REVISION GUIDE

How cells build big molecules, and the *sugars* they start with

Macromolecules and carbohydrates

A potato, a sheet of paper and a crab's shell are all made of sugar. Cells build every large molecule by taking water out, and break them down by putting it back. Then: why the same glucose can be a store or a wall.

6 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ap-biology-unit-1-macromolecules-and-carbohydrates

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By the end you can

- [ ] Name the monomer, the polymer and the bond for carbohydrates, proteins and nucleic acids, and say why lipids are not polymers 1.3.A
- [ ] Describe dehydration synthesis: the H and OH that leave as water and the covalent bond that forms 1.3.A
- [ ] Describe hydrolysis, and explain digestion and rebuilding as catabolism and anabolism 1.3.A
- [ ] Tell monosaccharides, disaccharides and polysaccharides apart, with an example of each 1.4.A
- [ ] Explain how coiling, branching and insolubility suit starch and glycogen to storing energy 1.4.A
- [ ] Explain how the form of the glucose monomer makes cellulose straight, strong and structural 1.4.A

Tick each one when you can do it without the book.

01

1.3.A MONOMERS AND POLYMERS

Big molecules from *small* parts

Living things are built mostly from four classes of large molecule: carbohydrates, lipids, proteins and nucleic acids. Each is huge by the standards of chemistry, which is why they are called **macromolecules**.

Three of the four are **polymers**: chains of small, similar units called **monomers**, joined by covalent bonds. A cell builds them the way you might build a necklace from beads, one bead at a time, and a cell holds only a few dozen kinds of bead. Twenty kinds of amino acid make every protein; four kinds of nucleotide make every molecule of DNA.

The order and the joining matter. The same glucose beads, linked in different ways, make a sugar store for a potato and the fibers of a plant cell wall (chapter 6). The same twenty amino acids, in different orders, make an enzyme or a strand of hair.

Lipids are the odd one out. A fat is one glycerol joined to three fatty acids: big, but not a chain of repeating units, so not a polymer. It is still built by the same reaction as the others (chapter 2).

KEY POINTS

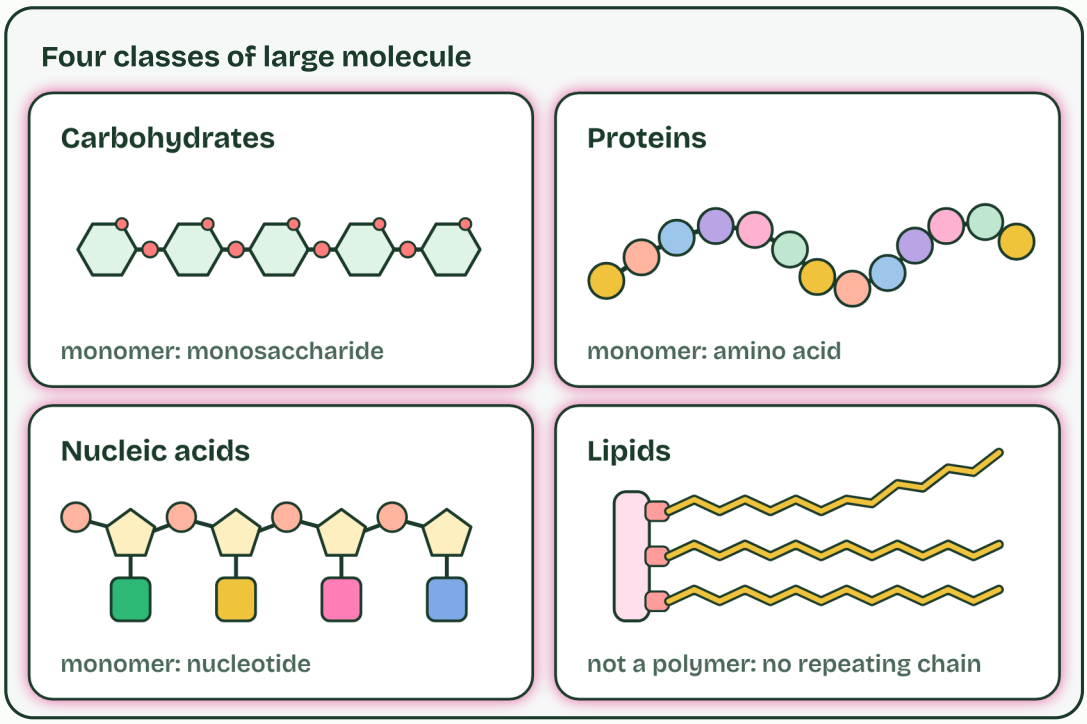
- Carbohydrates: monosaccharides, joined by glycosidic bonds.
- Proteins: amino acids, joined by peptide bonds.
- Nucleic acids: nucleotides, joined by phosphodiester bonds.

KEY TERMS

macromolecules
A very large molecule, such as a polysaccharide, a protein or a nucleic acid.

polymers
A large molecule made of many similar small units, the monomers, joined in a chain by covalent bonds.

monomers
One of the small units that join to make a polymer, such as a glucose unit in starch or an amino acid in a protein.



Three of the four are polymers, chains of repeating monomers. Which one is not, and why?

Carbohydrates. Monomer: a monosaccharide such as glucose. Polymer: a polysaccharide such as starch, glycogen or cellulose. Bond: glycosidic. Elements: C, H, O. Jobs: fuel, energy stores, cell walls.

Nucleic acids. Monomer: a nucleotide (a sugar, a phosphate and a base). Polymer: DNA or RNA. Bond: phosphodiester. Elements: C, H, O, N, P. Job: storing and passing on genetic information.

Proteins. Monomer: an amino acid, twenty kinds. Polymer: a polypeptide, folded into a protein. Bond: peptide. Elements: C, H, O, N, and S in some. Jobs: enzymes, transport, structure, signals (chapter 4 of this unit).

Lipids. Not polymers: a fat is one glycerol joined to three fatty acids, not a long chain of repeats, though it is built by dehydration synthesis too. Elements: C, H, O, and P in phospholipids. Jobs: long-term energy store, membranes, insulation, some hormones.

REMEMBER IT

Each polymer and its monomer

S	P	G
Sugar	Protein	Gene
Polysaccharide	**Polypeptide**	**Nucleic acid**
from monosaccharides	from amino acids	from nucleotides

WATCH OUT

"All macromolecules are polymers." Fats are large and built by dehydration synthesis, but they are not chains of repeating monomers.

PREDICT

A student says DNA, starch, a protein and a fat are all polymers. Which one breaks the rule, and why?

(A) DNA, because its units are not all the same: it has four different bases, so it is a mixture rather than a polymer

(B) The fat, because it is one glycerol joined to three fatty acids, not a long chain of similar units repeated

(C) The protein, because it folds up into a compact shape, and a polymer has to stay as a long, straight chain

Decide before you look. Answer on page 24.

02 Take water *out* to build

1.3.A DEHYDRATION SYNTHESIS

Every monomer has, in effect, an H at one end and an OH at the other. To join two monomers, a cell removes the OH from one and the H from the other. They leave together as a molecule of water, and a covalent bond forms between the two monomers. The reaction is **dehydration synthesis**: making something (synthesis) by taking water out (dehydration).

