Carbohydrates

BCH 100 – Introductory Biochemistry · Dr. Radi

By the end of this unit, you can…

- Classify monosaccharides (aldose/ketose, D/L, epimers, anomers) and convert Fischer ↔ Haworth projections
- Explain reducing sugars, glycosidic bonds, and the major di- and polysaccharides (maltose, lactose, sucrose, starch, glycogen, cellulose)
- Connect sugar chemistry to the body – glycation/HbA1c, lactose intolerance, cartilage GAGs, and ABO blood typing

Today's route

🗺️

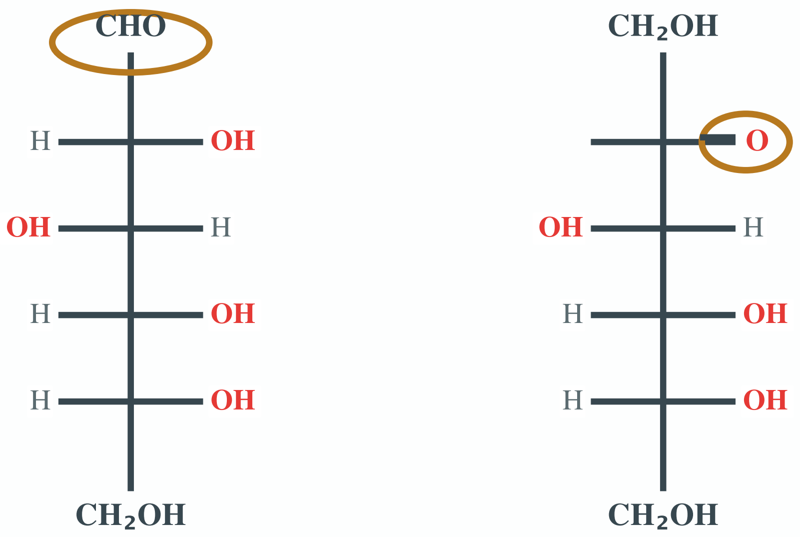
1. Monosaccharides – Structure & Stereochemistry
2. Fischer → Haworth – Drawing the Ring
3. Sugar Reactions – Reducing Sugars, Browning & Phosphates
4. Disaccharides & the Glycosidic Bond
5. Polysaccharides – Storage, Structure & Recognition

1 · Monosaccharides – Structure & Stereochemistry

"Name and classify the simple sugars – aldose vs ketose, D vs L, and the epimers that differ by a single –OH."

SUGAAAARRRR!

Carbohydrates are **$(CH_2O)_n$** – literally **hydrates of carbon**. The simplest ones, **monosaccharides**, come in two flavors by their carbonyl: an **aldose** carries an **–CHO** at the end, a **ketose** carries a **C=O** in the middle.



