Chemistry of Life

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Target Grade: 10th Grade Biology

Time Required: 75 minutes

Standards

Next Generation Science Standards (NGSS):

- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

Lesson Objectives

Students will be able to:

- Describe the properties of the monomers and the type of bonds that connect the monomers in biological molecules.
- Model the processes of hydrolysis and dehydration synthesis of specific macromolecules (proteins, carbohydrates, lipids, and nucleic acids).

Central Focus

For this lesson, students will investigate monomers and the bonds they make in different biological processes. Two investigations will be done: one using a saltine cracker to explain dehydration and the other using a sponge to explain hydrolysis. Next, students will collaborate together to create a model that explains the dehydration synthesis and hydrolysis of a macromolecule. They will present their models to the class and conclude with an exit ticket on what they learned.

Key terms: biology, chemistry, chemical, makerspace, amino acid, peptide, nucleotide, monosaccharide, polymer, molecule, protein, carbohydrate, lipid, nucleic acid

Background Information

Students should have a basic understanding of the structures and functions of carbohydrates, lipids, proteins, and nucleic acids.

- **Carbohydrates** represented by the formula $(CH_2O)_n$, where n is the number of carbons in the molecule. In other words, the ratio of carbon to hydrogen to oxygen is 1:2:1 in carbohydrate molecules. This formula also explains the origin of the term "carbohydrate": the components are carbon ("carbo") and the components of water (hence, "hydrate"). Carbohydrates are classified into three subtypes: monosaccharides, disaccharides, and polysaccharides. Figure 1 identifies the general structure of each subtype.

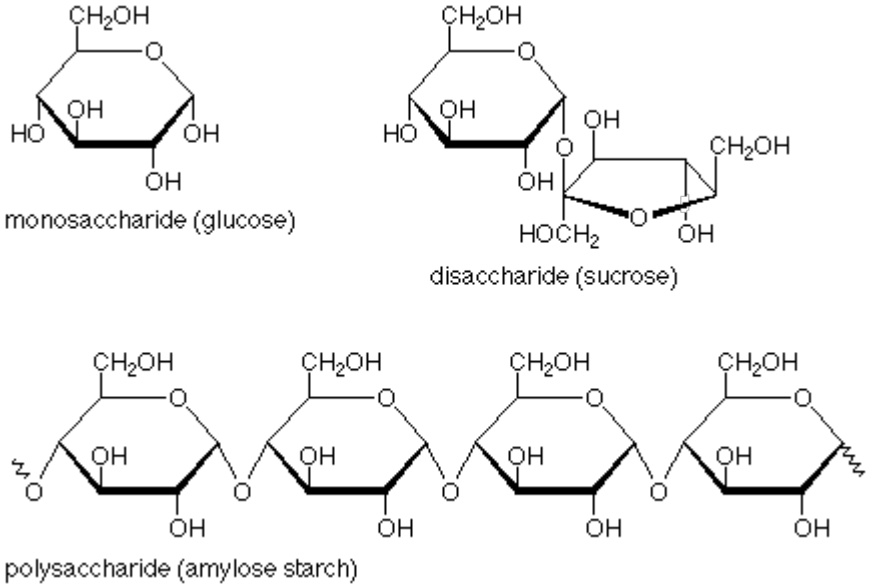


Figure 1: https://www.edinformatics.com/math_science/what_are_polysaccharides.htm

Reference Source for Carbohydrates: https://courses.lumenlearning.com/wm-biology1/chapter/reading-types-of-carbohydrates/

- **Lipids** are a diverse group of molecules that all share the characteristic that at least a portion of them is hydrophobic. An example structure of a lipid is shown in figure 2.

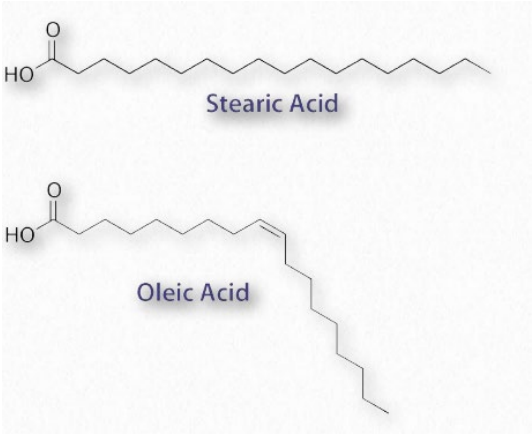


Figure 2: https://bio.libretexts.org/Bookshelves/Biochemistry/Book%3A_Biochemistry_Free_For_All_(Ahern_Rajagopal_and_Tan)/02%3A_Structure_and_Function/2.08%3A_Structure_and_Function_-_Lipids_and_Membranes

- A **protein** molecule is very large compared to molecules of sugar or salt and consists of many amino acids joined together to form long chains, similar to beads that are arranged on a string. Proteins are synthesized from DNA in a series of steps involving organelles including the nucleus, ribosome, rough endoplasmic reticulum, and golgi apparatus. The general structure of a protein is shown in figure 3.

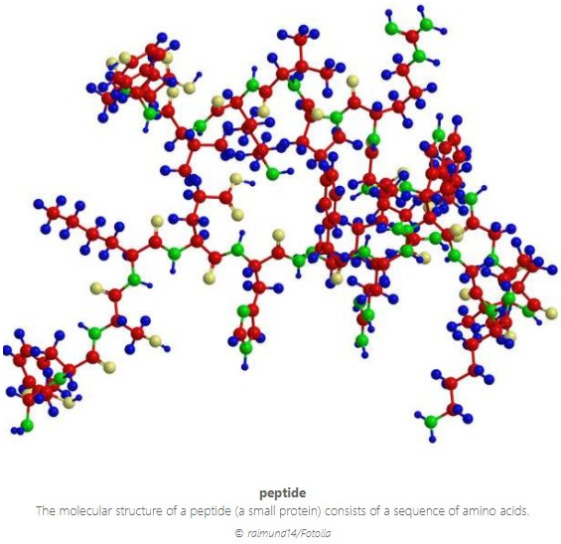


Figure 3: https://www.britannica.com/science/protein

- **Nucleic acids** are naturally occurring chemical compounds that are capable of being broken down to yield phosphoric acid, sugars, and a mixture of organic bases (purines and pyrimidines). Nucleic acids are the main information-carrying molecules of the cell, and, by directing the process of protein synthesis, they determine the inherited characteristics of every living thing. The general photo of nucleic acids are shown in figure 4.

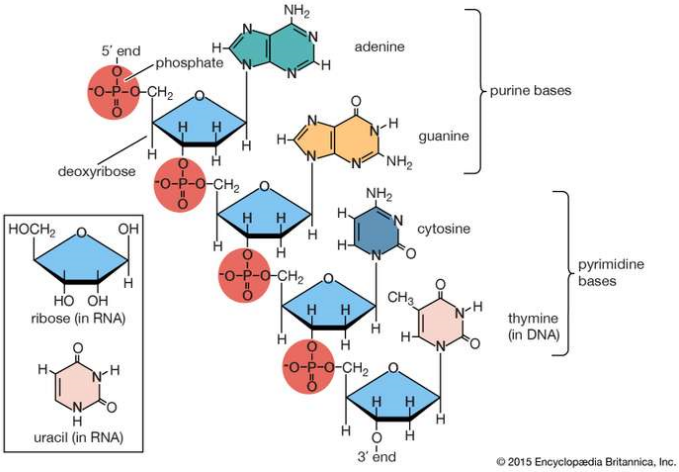


Figure 4: https://www.britannica.com/science/nucleic-acid

Students will need to understand that a polymer is a term for many monomers, and be familiar with prefixes such as mono, di, and tri.