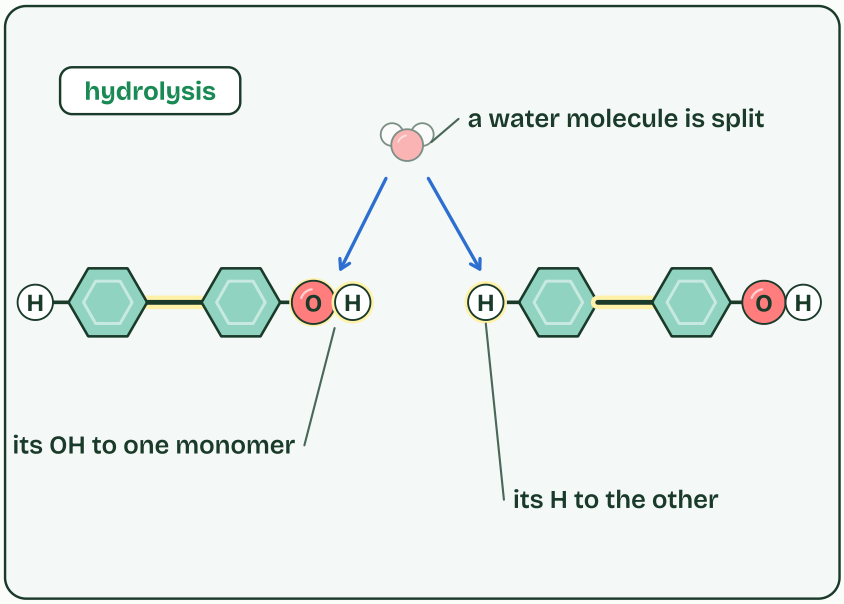
One water molecule is released for every bond made. Add a third monomer and a second water leaves; keep going and a chain grows, a polymer, with an H still at one end and an OH at the other, ready for the next.

Building costs energy. A cell does not join monomers by bumping them together: enzymes hold them in place, and the cell pays for each bond with energy from respiration (Unit 3). The energy stays in the bonds, which is part of why a polymer such as starch is a store of energy.

All three families of polymer are built this way: sugars into polysaccharides, amino acids into polypeptides, nucleotides into DNA and RNA. Fats are put together by the same reaction too.

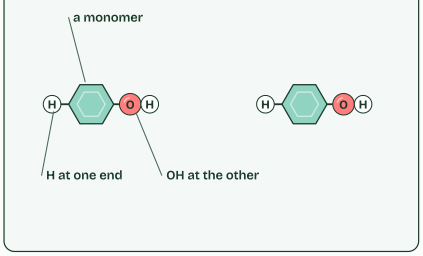
KEY TERMS

dehydration synthesis
A reaction that joins two monomers with a covalent bond and releases a molecule of water. Also called a condensation reaction.



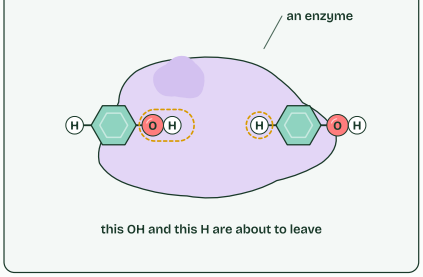
STEP BY STEP
5 STEPS

1



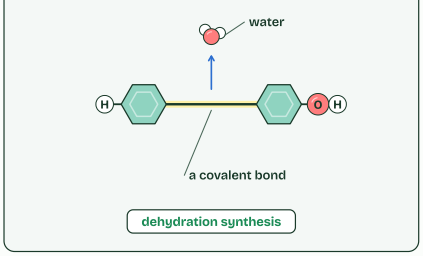
Two **monomers**. Each has an H at one end and an OH at the other.

2



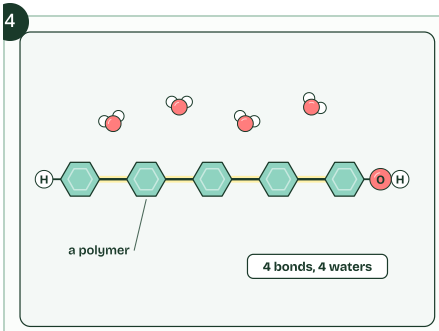
An enzyme brings them together: the OH of one and the H of the other are about to leave.

3



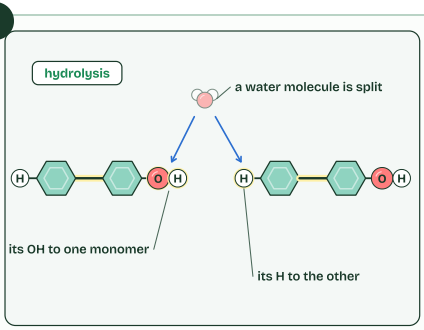
They leave as a molecule of **water**, and a **covalent bond** now joins the monomers: dehydration synthesis.

4



Repeat it and a chain grows, a **polymer**: one water released for every bond.

5



Hydrolysis runs it backward: a water molecule is split, its H to one monomer and its OH to the other, and the bond breaks.

WATCH OUT

"Dehydration means the molecule dries out." The water is made from atoms that were part of the two monomers; the product is not dry, and the reaction happens in the watery cytoplasm.

PREDICT

Ten glucose molecules are joined into one unbranched chain. How many water molecules were released?

(A) 10

(B) 11

(C) 9

(D) 20

Decide before you look. Answer on page 24.

03 Put water *back* to break

1.3.A HYDROLYSIS

Hydrolysis runs the other way. Hydro means water and lysis means splitting: a water molecule is split, its H joins one monomer and its OH joins the other, and the bond between them breaks. It is how polymers are taken apart, one bond and one water at a time.

Digestion is hydrolysis. Starch, protein and DNA in food are far too big to cross the wall of the small intestine, so enzymes split them into monomers (glucose, amino acids, nucleotides) that can be absorbed. Your cells then rebuild them, by dehydration synthesis, into their own polymers: the glucose from a potato can become glycogen in your liver.

Together the two reactions are a large part of **metabolism**. Building large molecules from small ones is **anabolism**; breaking them down is **catabolism**. In a cell, each reaction is sped up by its own enzyme.

KEY POINTS

- Dehydration synthesis: monomers in, polymer and water out.
- Hydrolysis: polymer and water in, monomers out.

