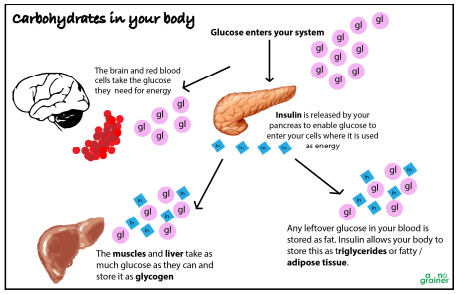
- Monosaccharide – glucose, galactose and fructose
- Disaccharide – sucrose (table sugar) and lactose (milk sugar)
- Ogliosaccharides - raffinose, stachose
- Polysaccharides – starch, cellulose

Lesson 3 Carbohydrates

Uses of carbohydrates

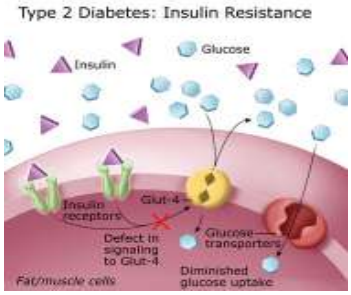
- Energy production – glucose and oxygen are metabolized to make energy in the cell
- Energy storage – glycogen in animals and starch in plants are used to store extra glucose
- Ribose production – glucose is converted to ribose which is needed to make DNA and RNA
- Cell signaling – Carbohydrates in the cell membrane help cells recognize each other and stick together.

Carbohydrates get broken down into simple sugars during digestion.



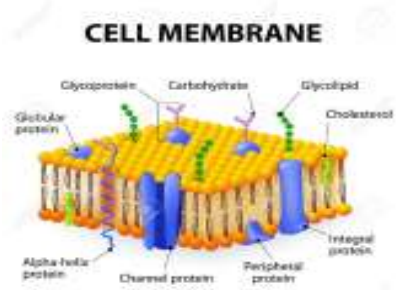
Glucose and insulin:

Glucose is used by the cell for energy, but it cannot enter the cell without insulin.



Glycoproteins and glycolipids:

In the cell membrane they help cells recognize each other and stick together.

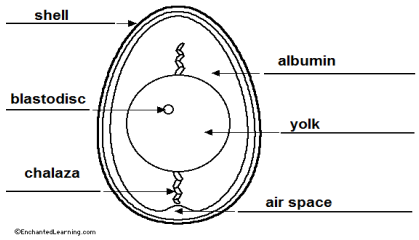


Glycoproteins line the digestive and respiratory tract in the form of mucus

Activity: Pulling it all together with an egg

- An egg has protein, carbohydrates, lipids and water, everything a growing embryo needs.
- Students work in groups. Each group gets two bowls and an egg.
- The egg is carefully cracked so as to not break the yolk.
- Students must not touch the egg, but observe it first.

Inside an egg



Now touch it!

- First separate the yolk from the white into separate bowls.
- Touch the egg white. Notice how slimy it is. There are glycoproteins in the albumin.
- Next break open the yolk. It is gooey and sticky. It contains the fats and carbohydrates.

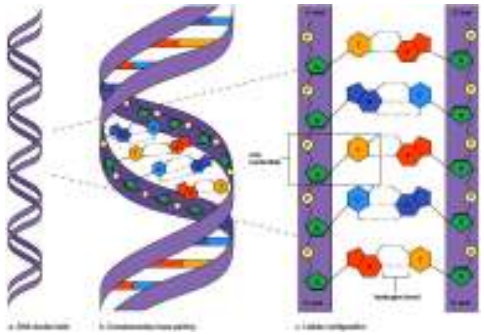
Lesson 4 Nucleic Acids

- There are three main nucleic acids:
- DNA – Deoxyribonucleic Acid: a very long double stranded molecule in a double helix shape.
- mRNA – messenger Ribonucleic Acid: a short segment of nucleotides that matches a section of DNA.
- tRNA – transfer Ribonucleic Acid: A short segment of nucleotides that matches amino acids to mRNA during protein synthesis.

Nucleotides

- Complex molecules made up of three parts: a phosphate, a 5-carbon sugar (ribose), and a nitrogenous base.
- The bases always match up in ordered pairs:
  - Adenine always pairs with Thymine (A-T)
  - Cytosine always pairs with Guanine (C-G)
  - The base Uracil replaces Thymine in RNA

DNA: a giant nucleotide polymer



Difference between DNA and RNA

There are 3 differences between DNA and RNA:

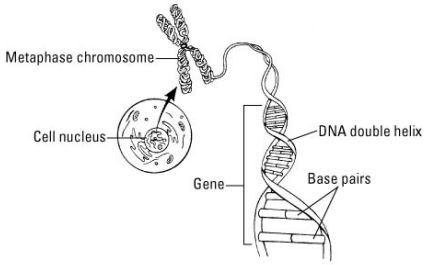
- DNA is double stranded; RNA is singe stranded.
- DNA has the base pairs adenine, thymine, cytosine and guanine; RNA has no thymine, it has uracil instead.
- RNA has a simple ribose sugar; DNA has the deoxygenated form, deoxyribose.