Materials

- Saltine crackers with no salt
- Notebook
- Chemistry of Life PowerPoint
- Sponge
- Water
- Bucket
- Various makerspace supplies
    - Pipe cleaners
    - Cardboard
    - Tape
    - Chalk markers
    - Construction paper
    - Glue
    - Foam pieces
    - Balloons
    - String
    - Markers
    - Tooth picks
    - Staples

Instruction

Introduction (10 min):

Note: All discussion questions, demonstration and model instructions are shown in the Chemistry of Life PowerPoint.

- In a notebook, have the students answer the following questions:
    - What do you think happens to the food you eat?
    - How do we use macromolecules?
- Have students discuss their responses with a partner.
- Once finished, conduct a class wide discussion over the student's responses.
- Students will often say "digest" or "use for energy" as their answers. Build on these known understandings with questions like the following:
    - Why would we need to digest it?
    - What is the point of breaking things that we eat into smaller pieces?

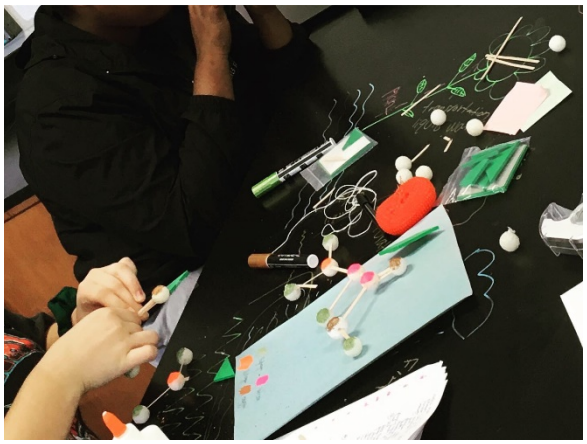
Explanation (20 min):

- Using the Chemistry of Life PowerPoint, introduce the students to hydrolysis.
- To demonstrate hydrolysis, have students perform the cracker demonstration.
- Cracker demonstration:
    - Have students place and hold a cracker in their month.
    - After it begins to feel soggy, ask them to record observations in their notes.
- Once students have recorded their observations, lead a class wide discussion using the following questions:
    - Did it begin to change taste?
    - Did it become sweeter? Why might that be?

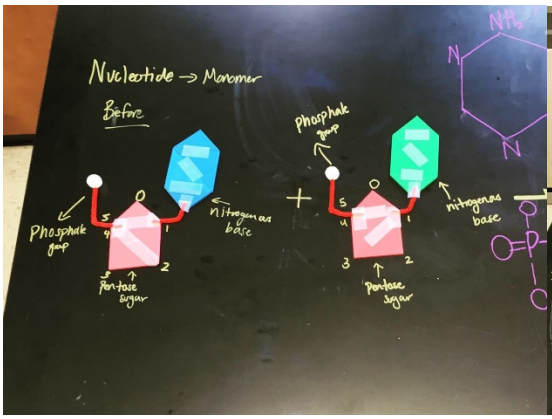
  - What process might be occurring?
- Using the PowerPoint, introduce dehydration synthesis.
- To demonstrate dehydration synthesis, have students preform the sponge demonstration.
- Sponge demonstration:
  - Have two student volunteers get a wet sponge.
  - One student holds the sponge in their right hand and the other holds it in their left.
  - Each student represents a monomer.
  - Have the students hold hands tightly using their sponge hands.
  - Water should flow from the sponges into a bucket bellow.
- Discuss with the students the following questions:
  - What did this demonstrate?
  - What did the water in the sponge demonstrate?
  - What molecule have we created through this bond?
- Next, continue with the PowerPoint to explain synthesis reactions of different macromolecules.

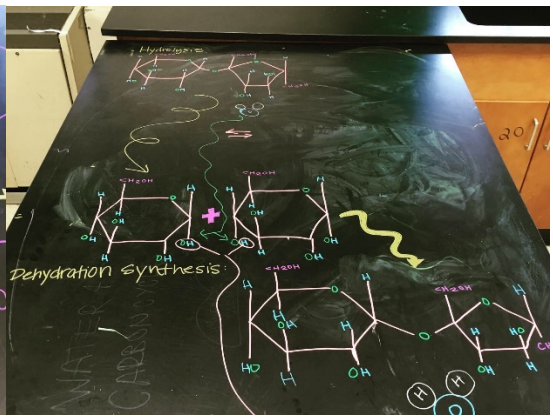
Investigation (35 min):

- Place students into groups of 2 or 3 and assign a macromolecule to model.
- Using the various supplies materials, have students create a model that explains the dehydration synthesis and hydrolysis of a macromolecule.
  - They must have a physical component that other students can manipulate.
  - They should be reversible (show both processes) and not be a static representation.



- Each group will present their model to the class and explain the representation of the two processes.
- Encourage students to ask questions about each model.





Closure (10 min):

- Lead a class wide discussion reflecting on the activity.
- Ask the following questions:
  - What did you notice? Wonder? Learn?
  - How did creating/interacting with the models help you?
- As an exit ticket, have the students respond to the following on a sheet of paper:
  - Three things you learned about today
  - Two things you found interesting or important
  - One thing you need help with, did not understand, or still have a question about

Differentiation

- Groups should have at least one member who has the ability to read the questions clearly to others – this will help those with reading difficulties understand what is being asked.
- Teacher can take a pad around to groups and create illustrations for questions to help visual learners, students with special needs, and ELLs further understand a concept.
- Google translate and speech to text is available online and may be utilized for ELL or special needs students.

Assessment

Formative assessment:

- All discussions, responses to questions during the presentation, and lab notes can be used as a quick assessment of learning and understanding.
- The exit ticket serves to gauge current student understanding to help direct lesson review.

Summative assessment:

- Students are assessed on their group models the rubric below. While the depth of knowledge is developing, the focus of this rubric is communication and creativity.

Element	Not Evident (0)	Emerging (1)	Proficient (2)
Accurate representation of macromolecules and monomers	Representation of macromolecules contains many errors and is simplistic. When bonded together molecule contains many errors or is too simplistic.	Representation contains two monomers that are mostly physically accurate. When bonded together show mostly correct organization.	Representation contains two monomers that are physically accurate and, when bonded together, show correct organization.
Creativity of Design	Model is a static picture that does not show steps either through 2D or 3D rendering of the processes.	Model uses only 2D or 3D elements to explain processes. Model mostly resembles the physical structure of the molecules and can be used to step through the processes.	Model uses both 2D and 3D elements to explain processes. Model resembles the physical structure of the molecules and can be used to recreate the processes through physical manipulation.
Communication of Model	Students' explanations are limited to superficial understanding. The model does not help to explain the processes.	Students are able to articulate processes, but some details may be missing or inaccurate. Students do not use the model to support their explanation.	Students are able to articulate the processes to their peers, using the model to support their explanations.
Collaboration and Group Work	Group did not work cohesively towards a mutual goal.	One or two students did not meaningfully contribute to the final model goals.	All students participated in the execution of the model and presentation in a meaningful way.
Peer Review	Student was disengaged from the review and presentation processes.	Student paid attention, but had limited or no engagement with the presentations and peers.	Student was engaged, offering one or two questions or comments during the review session.

Chemistry of Life

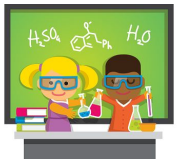
Macromolecule Bonds

PREP NOTES

Materials:

- Saltine crackers (no salt) ideally enough for each student in class
- Sponge
- Water
- Bucket
- Various Modeling Supplies (enough for groups of 2-3)
    - Pipe cleaners, foam pieces, cardboard
    - Balloons, tape, string
    - Chalk markers, markers
    - Construction paper, tooth picks
    - Glue, hot glue, staples, brads
    - Anything else you have on hand!