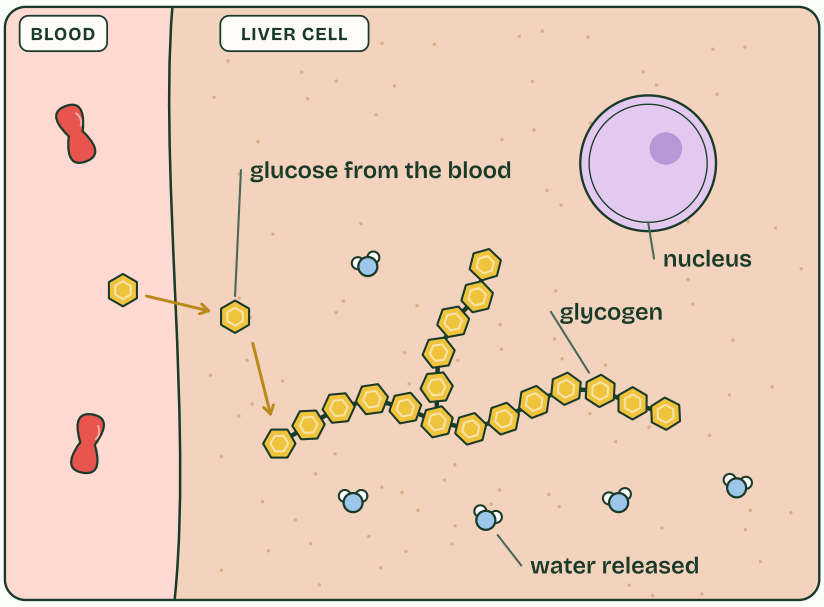
KEY TERMS

hydrolysis
A reaction that breaks the covalent bond between two monomers by adding a molecule of water: its H goes to one monomer and its OH to the other.

metabolism
All the chemical reactions in an organism.

anabolism
The building up of large molecules from smaller ones, which uses energy. Dehydration synthesis is an example.

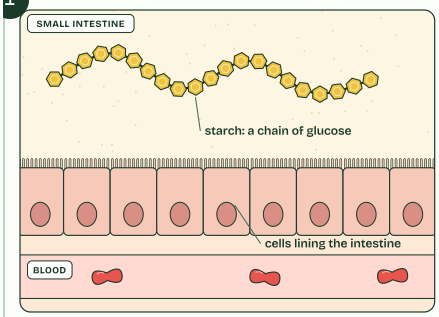
catabolism
The breaking down of large molecules into smaller ones, which releases energy. Hydrolysis is an example.



STEP BY STEP

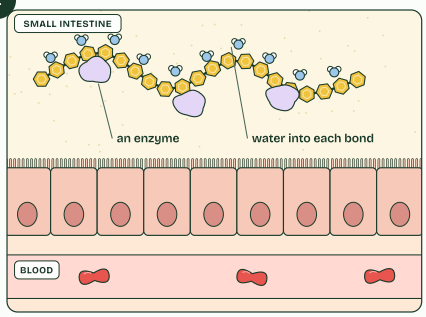
4 STEPS

1



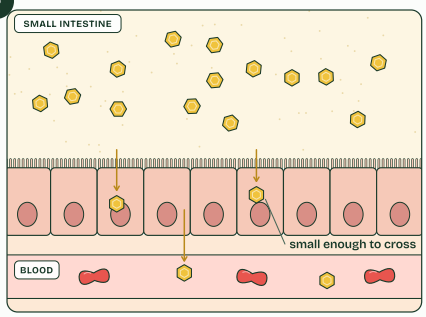
Starch from a meal reaches the small intestine: a chain of glucose units too big to cross into the blood.

2



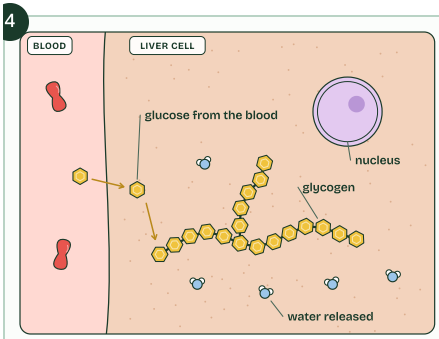
Enzymes split it by **hydrolysis**, one water molecule into every bond.

3

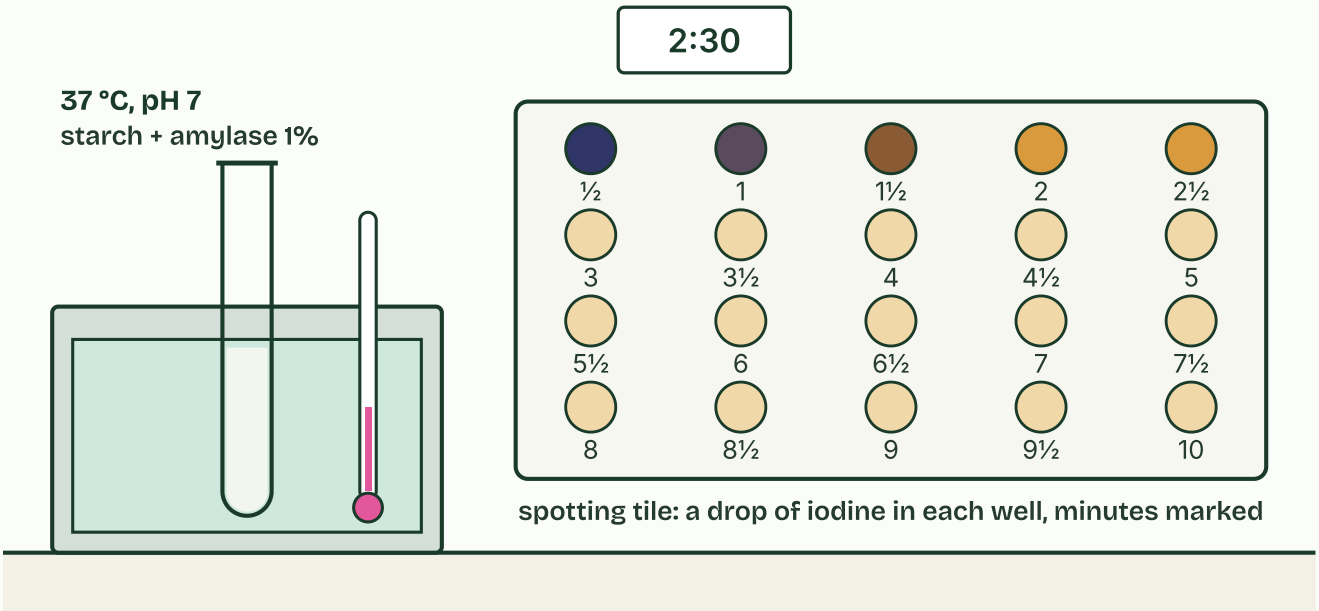


What is left is **monomers**, glucose small enough to be absorbed. Breaking down like this is **catabolism**.

4



In the liver the same glucose is joined into glycogen by **dehydration synthesis**, releasing water: building up, **anabolism**.



Every 30 seconds a drop of the mixture goes into iodine. Blue-black means starch is still there; when a drop stays orange-brown, the starch is gone.

REMEMBER IT

Which way the water goes

D	H
Dehydrate	**Hydrolyze**
Water out	**Water in**
to build a bond	to break a bond

WATCH OUT

In hydrolysis the water is not simply stuck on: it is split, and its H and its OH end up on the two new ends.

PREDICT

A starch molecule of 300 glucose units, in one unbranched chain, is digested completely to glucose. How many water molecules does that use?

(A) 300

(B) 299

(C) 150

(D) 301

Decide before you look. Answer on page 24.

04

1.4.A SUGARS

One unit, two units, *many*

Carbohydrates are made of carbon, hydrogen and oxygen, usually in the ratio 1:2:1. The monomers are **monosaccharides**, single sugars. Glucose, fructose and galactose all have the formula $C_6H_{12}O_6$, but their atoms are arranged differently, and so they behave differently: they are **isomers**. Ribose and deoxyribose, with five carbons, are the sugars in RNA and DNA (chapter 3 of this unit).