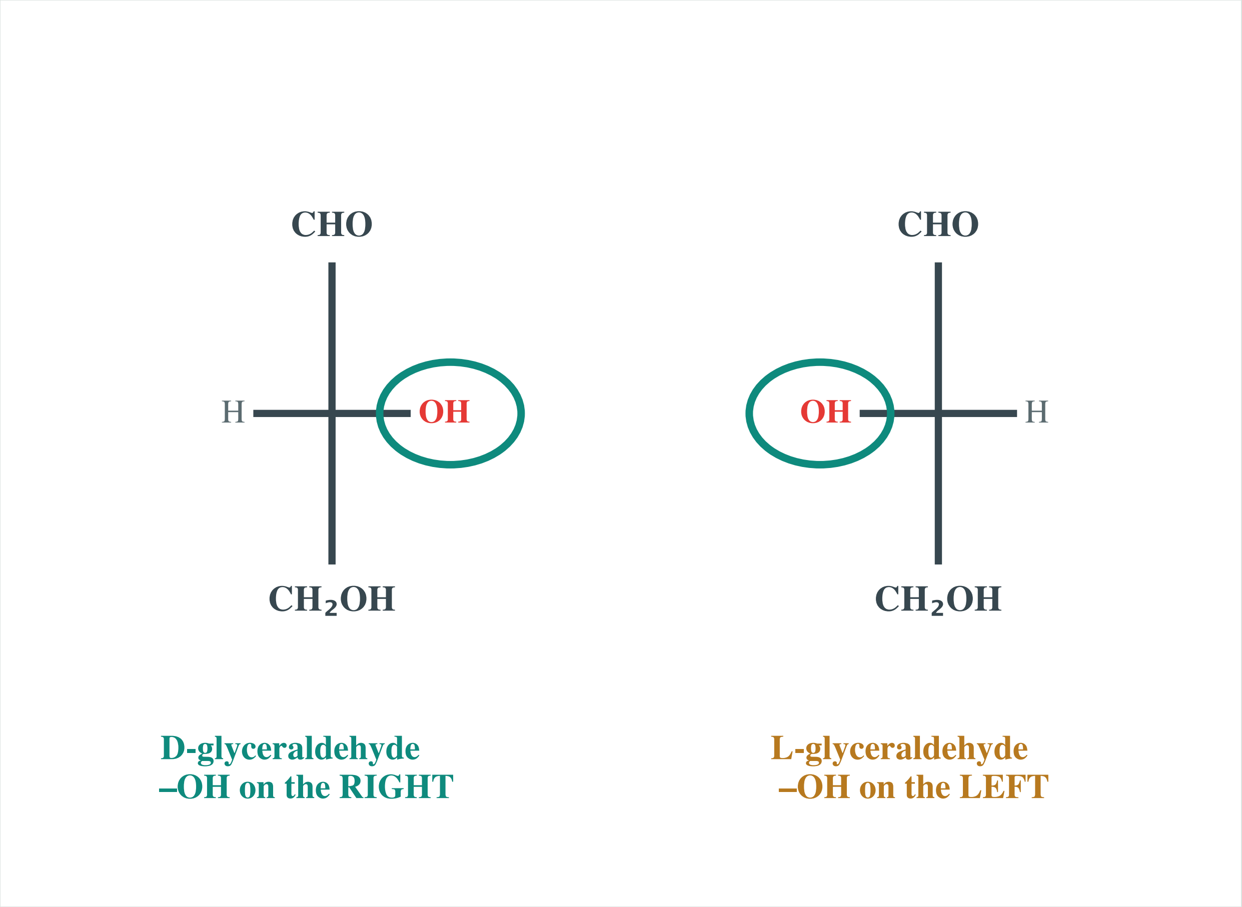
D-glucose
aldose (–CHO)

D-fructose
ketose (C=O)

💡 Glucose (aldose) and fructose (ketose) share the same