CATALYST:



- What do you think happens to the food you eat?
- How do we use macromolecules?

Objectives and Standards

1. Describe the properties of the monomers (nucleotides) and how those properties affect the structure of macromolecules (nucleic acids).

2. Describe the properties of the monomers and the type of bonds that connect the monomers in biological molecules.

EK: Living systems are organized in a hierarchy of structural levels that interact.

EK: The properties of chemical units determine the structure and function of parts of living systems.

Creating and Using Macromolecules

- **What do you think happens to the food you eat?**
- **How do we use macromolecules?**

Creating and Using Macromolecules

When you eat, there are a series of chemical reactions that occur that break down complex macromolecules into their monomer parts.

From there we reuse those monomers to create the stuff we actually need.

Creating and Using Macromolecules

Catabolism

- **Breaking down complex molecules to form simpler ones**
- **Results in a release of energy**

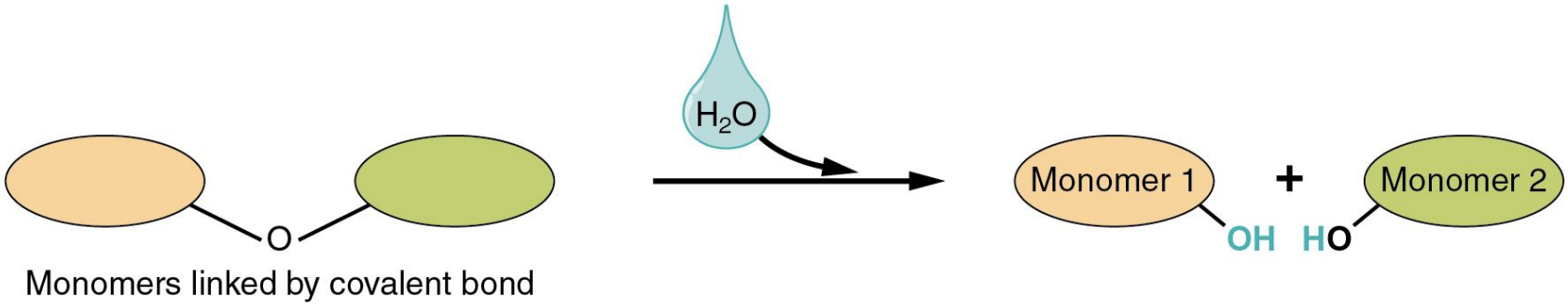
… Whenever you break a bond, it releases energy!

Creating and Using Macromolecules

Hydrolysis

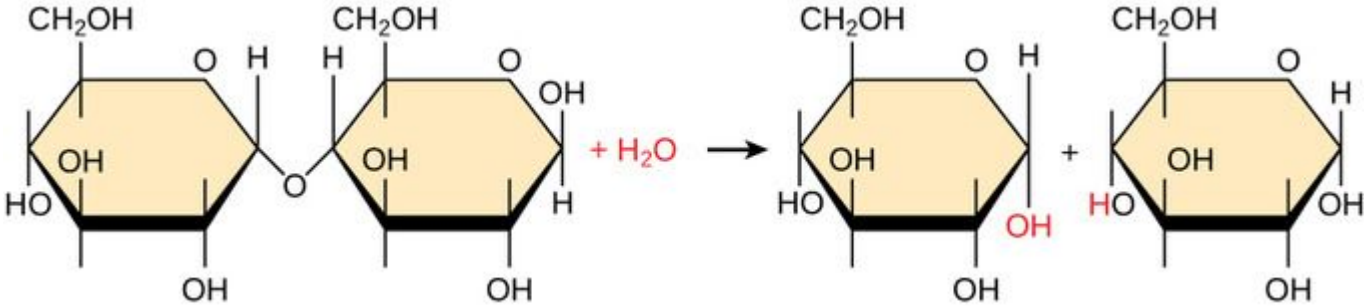
- **Chemical breakdown due to a reaction with water**

Monomers are released by the addition of a water molecule, adding OH to one monomer and H to the other.



Creating and Using Macromolecules

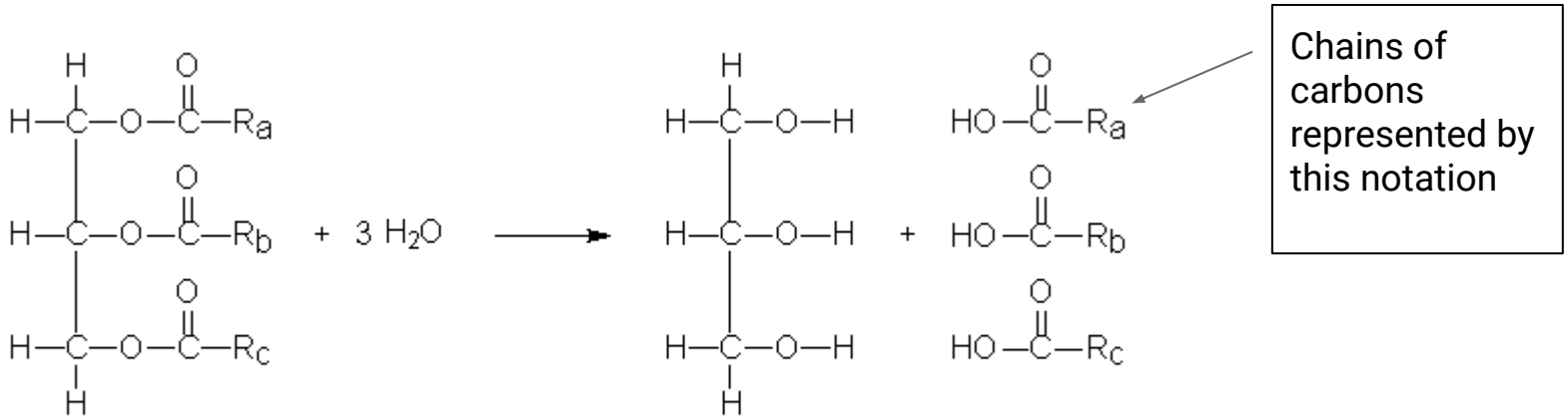
So the hydrolysis of each macromolecule will result in the monomers…



Disaccharide + H_2O → 2 Monosaccharides

Creating and Using Macromolecules

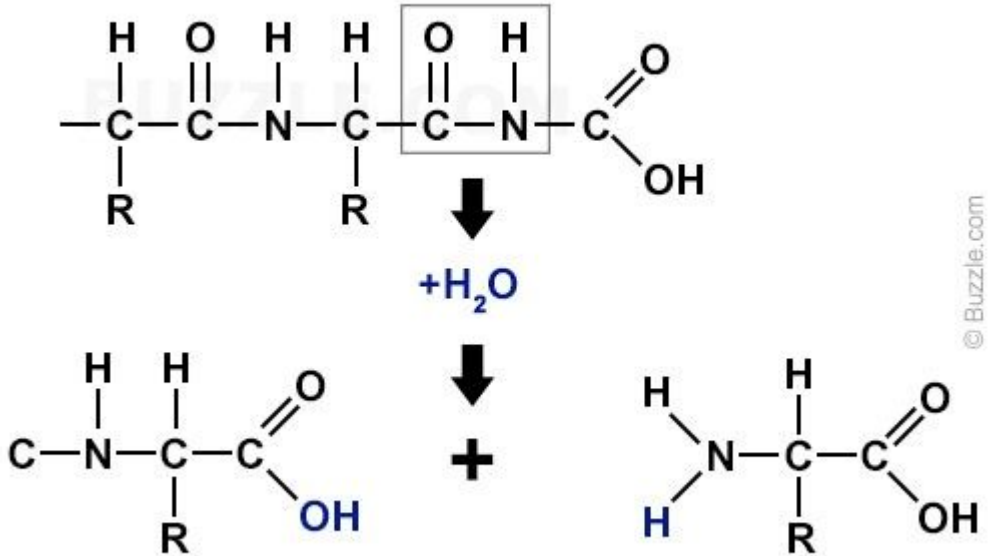
So the hydrolysis of each macromolecule will result in the monomers…