Two monosaccharides joined by dehydration synthesis make a **disaccharide**. Glucose and fructose make sucrose, the sugar plants carry in their phloem and we buy as table sugar; glucose and galactose make lactose, the sugar in milk; two glucose make maltose. The bond between sugars is a **glycosidic bond**.

Hundreds to thousands joined make a **polysaccharide**. Monosaccharides and disaccharides dissolve and taste sweet; polysaccharides are too large to do either.

Small sugars are also easy to detect. Glucose, fructose, galactose, maltose and lactose are **reducing sugars**: heated with Benedict's reagent, they turn it from blue to green, orange or brick red. Sucrose is not, until it is hydrolyzed. Iodine turns blue-black with starch. The food tests dry lab, on the Lab tab, has both.

KEY TERMS

monosaccharides
A single sugar unit, the monomer of carbohydrates, such as glucose, fructose or galactose.

isomers
Molecules with the same formula but a different arrangement of their atoms.

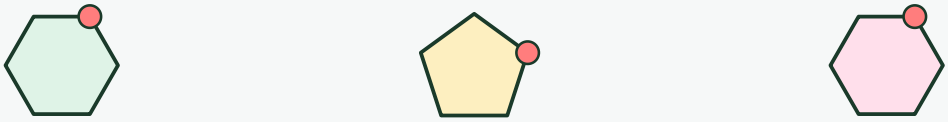
disaccharide
Two monosaccharides joined by a glycosidic bond, such as sucrose, lactose or maltose.

glycosidic bond
The covalent bond between two sugar units, formed by dehydration synthesis.

polysaccharide
A polymer of many monosaccharides: starch, glycogen and cellulose are examples.

reducing sugars
A sugar that can give electrons to copper ions in Benedict's reagent, turning it from blue to green, orange or red when heated.

Monosaccharides: one sugar unit



glucose
the fuel of cells

fructose
in fruit and honey

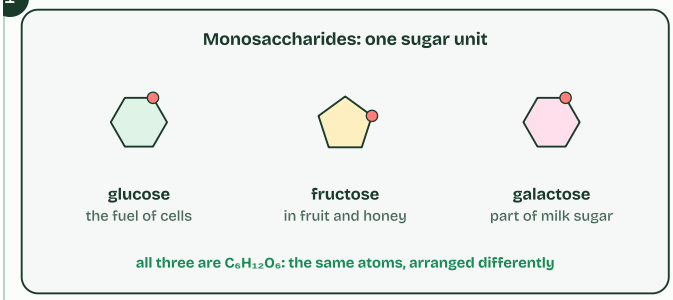
galactose
part of milk sugar

all three are $C_6H_{12}O_6$: the same atoms, arranged differently

Each shape is one sugar unit, drawn plain. Switch from one unit to two to many.

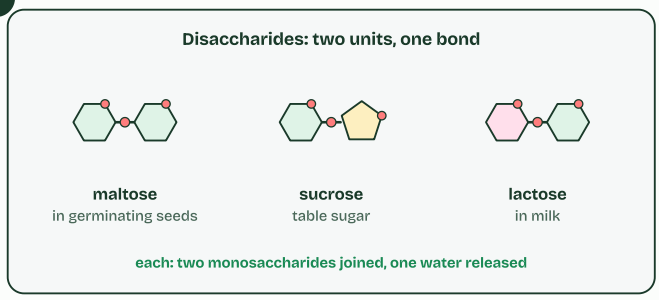
SWITCH IT 3 SETTINGS

1



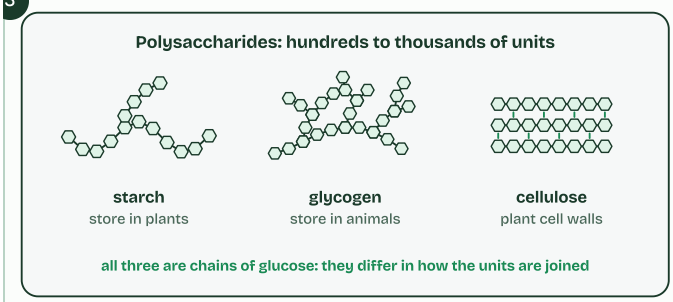
One unit

2



Two units

3



Many units

WATCH OUT

"Sugar means sucrose." To a biologist, sugars are all the monosaccharides and disaccharides. Sucrose is just one of them.

PREDICT

Glucose and fructose are both $C_6H_{12}O_6$. Sucrose, made from one of each, is $C_{12}H_{22}O_{11}$. Why is it not $C_{12}H_{24}O_{12}$?

(A) Some atoms are always lost to the air when two sugars are mixed together, so the formula of the mixture comes out smaller

(B) Joining them released one molecule of water, H_2O, taking two hydrogens and one oxygen from the pair

(C) Fructose loses one oxygen and two hydrogens as it changes into glucose, and then the two glucose units join

Decide before you look. Answer on page 24.

05 Energy packed *tight*

1.4.A STARCH AND GLYCOGEN

Plants store glucose as **starch** and animals and fungi store it as **glycogen**. Both are polymers of the same form of glucose, built by dehydration synthesis, and the way the units are joined makes the chain coil.

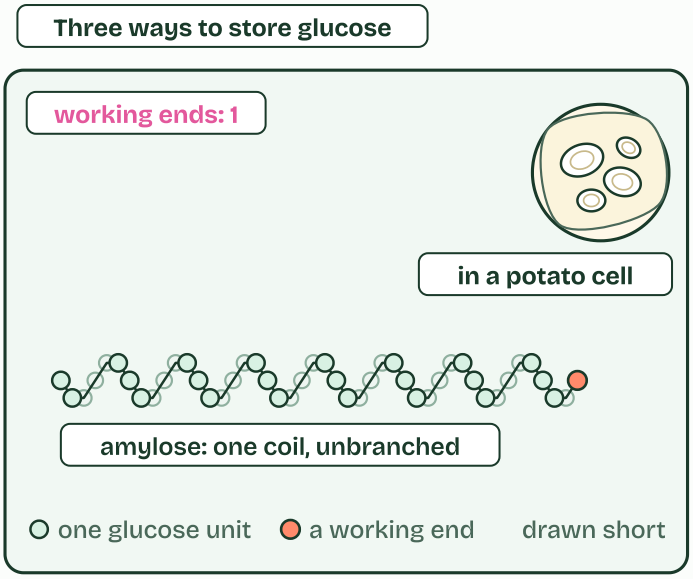
Starch is a mixture of two polysaccharides: one an unbranched coil, the other a coil with occasional branches. Glycogen branches far more often. Coiling and branching make both stores compact, a great deal of glucose in a small space: starch grains in a potato, glycogen granules in liver and muscle cells.

Being so large, a store barely dissolves, so it stays where it is put and does not draw water into the cell as the same glucose, dissolved, would. And glucose comes off easily when it is needed: enzymes hydrolyze it from the ends of the chains, one unit at a time. More branches mean more ends, so more enzymes can work at once.