formula, $C_6H_{12}O_6$ – same atoms, different shape, different taste.

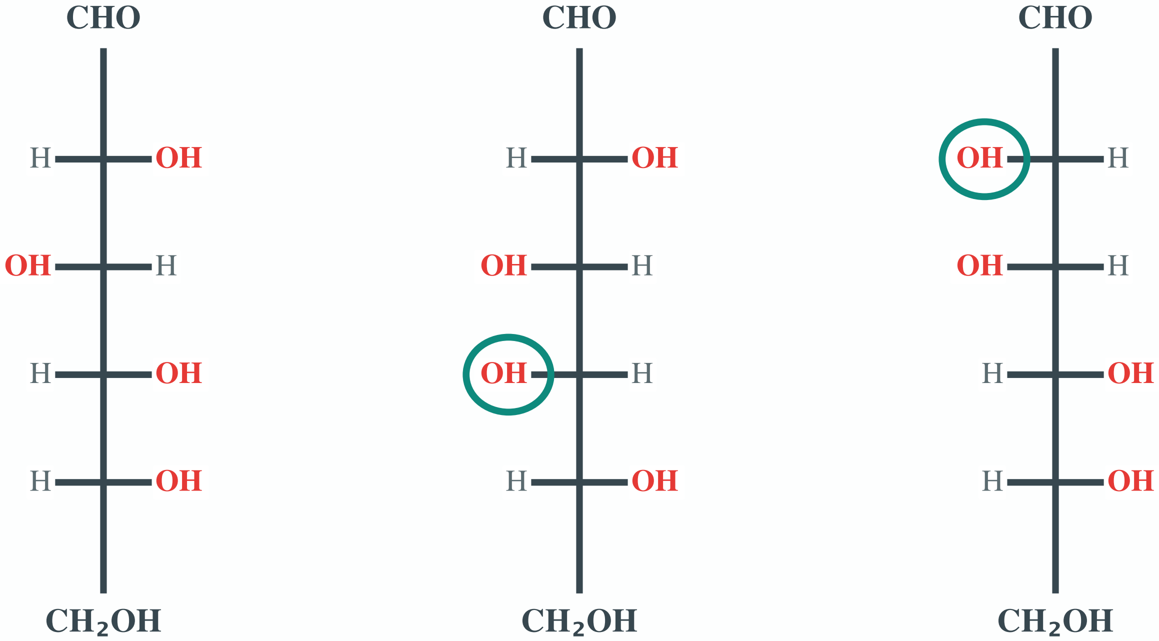
D or L? Look at the bottom chiral carbon