Triglyceride + H_2O → Glycerol + 3 Fatty Acids

Creating and Using Macromolecules

So the hydrolysis of each macromolecule will result in the monomers…



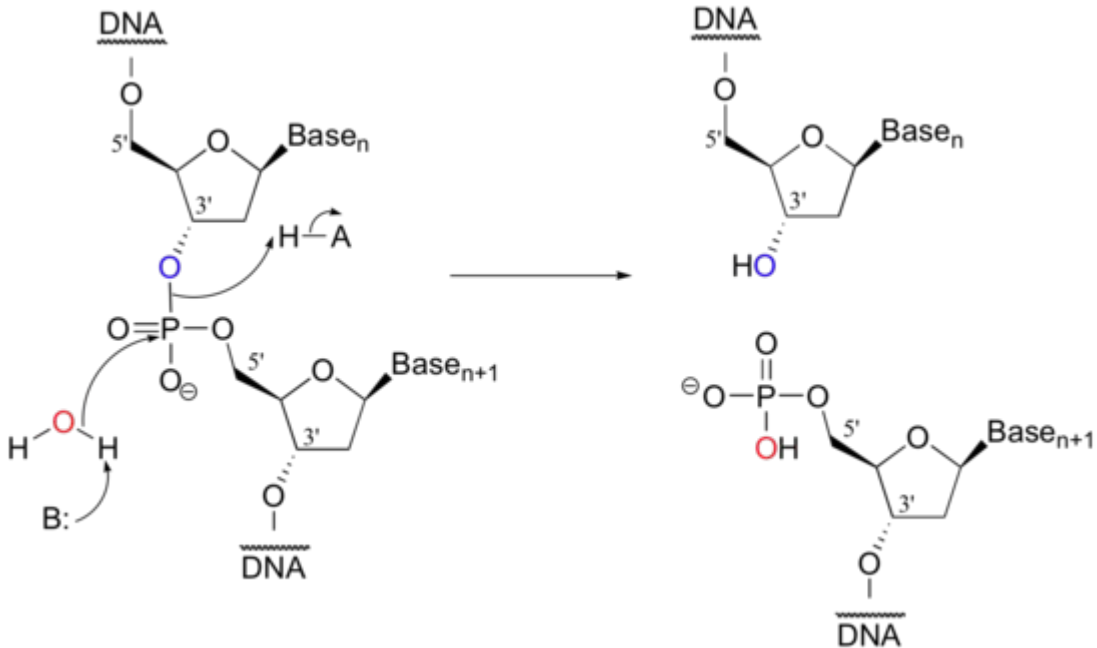
Polypeptide Chain + H_2O

→

2 Amino Acids

Creating and Using Macromolecules

So the hydrolysis of each macromolecule will result in the monomers…



Nucleic Acid + H_2O

→

2 Nucleotides

Creating and Using Macromolecules

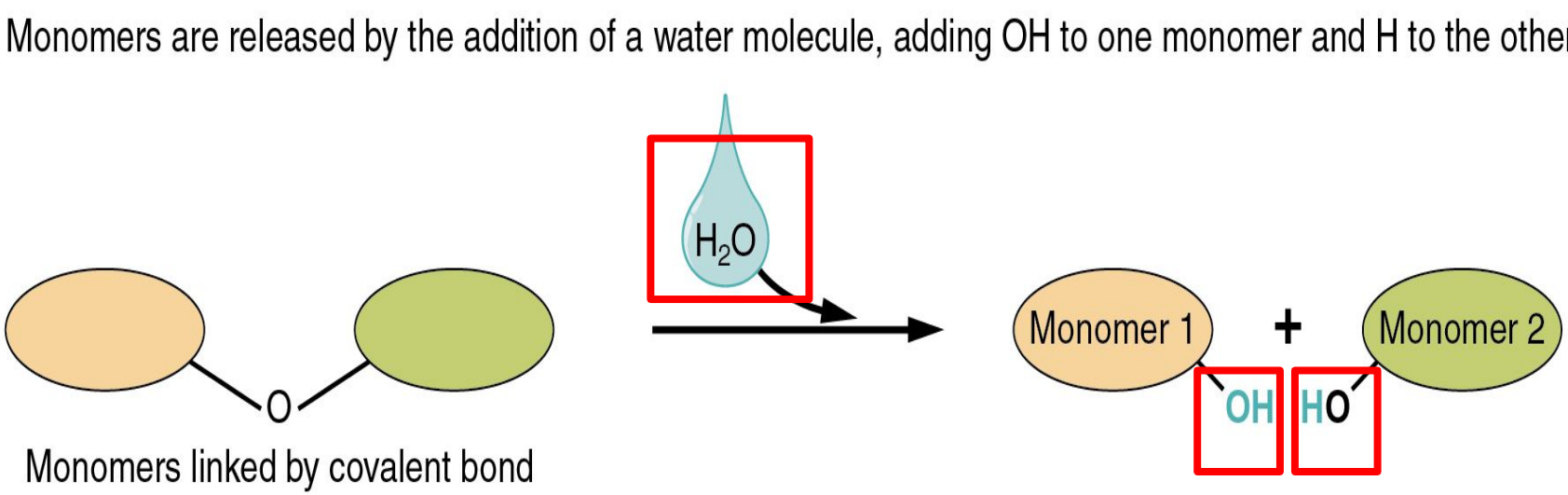
Why is it called hydrolysis?

- **Hydro = water**
- **Lysis = to split**

It is the water that is being split up…

Creating and Using Macromolecules

It is the water that is being split up…



Creating and Using Macromolecules

Enzymes (one of the types of proteins) assist with this process making it easier to break the bonds.

If you hold a cracker in your mouth, it begins to taste sweet... try it...