KEY TERMS

starch
The energy store of plants: chains of glucose, some coiled and unbranched (amylose), some coiled and branched (amylopectin).

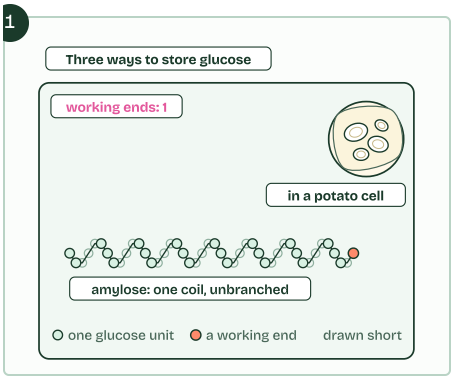
glycogen
The energy store of animals and fungi: a highly branched polymer of glucose, kept in liver and muscle cells.



Each bead is one glucose unit. Switch between the three stores and compare their shapes and their ends.

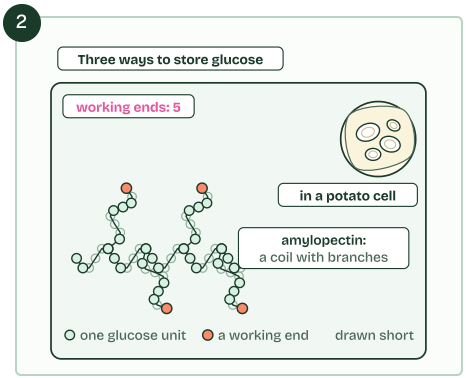
SWITCH IT 3 SETTINGS

1



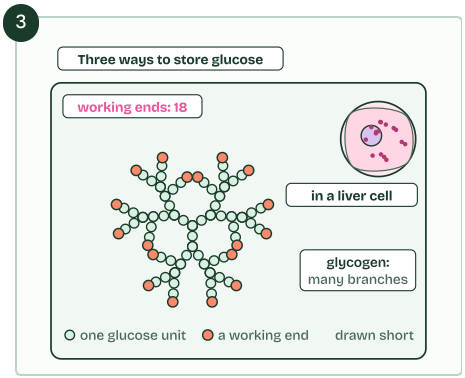
Amylose

2



Amylopectin

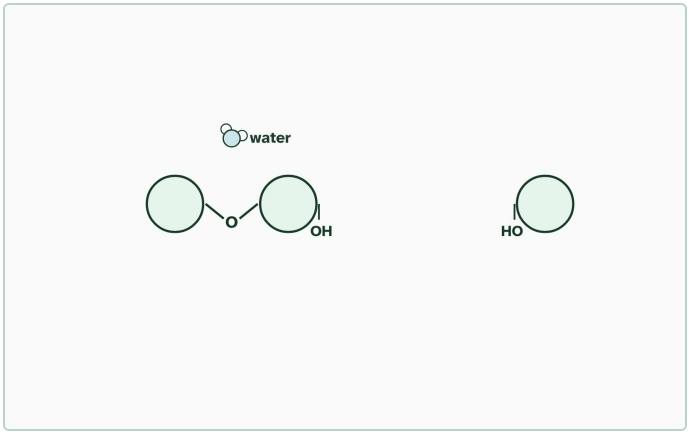
3



Glycogen

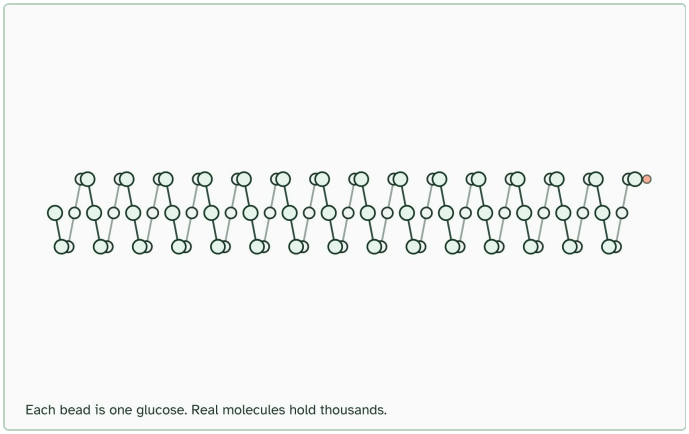
ANIMATION · WATCH IT HAPPEN: BUILDING AND USING A STORE 4 MOMENTS

1 WATER RELEASED: 1



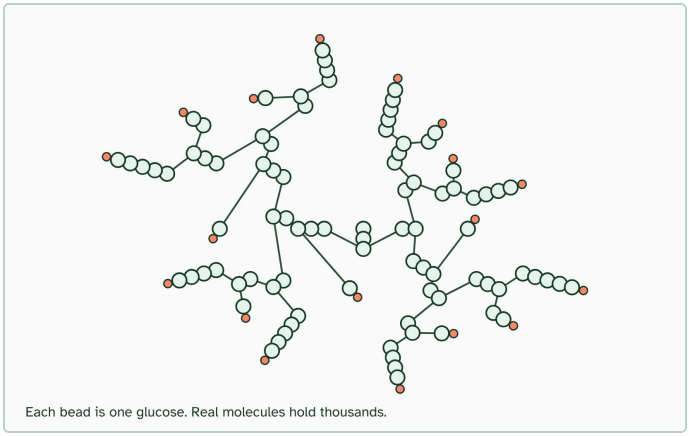
Glucose units join one at a time; a **water** molecule leaves at each link.

2 ENDS: 1



Amylose **coils** into a helix: a lot of glucose in a small space.

3 ENDS: 18



Amylopectin and glycogen **branch**, so they have many ends.

4 ENDS: 8, GLUCOSE RELEASED: 43



Enzymes take glucose off the **ends**, using a water molecule each time.

Watch it move, and change it as it runs: biologybybradford.com/guides/ap-biology-unit-1-macromolecules-and-carbohydrates#stores

EXAMPLE

A potato tuber is roughly a sixth starch by mass. An adult human liver holds about 100 g of glycogen and the muscles about 400 g more.

WATCH OUT

Insoluble does not mean hydrophobic. Starch and glycogen are covered in polar OH groups: they barely dissolve because each molecule is so large.

PREDICT

An unbranched starch chain and a glycogen molecule hold the same number of glucose units. A sprinter's muscles suddenly need glucose. Which store can release it faster?

(A) The unbranched starch, because its single coiled chain is easier for enzymes to unwind from end to end

(B) Both the same, because they hold the same number of glucose units, so the same amount comes off

(C) The glycogen, because its many branches give enzymes many ends to work on at the same time

Decide before you look. Answer on page 24.

1.4.A CELLULOSE AND CHITIN

06 Turn every other unit over and the chain runs *straight*

Glucose comes in two forms that differ only in which way one OH group points: alpha (α) glucose, the monomer of starch and glycogen, and beta (β) glucose, the monomer of **cellulose**. The first figure shows the difference. You do not need to draw it for the exam, but it shows a rule of this unit: the structure of a monomer decides the properties of the polymer.