Sugars are chiral, and we anchor them to **glyceraldehyde**. The **–OH on the last stereocenter** decides it: on the **right = D**, on the left = L. **Almost every sugar in your body is D.**



Epimers: one –OH flipped

Change the configuration at **just one** carbon and you get an **epimer** – a different sugar with a different job. **Galactose** is glucose flipped at **C4**; **mannose** is glucose flipped at **C2**. That's it. One –OH.



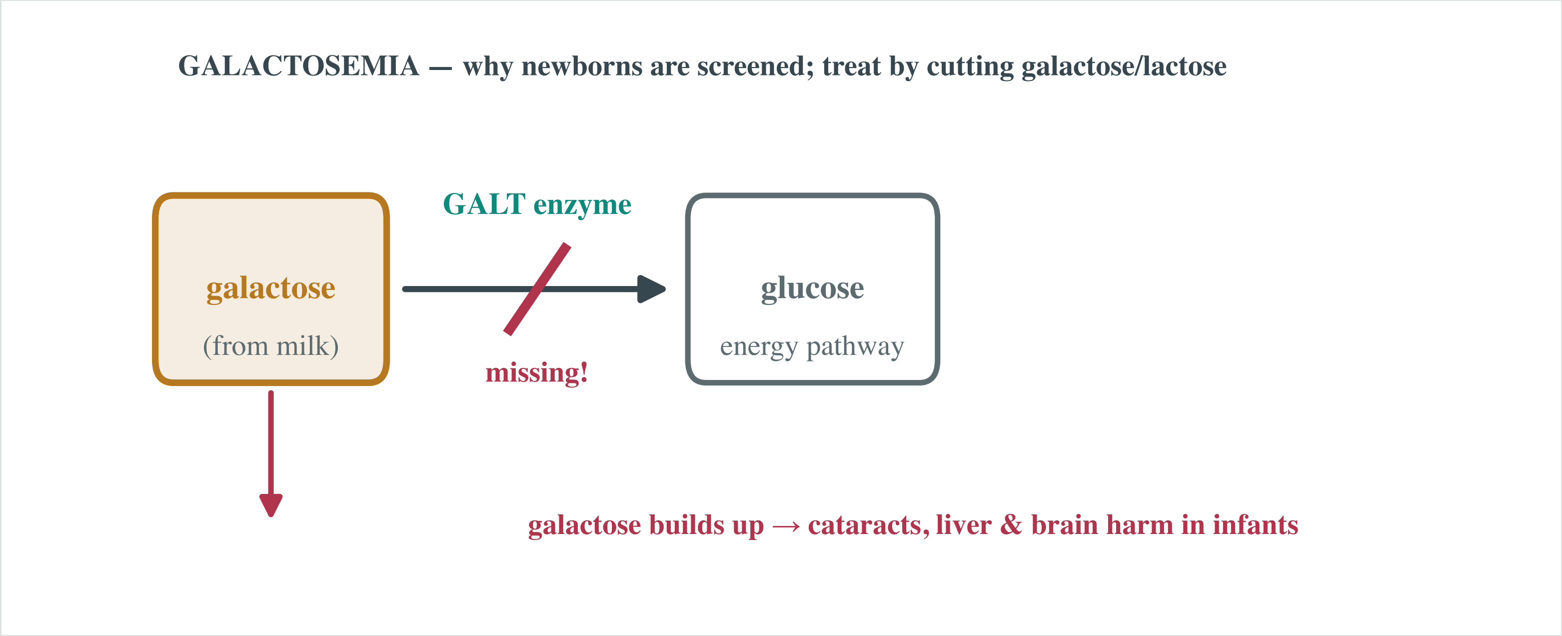
D-glucose
the reference

D-galactose
C4 epimer

D-mannose
C2 epimer

When a sugar can't be handled: galactosemia

Babies get **galactose** from milk (it's half of lactose). If the enzyme **GALT** is missing, galactose can't be turned into glucose – it **backs up** and poisons the infant (cataracts, liver and brain damage). That's why every newborn is screened.

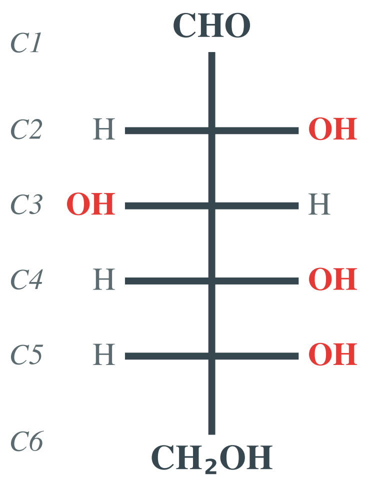


2 · Fischer → Haworth – Drawing the Ring

"Close the open chain into a ring and convert a Fischer projection to a Haworth – the right→down rule, and the α/β anomers it creates."

The Fischer projection

A **Fischer projection** draws the sugar as a straight vertical chain: **horizontal bonds come toward you, vertical bonds go back**. Number from the **carbonyl end** (that's C1). Glucose is an **aldohexose** – six carbons, aldehyde on top.