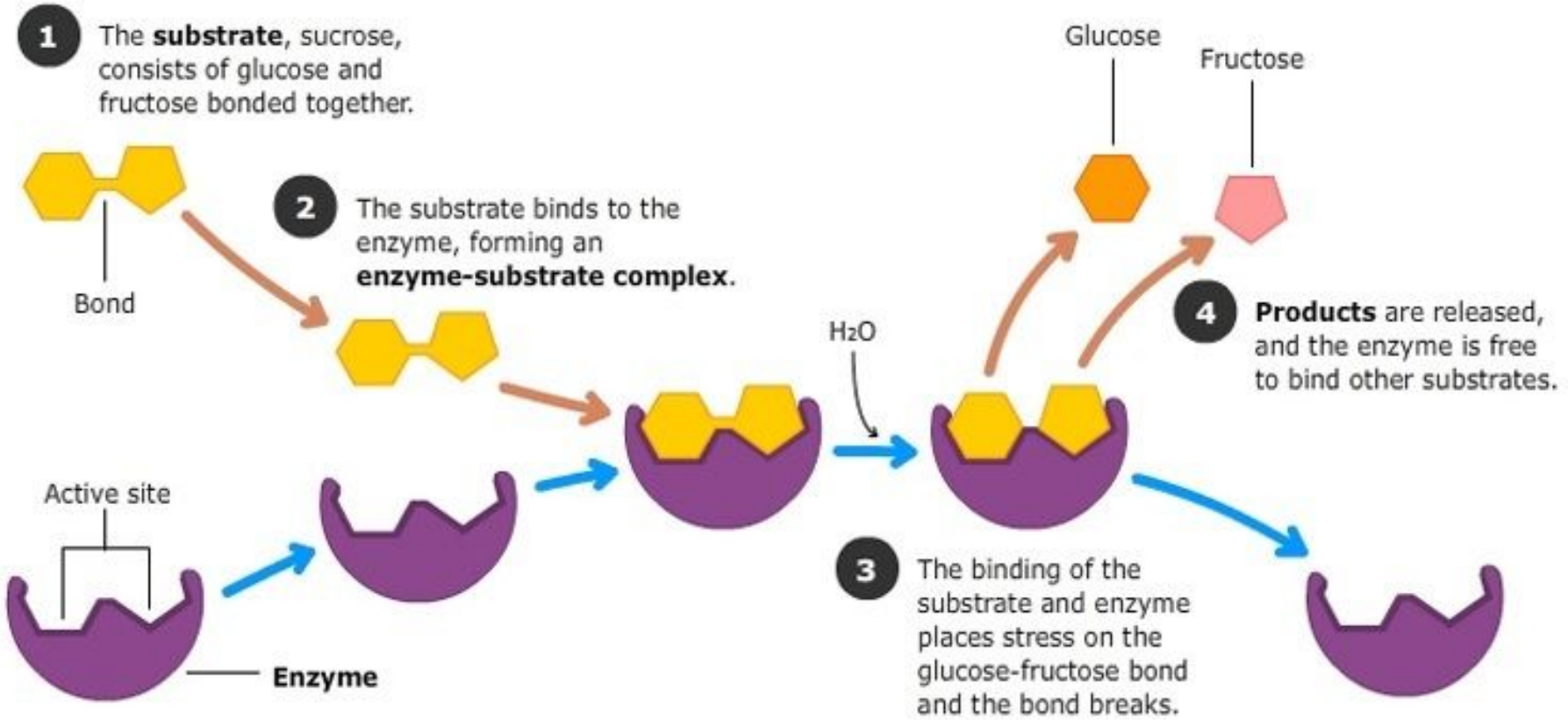
What is happening?

Creating and Using Macromolecules

Complex carbohydrate of starch is being broken down into its smaller monosaccharides which we perceive as sweeter.

- **Enzyme holds the molecule**
- **Allows water to split and break the bond between the monomers**

Creating and Using Macromolecules



Creating and Using Macromolecules

Now that we have broken down the macromolecules into their monomers, what do we do with them?

Build the macromolecules we need!

Creating and Using Macromolecules

Anabolism

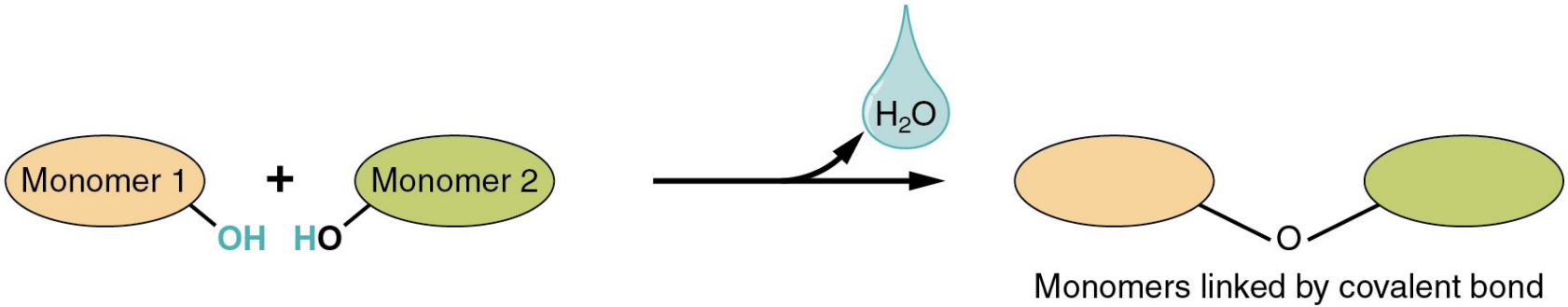
- **Building of more complex molecules from smaller subunits**
- **Requires energy (ATP)**

Many Monomers → Polymer

Creating and Using Macromolecules

Dehydration synthesis

- **Building of larger molecules through the removal of water**

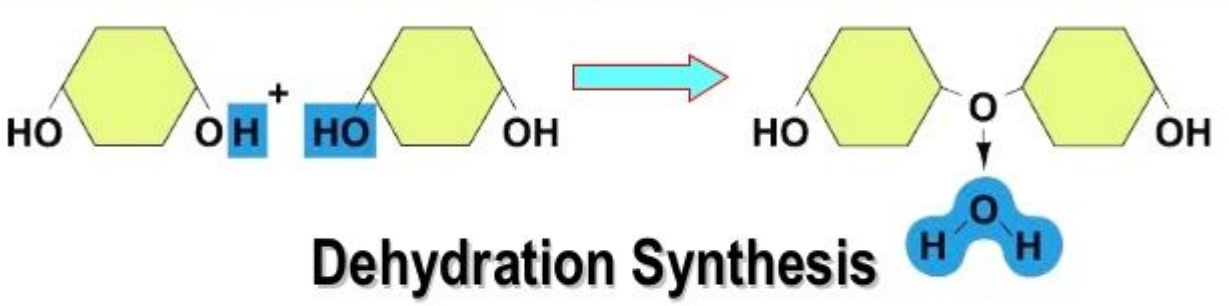


I need two volunteers...

What process does this represent?