To join beta glucose, every other unit has to be turned over. The chain that results runs straight instead of coiling. Straight chains lie side by side, and the OH groups of neighboring chains form many hydrogen bonds that tie them into bundles called **microfibrils**. One hydrogen bond is weak, but thousands are strong: a cell wall built from layers of microfibrils holds a plant up and stops its cells from bursting.

The same few atoms, joined another way, have a different job. Starch and glycogen are stores, coiled and easy to take apart; cellulose is structure, straight and hard to break down. Humans make no enzyme that can hydrolyze it, so it passes through us as fiber.

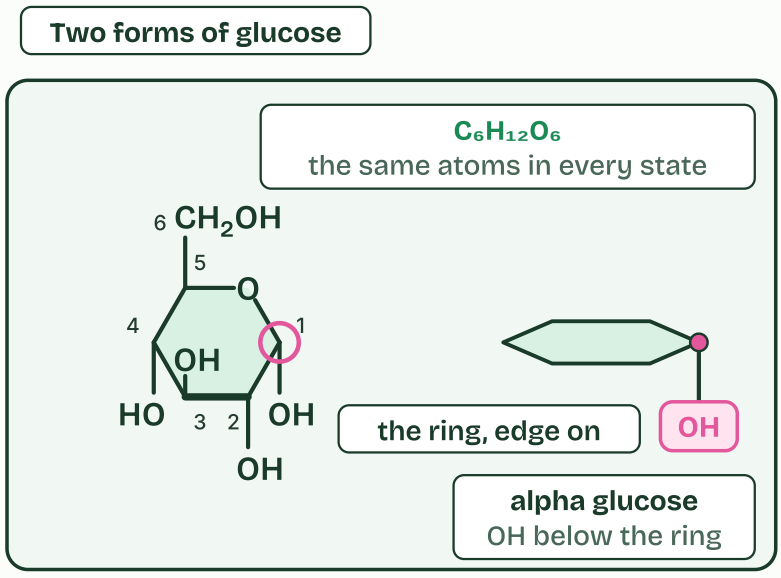
Chitin is another structural polysaccharide, of a glucose that carries a nitrogen-containing group. It makes the cell walls of fungi and the tough exoskeletons of insects and crabs.

KEY TERMS

cellulose
An unbranched polymer of beta glucose, the main material of plant cell walls.

microfibrils
Bundles of cellulose chains held together by hydrogen bonds; very strong when pulled.

chitin
A structural polysaccharide of a modified glucose that carries nitrogen; it makes the cell walls of fungi and the exoskeletons of insects and crustaceans.

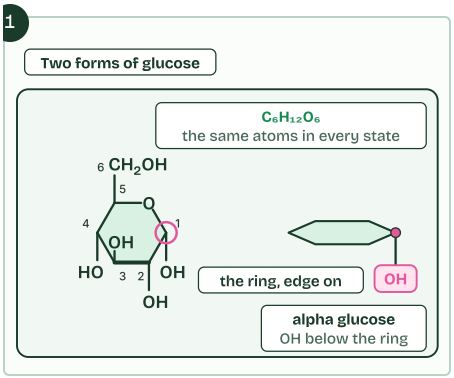


One glucose ring, with carbon 1 ringed in pink. Switch between the two forms, or lay one over the other.

SWITCH IT

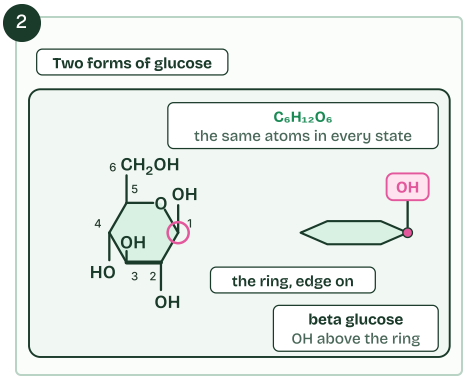
3 SETTINGS

1



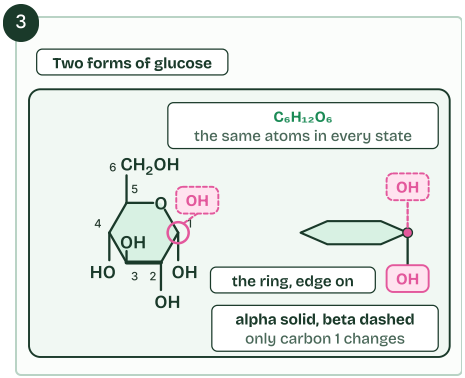
α-glucose

2

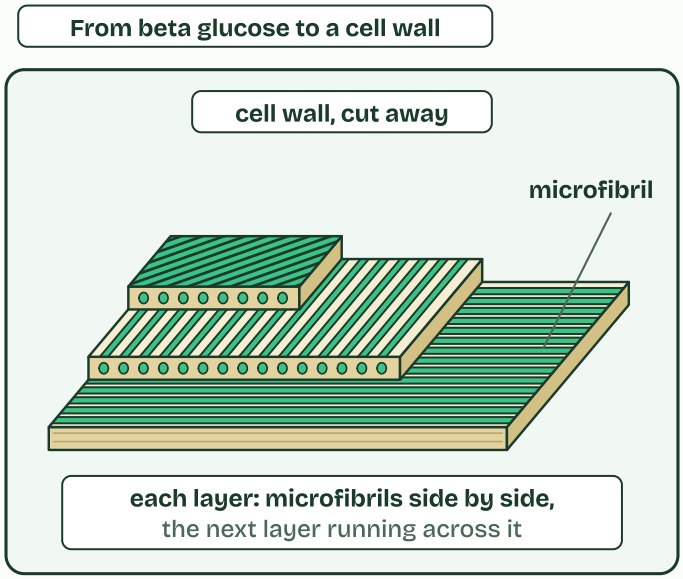


β-glucose

3



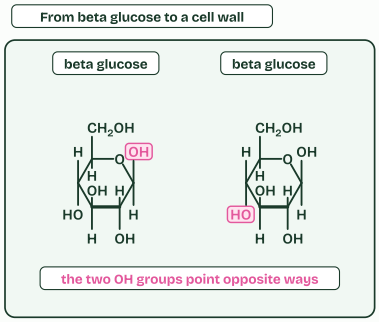
Both



STEP BY STEP

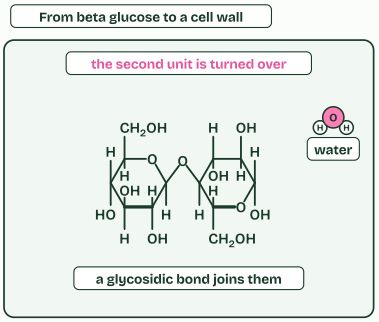
6 STEPS

1



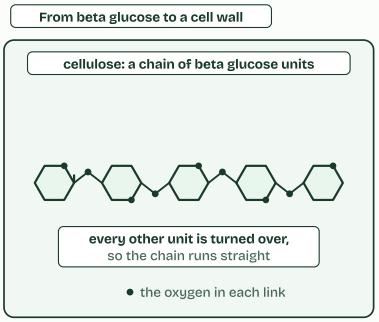
Two **beta glucose** molecules. Their OH groups point opposite ways.