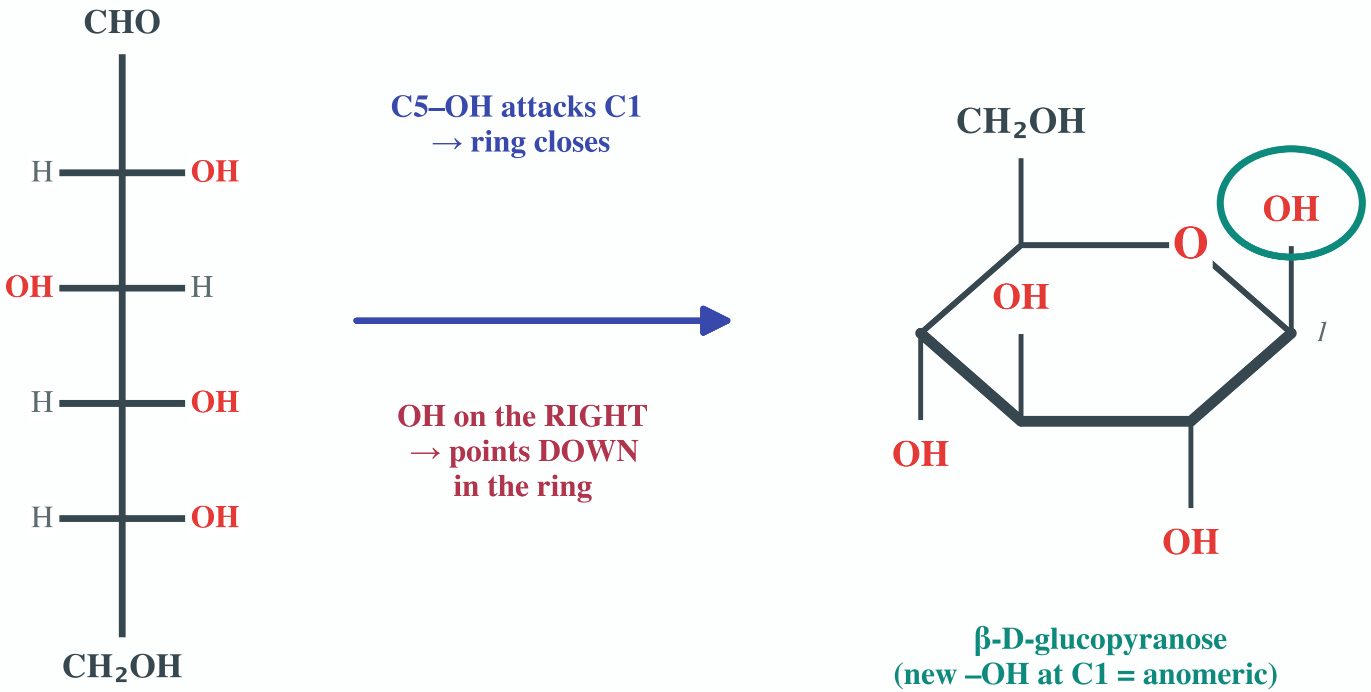


D-glucose · the –OH at C5 (right) makes it D

💡 **KNOW HOW TO DRAW GLUCOSE.** The –OH pattern (right, left, right, right) is worth memorizing.

Close the ring: Fischer → Haworth

In water the sugar curls up: **C5's –OH attacks C1**, making a six-membered ring (a **hemiacetal**). Converting is one rule – **an –OH on the RIGHT in Fischer points DOWN in the ring**. The C1 carbon is now brand-new and special: the **anomeric carbon**.

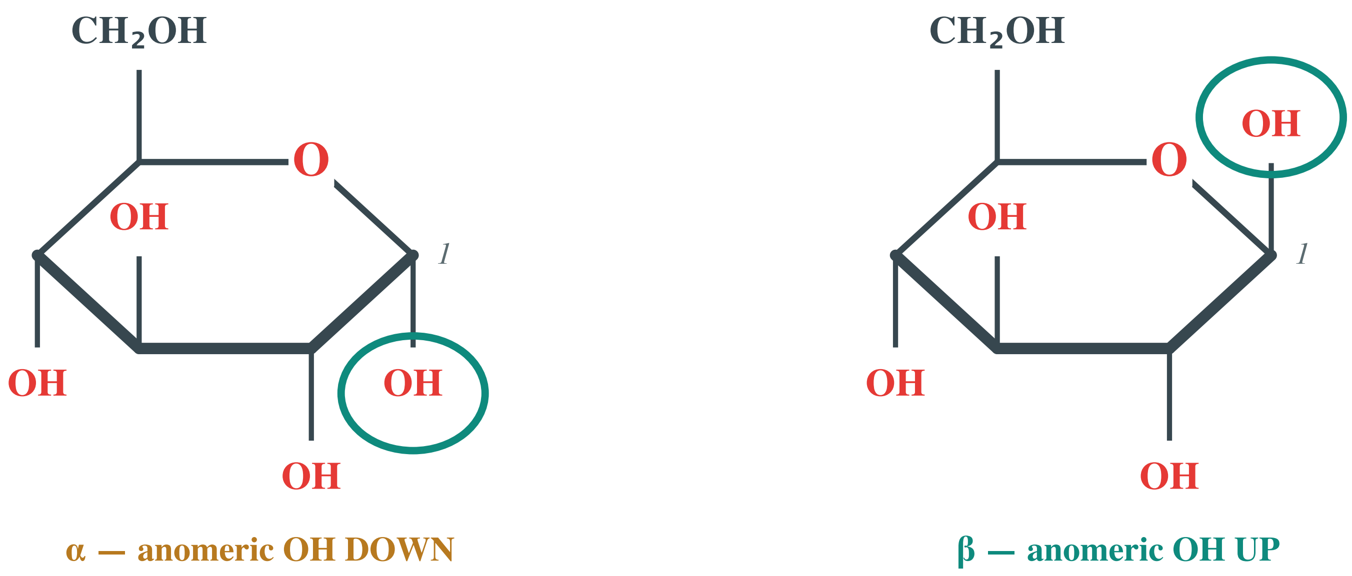


β-D-glucopyranose
(new –OH at C1 = anomeric)