Creating and Using Macromolecules

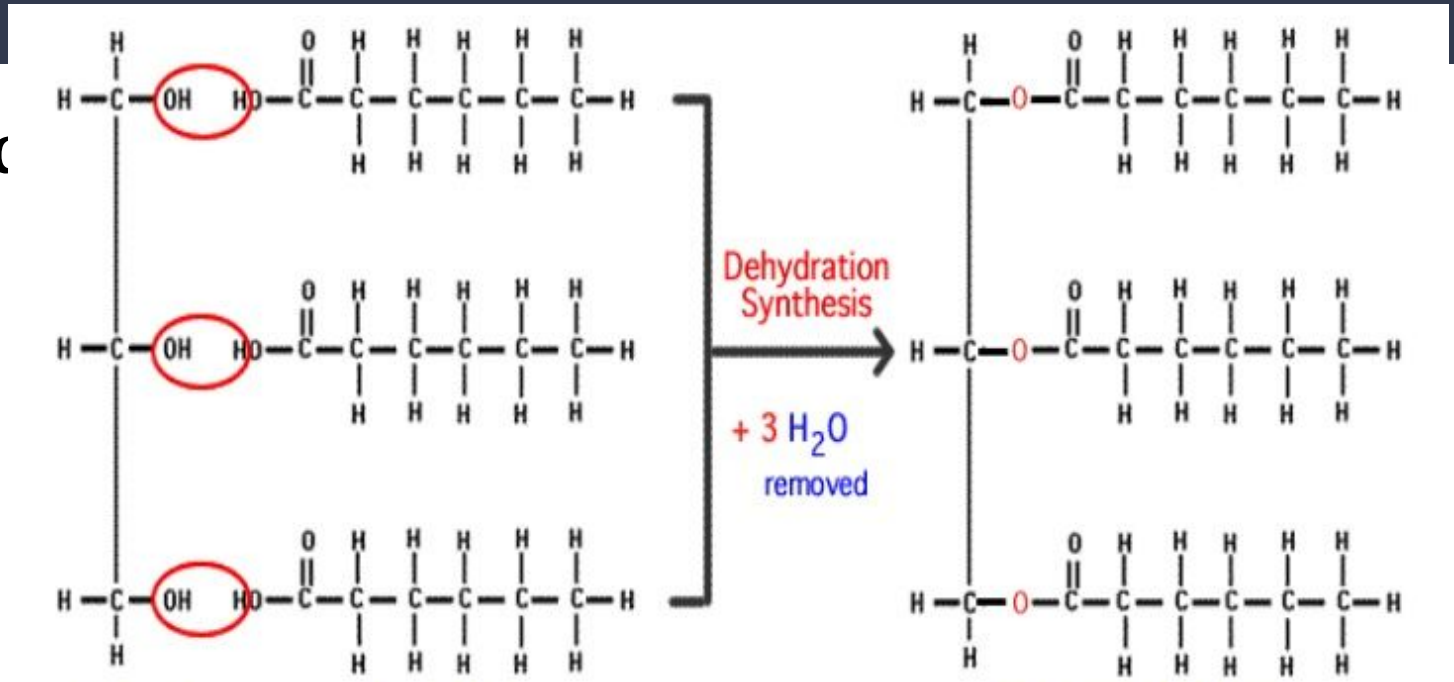
Dehydration synthesis



2 Monosaccharides → Disaccharide + H_2O

Creating and Using Macromolecules

Dehyc



Glycerol +3 Fatty Acids → Triglyceride + $3H_2O$

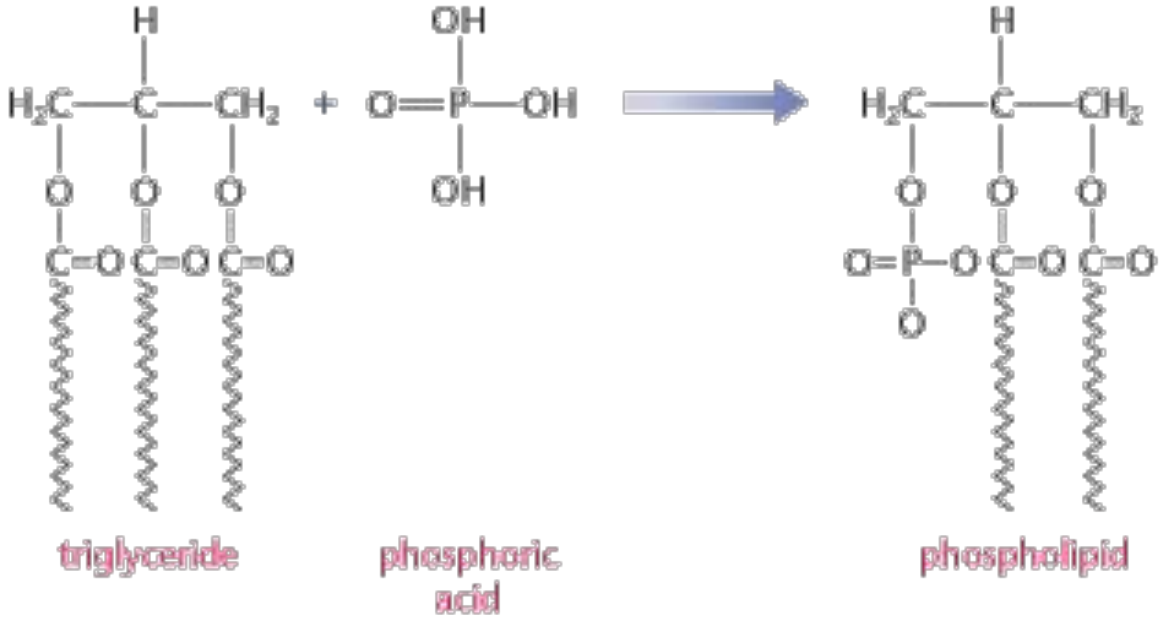
Creating and Using Macromolecules

Why might it be important for us to be able to break down and reform lipids?

Consider the form of lipid you most usually consume...

Allows us to turn triglycerides into phospholipids which we use to build new cell membranes!

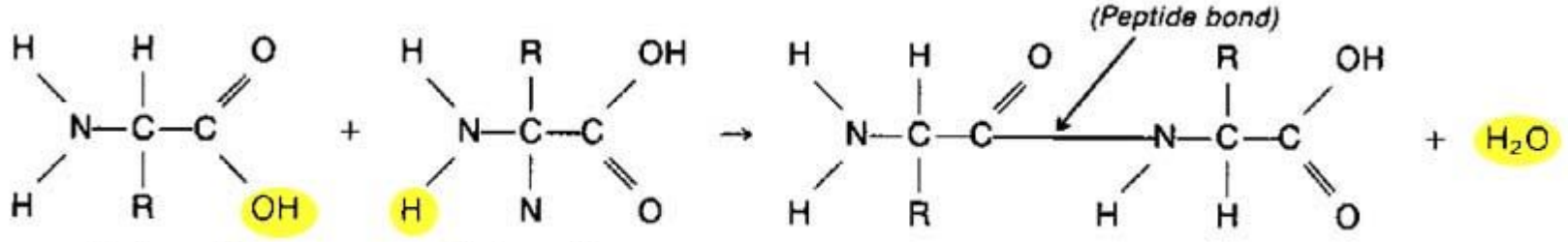
Creating and Using Macromolecules



Allows us to turn triglycerides into phospholipids which we use to build new cell membranes!

Creating and Using Macromolecules

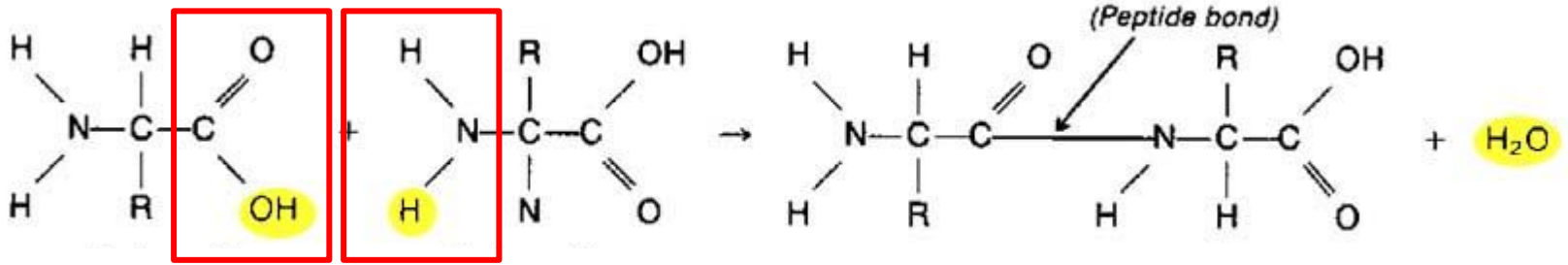
Dehydration Synthesis



2 Amino Acids → Dipeptide + H_2O

Creating and Using Macromolecules

Protein Synthesis Note:

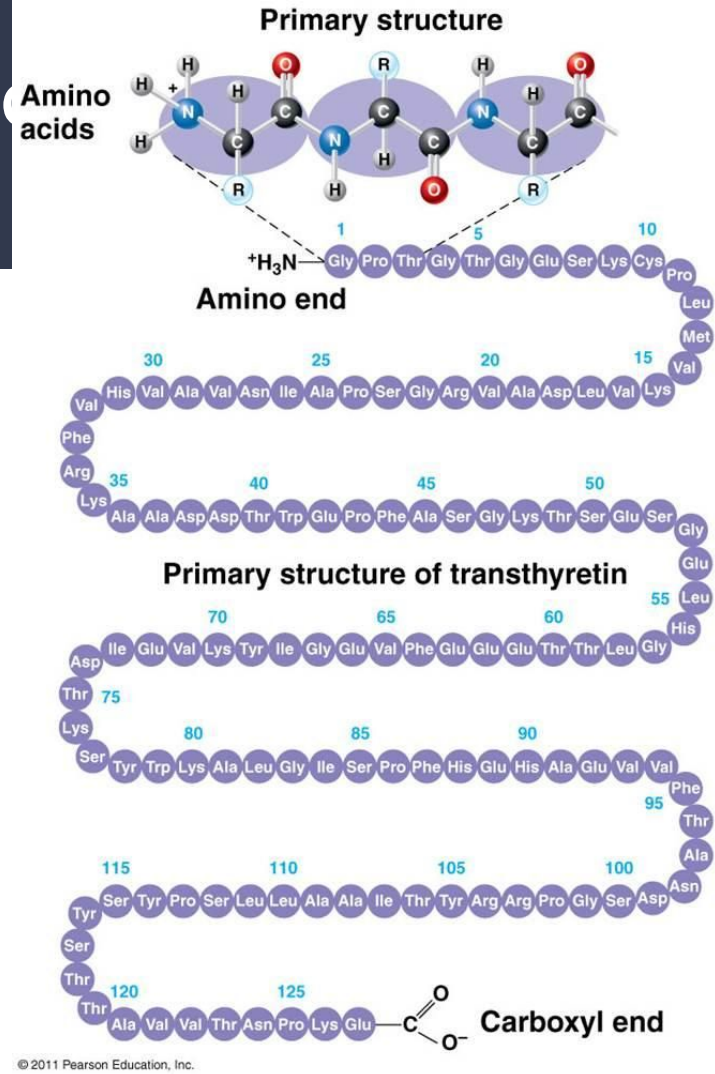


Bond is ALWAYS between the carboxyl group and the amine group

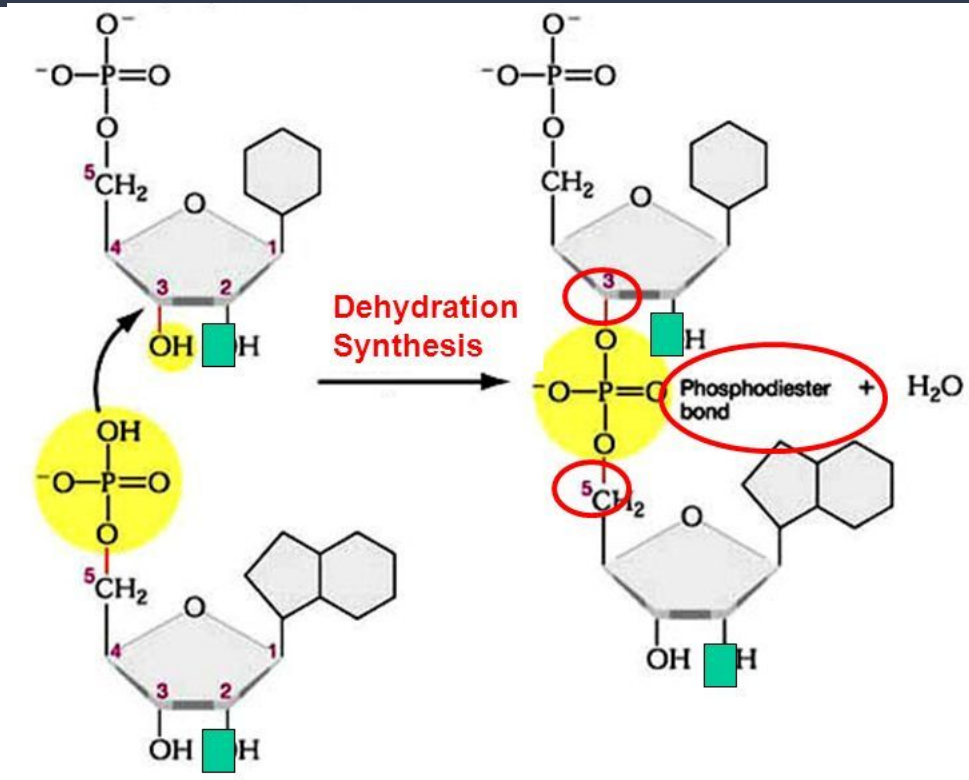
Creating and Using Macromole

Protein Synthesis Note:

- Primary structure is the order of amino acids
- The order determines how it folds
- The way it folds determines its function