2



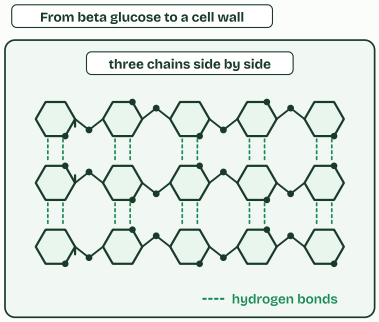
Turn one **over** and they can join: water leaves and a bond forms.

3



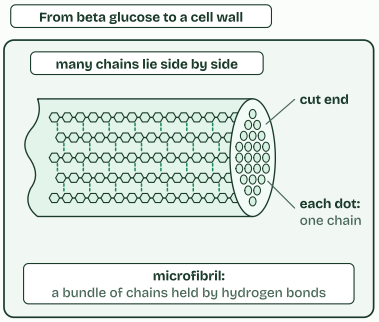
Every other unit is turned over, so the chain runs **straight**.

4



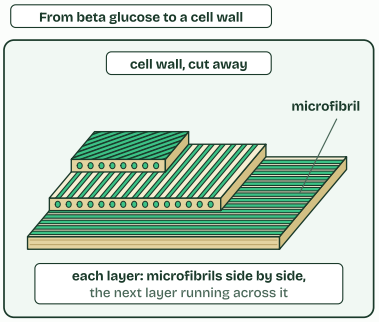
Neighboring chains are linked by many **hydrogen bonds**.

5



Bundles of chains form **microfibrils**.

6



Layers of microfibrils give the **cell wall** its strength.

WATCH OUT

Cellulose is the plant's structure, not its energy store: plants store glucose as starch.

PREDICT

Cows eat grass, which is mostly cellulose, but cows make no enzyme that can hydrolyze cellulose. How do they get energy from it?

(A) Their stomach acid is strong enough to break the bonds in cellulose without needing any enzyme to speed it up

(B) They chew it for so long that the chains fall apart into glucose, which is then absorbed from the cow's stomach

(C) Microorganisms living in their gut make the enzymes, hydrolyze the cellulose, and the cow absorbs what they produce

Decide before you look. Answer on page 24.

Key terms

Every term this guide defines, A to Z, with the chapter it is in. Cover the right-hand side and test yourself.

anabolism 03
The building up of large molecules from smaller ones, which uses energy. Dehydration synthesis is an example.

catabolism 03
The breaking down of large molecules into smaller ones, which releases energy. Hydrolysis is an example.

cellulose 06
An unbranched polymer of beta glucose, the main material of plant cell walls.

chitin 06
A structural polysaccharide of a modified glucose that carries nitrogen; it makes the cell walls of fungi and the exoskeletons of insects and crustaceans.

dehydration synthesis 02
A reaction that joins two monomers with a covalent bond and releases a molecule of water. Also called a condensation reaction.

disaccharide 04
Two monosaccharides joined by a glycosidic bond, such as sucrose, lactose or maltose.

glycogen 05
The energy store of animals and fungi: a highly branched polymer of glucose, kept in liver and muscle cells.

glycosidic bond 04
The covalent bond between two sugar units, formed by dehydration synthesis.

hydrolysis 03
A reaction that breaks the covalent bond between two monomers by adding a molecule of water: its H goes to one monomer and its OH to the other.

isomers 04
Molecules with the same formula but a different arrangement of their atoms.

macromolecules 01
A very large molecule, such as a polysaccharide, a protein or a nucleic acid.

metabolism 03
All the chemical reactions in an organism.

microfibrils 06
Bundles of cellulose chains held together by hydrogen bonds; very strong when pulled.

monomers 01
One of the small units that join to make a polymer, such as a glucose unit in starch or an amino acid in a protein.

monosaccharides 04
A single sugar unit, the monomer of carbohydrates, such as glucose, fructose or galactose.

polymers 01
A large molecule made of many similar small units, the monomers, joined in a chain by covalent bonds.

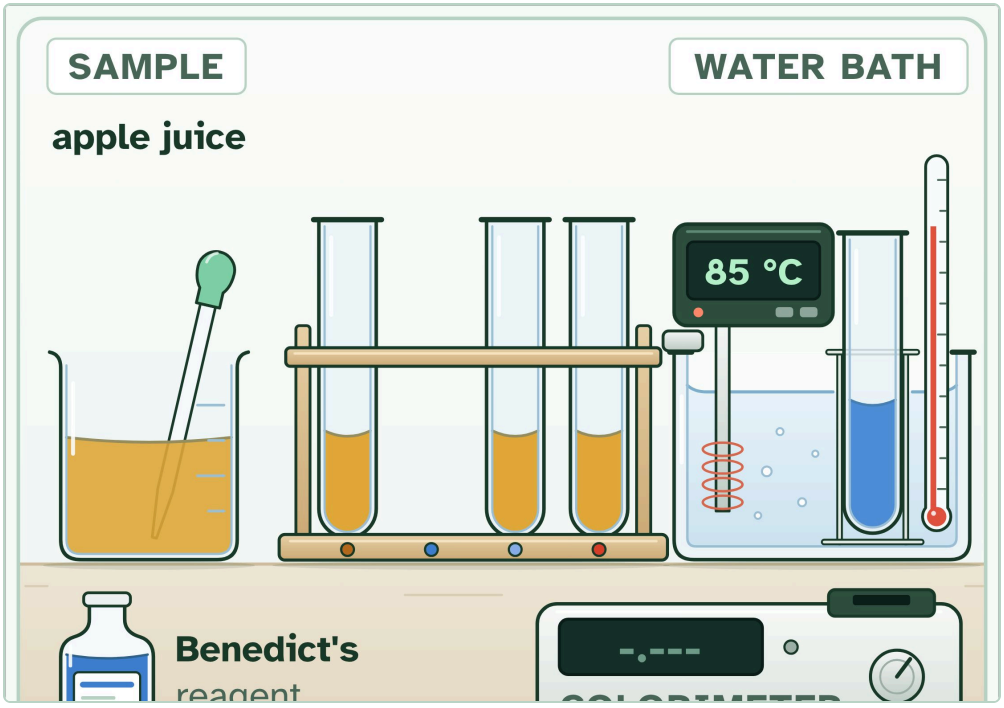
polysaccharide 04
A polymer of many monosaccharides: starch, glycogen and cellulose are examples.

reducing sugars 04
A sugar that can give electrons to copper ions in Benedict's reagent, turning it from blue to green, orange or red when heated.

starch 05
The energy store of plants: chains of glucose, some coiled and unbranched (amylose), some coiled and branched (amylopectin).

Dry lab: *Test the food*

Four tests, nine foods and controls, a set of glucose standards and two unknowns. Work out what each color means, then what the unknowns contain.



Run it online: change the variables, run the trials, and the table and graph fill in as you go.
`biologybybradford.com/guides/ap-biology-unit-1-macromolecules-and-carbohydrates#lab`

Your question

Which large molecules does each food contain? And how much reducing sugar is in an unknown solution?

What you can change

The sample (water, glucose, sucrose, starch, egg white, oil, milk, apple juice, potato, five glucose standards and two unknowns), the test (iodine, Benedict's, biuret, Sudan III), and for Benedict's whether to heat and whether to boil with acid first.