α and β: the anomers

Closing the ring makes C1 a fresh stereocenter, so you get **two** versions. **α** puts the new -OH **down**; **β** puts it **up**. They freely interconvert in solution through the open chain – that's **mutarotation**.

same sugar, two anomers — they interconvert through the open chain (mutarotation)



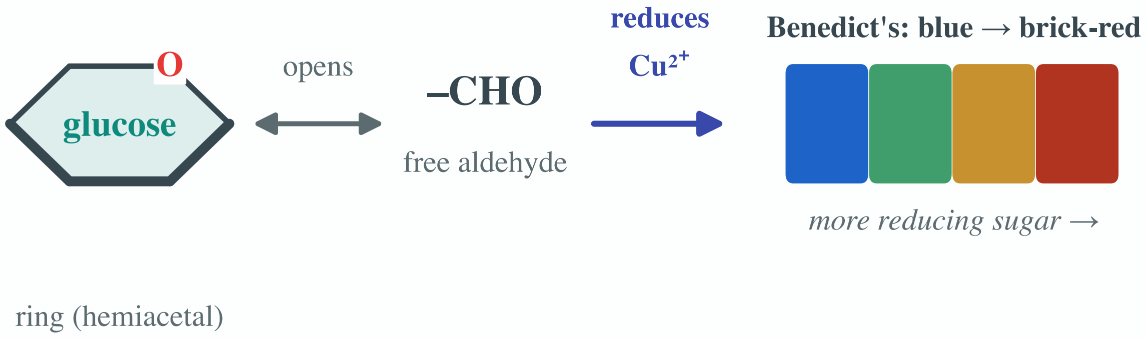
3 · Sugar Reactions – Reducing Sugars, Browning & Phosphates

"Follow what that free anomeric carbon does – reduce copper, brown your toast, glycate your hemoglobin, and pick up a phosphate."

Reducing sugars

If a sugar's **anomeric carbon is free**, the ring can pop open to a reactive **aldehyde** – and an aldehyde will **reduce Cu^{2+}**, turning blue **Benedict's** reagent brick-red. That's a **reducing sugar**. **Sucrose can't** (both anomeric carbons are tied up) – so it's **non-reducing**.

REDUCING SUGAR = a free anomeric carbon (sucrose has none → non-reducing)