Both have the helical shape formed from the phosphate-ribose complex

Chromosomes and genes

- DNA is found in the nucleus of cells and is organized as pairs of chromosomes.
- Humans have 23 pairs of chromosomes, and about 20,000-25,000 genes.
- A gene is a sequence in the DNA molecule which codes for a certain protein.
- Genes are responsible for our physical traits, such as eye color, height, number of fingers, blood type, etc.

A gene is a section of DNA on a chromosome



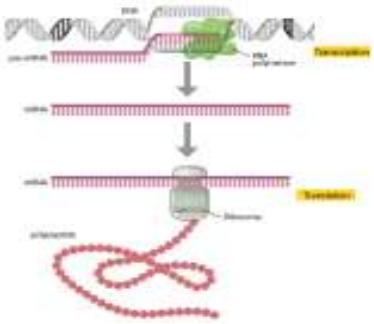
Transcription of a gene

- An enzyme opens double strands of the DNA in the proper region, unlocking the sequence of base pairs.
- With the help of other enzymes, matching nucleotides are joined together to make a copy the sequence, forming a single strand molecule of messenger RNA.

Translation of the gene

- The messenger RNA leaves the nucleus and goes into the cytoplasm.
- The message gets read at a ribosome. The message gives exact instructions on how to make a certain protein.
- Transfer RNA match amino acids to the sequence of messenger RNA, building the protein strand.

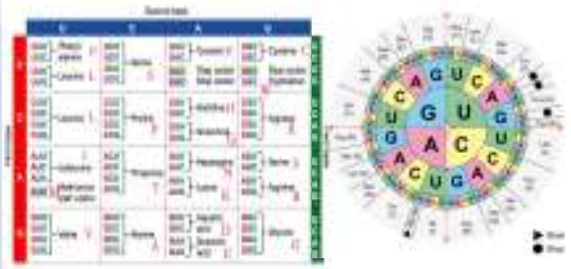
DNA->mRNA->tRNA->Protein



Codons

- The genetic code is written in series of three bases, called codons.
- Each codon codes for a specific amino acid.
- There are 64 different codons, but only 20 amino acids, so that tells you that there is more than one codon for some amino acids.

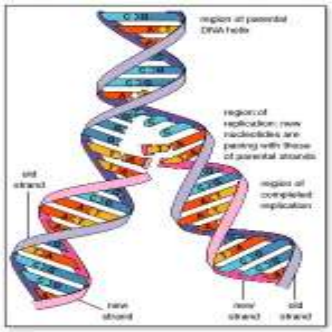
To figure out which codon matches which amino acid students can use a table or wheel chart



DNA Replication

- Prior to cell division, the cell makes a copy of all the chromosomes first.
- The two strands of the DNA separate and make a copy, each nucleotide to its partner.
- Created are two new double strands of DNA, one strand is the original and the other the copy.

Replication



Mutation

- Sometimes a mistake happens during replication, mitosis or meiosis.
- Special enzymes look for mistakes and fix them, but occasionally they miss one.
- New species arise from beneficial mutations passed on to offspring.

Activity 1: Replication, transcription and translation practice

- Students use their knowledge of complimentary base pairs to match the base pairs Cytosine-Guanine and Adenine-Thymine to fill in the second strand of DNA.
- Use the first strand to create a strand of mRNA. Remember to replace Thymine with Urasil.
- Use the codon chart to match the amino acids.

Activity 2: Paper DNA Model

- Decide as a class which four colors of construction paper will represent the base pairs in the model.
- Get DNA backbone sheets, at least 2 each. The backbone goes one way on one side and the opposite way on the other. Match the sheets by the number on the bottom, "5" to "5" and "3" to "3", they will have have the backbone oriented correctly.
- Cut the sheets along the dotted line and tape the backbone sheets together (5' to 5', 3' to 3').
- Pass out strips of colored construction paper. On board, show how they match up: for example yellow A with blue T, green G with red C.
- Staple or tape the base strips to backbone after matching the colors. Connect bases with tape. For a more authentic model, don't have the bases actually touch, leave a small gap to represent the hydrogen bonding between the bases.
- Tape them all together and make a long molecule, give it a twist and hang it from the ceiling.