What to record

The color each test gives with each sample, and for heated Benedict's tubes the absorbance from the colorimeter. Every result is compared with water, the control.

Find out

- **Controls first.** Run every test on water. Write down the color each reagent stays when there is nothing for it to find.
- **Build a key.** Run each test on glucose, sucrose, starch, egg white and oil. Which test picks out which molecule? Which sugar does not change Benedict's?
- **Real foods.** Test milk, apple juice and potato with all four. What does each contain?
- **Hydrolyze it.** Test sucrose with Benedict's again, boiled with acid first. What changed, and why?
- **How much sugar?** Heat each glucose standard with Benedict's and read it in the colorimeter. Read unknown X the same way and find its glucose on the curve.
- **The unknowns.** Tick what X and Y contain, then check.

Record

- A table: one row a sample, one column a test, the color in each box.
- For Benedict's: heated or not, acid first or not, and the absorbance.
- A calibration curve of absorbance against glucose concentration, with the unknown's reading on it.

Your question Which large molecules does each food contain? And how much reducing sugar is in an unknown solution?**What you can change**The sample (water, glucose, sucrose, starch, egg white, oil, milk, apple juice, potato, five glucose standards and two unknowns), the test (iodine, Benedict's, biuret, Sudan III), and for Benedict's whether to heat and whether to boil with acid first.**What to record**The color each test gives with each sample, and for heated Benedict's tubes the absorbance from the colorimeter. Every result is compared with water, the control.

Back to monomers and polymers

Glucose, sucrose and starch are all carbohydrates, yet no two gave the same results with iodine and Benedict's. Use your results to explain why, and what the acid did to the sucrose.

QUESTIONS ON THE LAB

QUESTION 1

Benedict's stayed blue with sucrose, but turned brick red after the sucrose was boiled with acid and neutralized. What did the acid do?

(A) It made the reagent more sensitive, so a sugar too weak to see before could now change the color in the tube

(B) It hydrolyzed the glycosidic bond, so the sucrose became glucose and fructose, which are reducing sugars

(C) It joined the sucrose molecules together by dehydration synthesis, and the longer chains reduced the copper

Answer on page 25.

QUESTION 2

Potato turned iodine blue-black but gave only a green Benedict's result. What does that say about how a potato stores its sugar?

(A) Most of its glucose is held as starch, a polymer, with only a little as free reducing sugar

(B) Its sugar is all sucrose, which is why the Benedict's turned green instead of brick red

(C) It holds no sugar at all, and the iodine and Benedict's are both reacting with its protein

Answer on page 25.

QUESTION 3

Milk gave a brick-red Benedict's result, a purple biuret result and red droplets with Sudan III. Which of its molecules is the reducing sugar?

(A) Sucrose, the same sugar as in table sugar, which cows make in their udders from the grass they eat

(B) Glycogen, the store of glucose that animals make, which is carried into milk from the cow's liver

(C) Lactose, a disaccharide of glucose and galactose, which is a reducing sugar even before it is hydrolyzed

Answer on page 25.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on 1.3 and 1.4 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?program=ap&units=U1&ced=1.3,1.4&paper=quiz&marks=15&src=ep

Answers

PREDICTIONS IN THE CHAPTERS

01 A student says DNA, starch, a protein and a fat are all polymers. Which one breaks the rule, and why?

B **The fat, because it is one glycerol joined to three fatty acids, not a long chain of similar units repeated**

The fat. A polymer is a chain of many similar monomers. DNA's nucleotides differ in their bases but are all built the same way, and a protein's amino acids are joined in a chain before it folds. A fat has only four parts, one glycerol and three fatty acids, joined to each other but not repeated.

02 Ten glucose molecules are joined into one unbranched chain. How many water molecules were released?

C **9**

Nine. One water leaves for every bond, and a chain of ten units has nine bonds between them.

03 A starch molecule of 300 glucose units, in one unbranched chain, is digested completely to glucose. How many water molecules does that use?

B **299**

299. A chain of 300 units has 299 bonds, and hydrolysis uses one water for each. It is the same number of waters that were released when the chain was built.

04 Glucose and fructose are both $C_6H_{12}O_6$. Sucrose, made from one of each, is $C_{12}H_{22}O_{11}$. Why is it not $C_{12}H_{24}O_{12}$?

B **Joining them released one molecule of water, H_2O, taking two hydrogens and one oxygen from the pair**

A water molecule left. $C_{12}H_{24}O_{12}$ minus H_2O is $C_{12}H_{22}O_{11}$: dehydration synthesis, one water for the one glycosidic bond. Hydrolyze sucrose and the water goes back in, giving one glucose and one fructose.

05 An unbranched starch chain and a glycogen molecule hold the same number of glucose units. A sprinter's muscles suddenly need glucose. Which store can release it faster?

C **The glycogen, because its many branches give enzymes many ends to work on at the same time**

Glycogen. Enzymes take glucose off the ends of chains, one unit at a time. A heavily branched molecule has many ends, so many enzymes can work on it at once. That suits animals, which may need glucose in seconds.

06 Cows eat grass, which is mostly cellulose, but cows make no enzyme that can hydrolyze cellulose. How do they get energy from it?

C **Microorganisms living in their gut make the enzymes, hydrolyze the cellulose, and the cow absorbs what they produce**

Microorganisms do it. A cow's rumen holds huge numbers of bacteria and other microbes that make cellulose-digesting enzymes. They break the cellulose down and the cow lives largely on the products of their work. Chewing only breaks the grass into smaller pieces, with more surface for the microbes.

QUESTIONS ON THE DRY LAB

Q1 Benedict's stayed blue with sucrose, but turned brick red after the sucrose was boiled with acid and neutralized. What did the acid do?

B **It hydrolyzed the glycosidic bond, so the sucrose became glucose and fructose, which are reducing sugars**

Hydrolysis. Sucrose is a disaccharide, and the way its two units are joined leaves it unable to reduce Benedict's. Boiling with acid splits the bond with water, freeing glucose and fructose, and both are reducing sugars. Neutralizing matters because Benedict's works only when the mixture is alkaline.

Q2 Potato turned iodine blue-black but gave only a green Benedict's result. What does that say about how a potato stores its sugar?

A **Most of its glucose is held as starch, a polymer, with only a little as free reducing sugar**

As starch. A potato tuber is a store: glucose is packed away as starch, which is insoluble and stays put, and only a trace is free as reducing sugar. Leave a potato in the fridge for a few weeks and some of its starch is hydrolyzed to sugar, which is why cold-stored potatoes taste sweeter.

Q3 Milk gave a brick-red Benedict's result, a purple biuret result and red droplets with Sudan III. Which of its molecules is the reducing sugar?

C **Lactose, a disaccharide of glucose and galactose, which is a reducing sugar even before it is hydrolyzed**

Lactose. Unlike sucrose, lactose is a reducing sugar, so it changes Benedict's without hydrolysis. Milk is also about 3% protein (the biuret) and about 3.5% fat, held as tiny droplets (the Sudan III).

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.

Written and drawn for Biology by Bradford, biologybybradford.com. Free to print and share with a class.