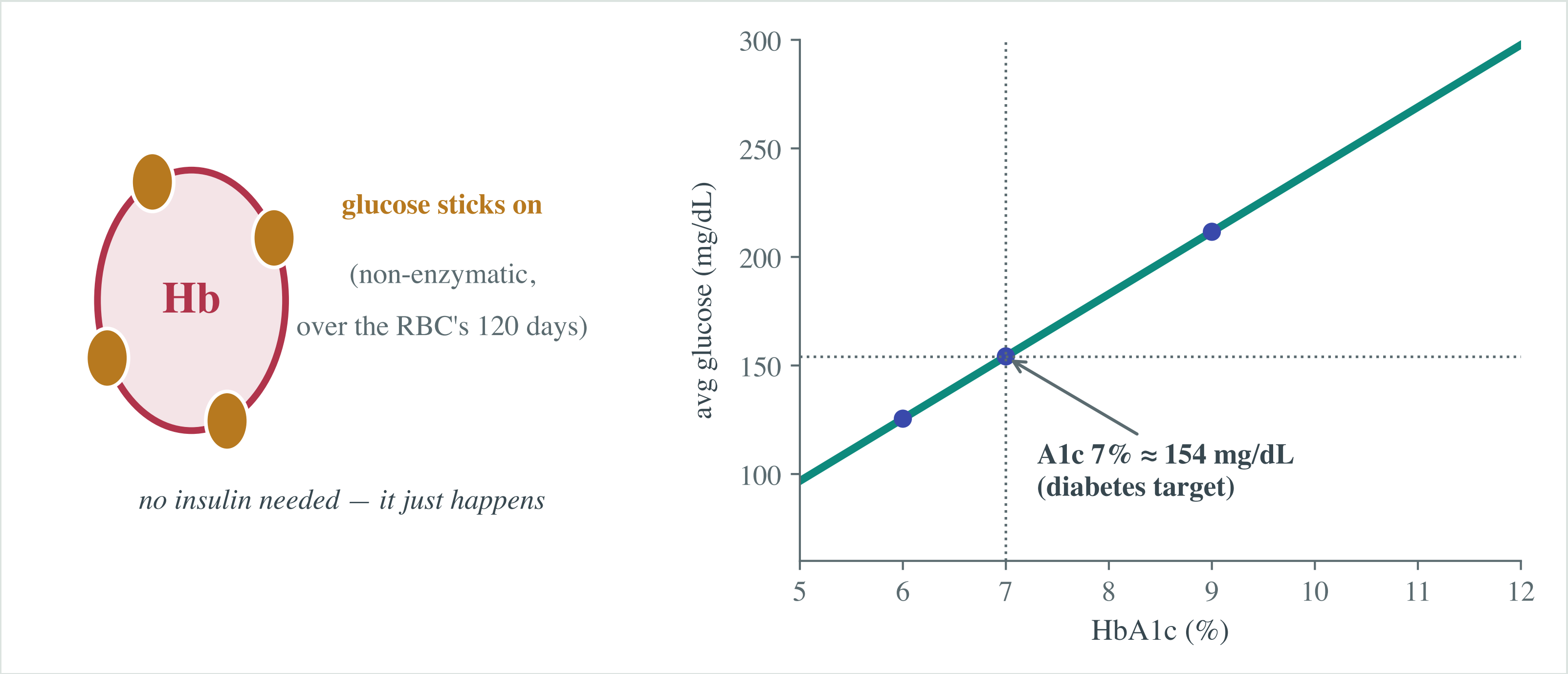
The Maillard reaction – why seared food is delicious

Heat a reducing sugar next to a protein's **$-NH_2$** and they fuse into **brown, savory melanoidins**: the crust on bread, the sear on a steak. Same chemistry, no enzyme needed.

💡 Delicious in the pan – but the exact same reaction quietly runs on the proteins inside you (that's HbA1c).

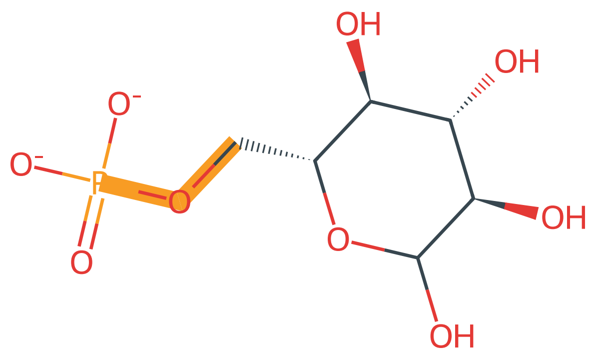
HbA1c: sugar on your hemoglobin

Glucose sticks onto **hemoglobin** all on its own – no enzyme. Since a red cell lives **~120 days**, the **% of glycated Hb (HbA1c)** reports your **average** blood sugar over months. An A1c of **7%** works out to about **154 mg/dL** – the diabetes target.



Sugar phosphates

Bolt a **phosphate** onto a sugar's –OH and you make a **phosphoester** – like **glucose-6-phosphate**. The charge **traps it inside the cell** (no sneaking back across the membrane) and **primes it** for metabolism. Every sugar entering a pathway gets tagged this way.