Creating and Using Macromolecules

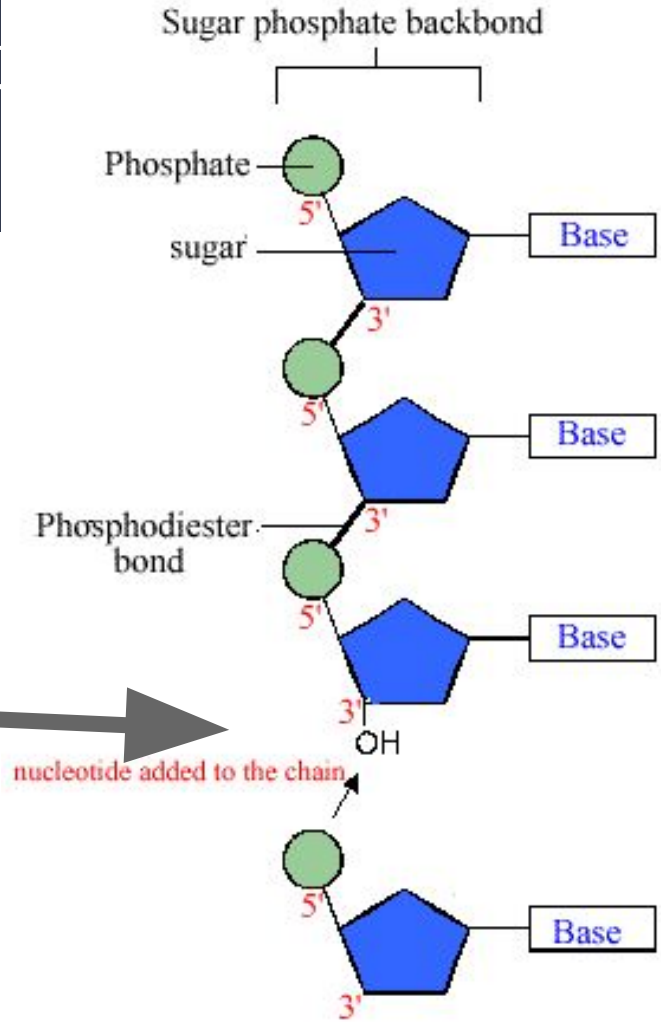


2 Nucleotides → Nucleic Acid + H_2O

Creating and Using Macromolec

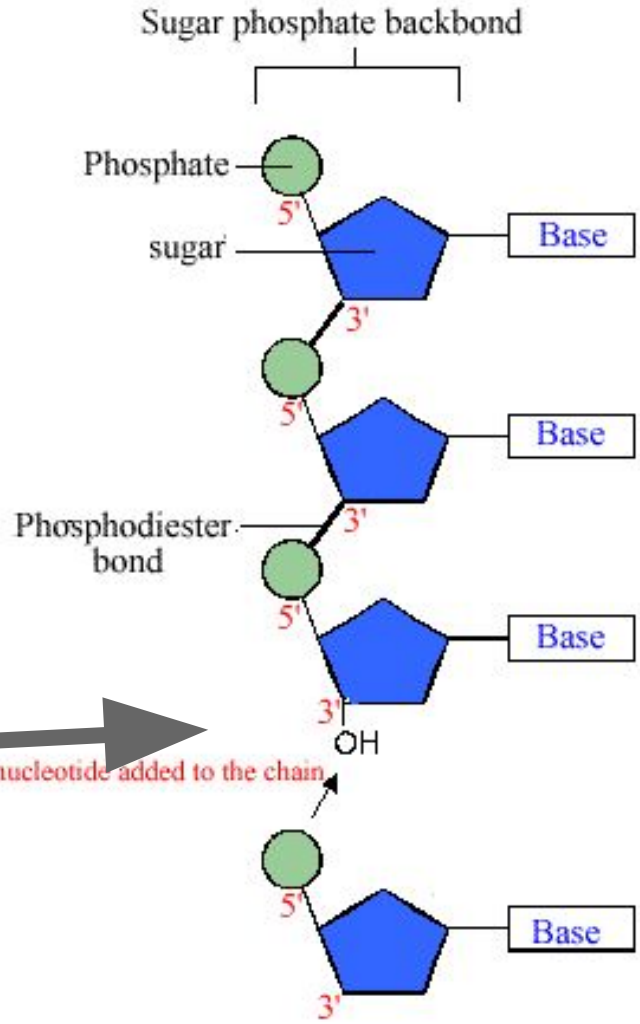
Nucleic Acid Note:

- **Built in only one direction**
- **5’ carbon is added to the 3’ carbon of the chain**



Creating and Using Macromolec

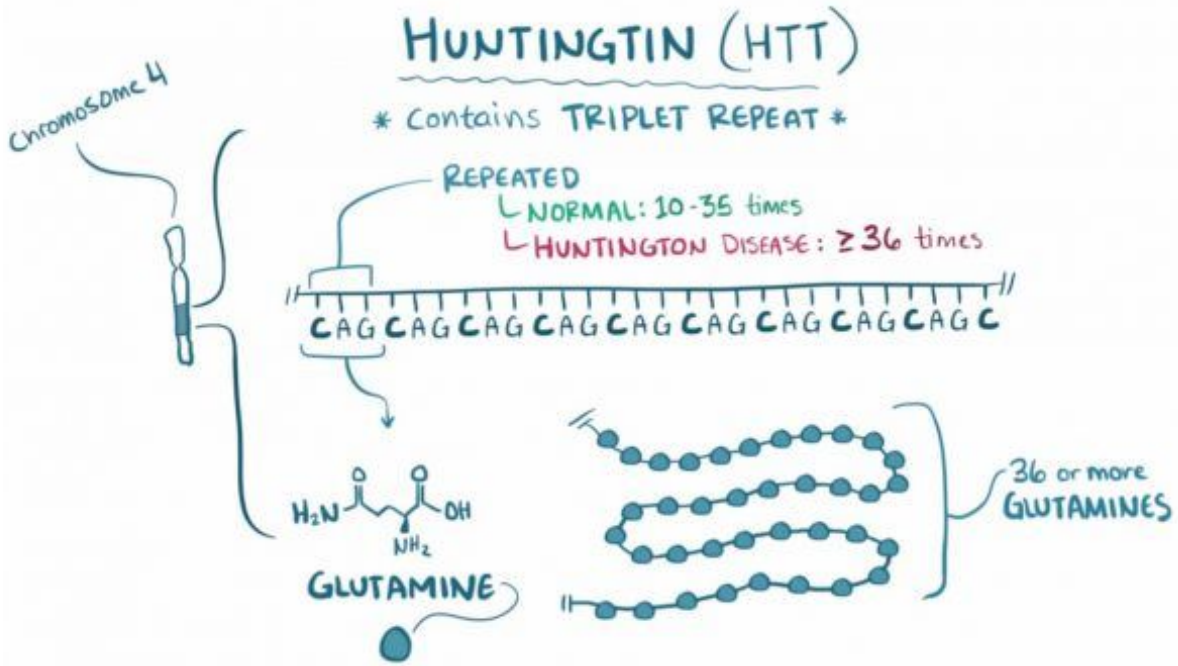
- **Think of it as a wall… it can only be built in one direction**
- **This is important for DNA replication and protein synthesis later in the year!**



Creating and Using Macromolecules

Nucleic Acid Note:

- **The order of the nucleotides is your unique genetic code**
- **It codes for building proteins**



Creating and Using Macromolecules

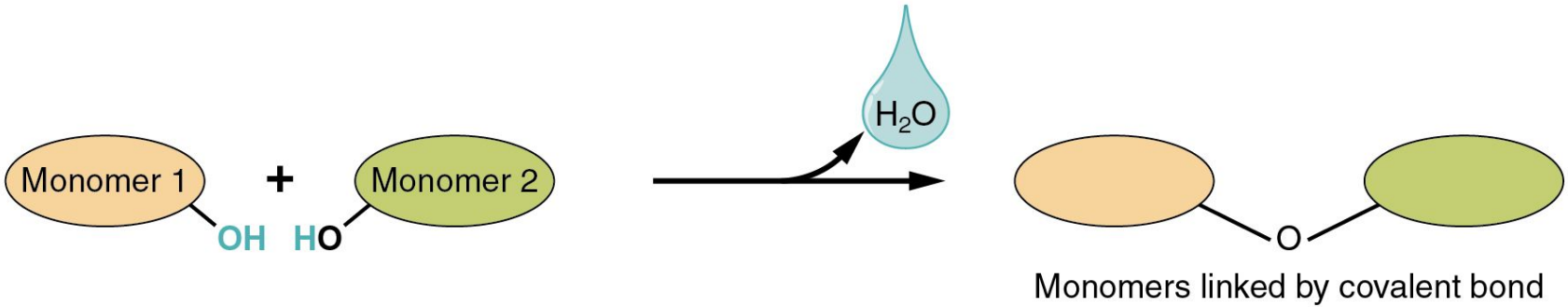
Why is it called dehydration synthesis?

- **dehydration = loss of water**
- **synthesis = to create something from smaller parts**

It is the water that is being lost as the polymers are made…

Creating and Using Macromolecules

It is the water that is being lost as the polymers are made…



Modeling Activity

Each group is responsible for creating a model that explains the dehydration synthesis and hydrolysis of a macromolecule

- **Must have a physical component**
- **Can use any material in the room (within reason)**

Think beyond a diagram... what else can you do?!

Modeling Activity

After you create your model, you will show your model to your peers!

- **One person will stay with the model and explain and the rest of the group rotates around the stations offering feedback and asking questions!**

Modeling Activity

What makes a good model?

- **Something that can be understood by others!**
  - **Labels**
  - **Keys**
  - **Representative colors**
  - **Shows change (before, during, after)**
  - **Using more than one representation**

Modeling Activity

You have 15 minutes to create your model!

- **Explain dehydration synthesis and hydrolysis of your macromolecule!**

Modeling Activity

Now show your model to your peers!

- **One person will stay with the model and explain and the rest of the group rotates around the stations offering feedback and asking questions!**

Modeling Activity

You have 20 minutes to explore other models.

- **Ask questions!**
- **Interact with the model!**

Modeling Activity

Reflections…

- **Notices?**
- **Wonders?**
- **What model was most effective? Why?**

Exit Ticket - 3, 2, 1

On a sheet of paper, DESCRIBE the following:

- **3 Things You Learned About Today**
- **2 Things You Found Interesting or Important**
- **1 Thing You**
  - **Need help with OR**
  - **Didn't understand OR**
  - **Still have questions about (what is your question?)**