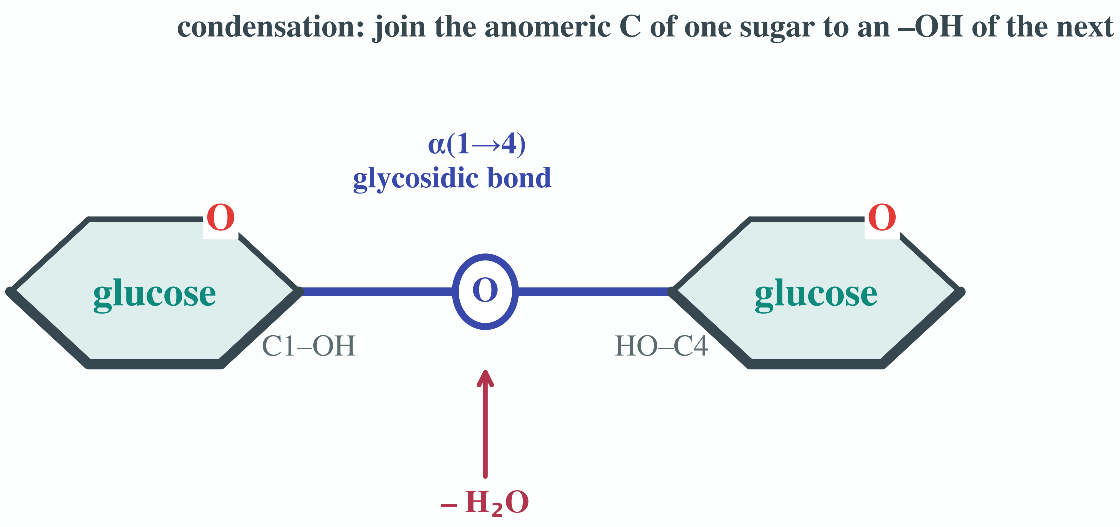


4 · Disaccharides & the Glycosidic Bond

"Join two sugars with a glycosidic bond and meet the big three – maltose, lactose, and sucrose."

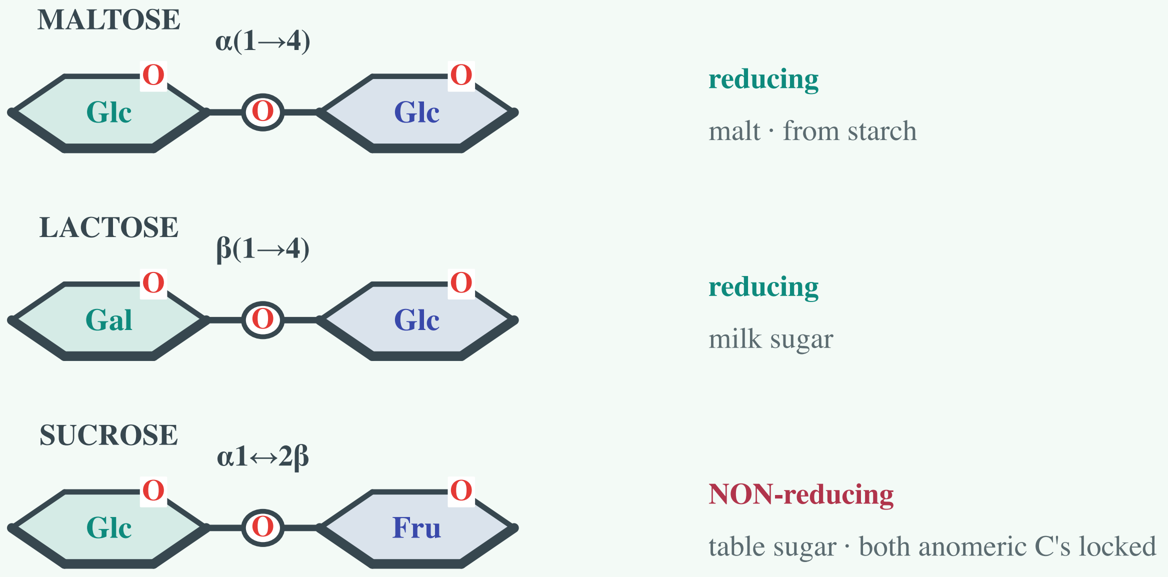
The glycosidic bond

Link two sugars by joining the **anomeric carbon** of one to an **–OH** of the other, kicking out a **water**. That's a **glycosidic bond**. Its flavor – **α or β** – is set by the anomer you started from, and it decides everything about the chain you build.



The big three disaccharides

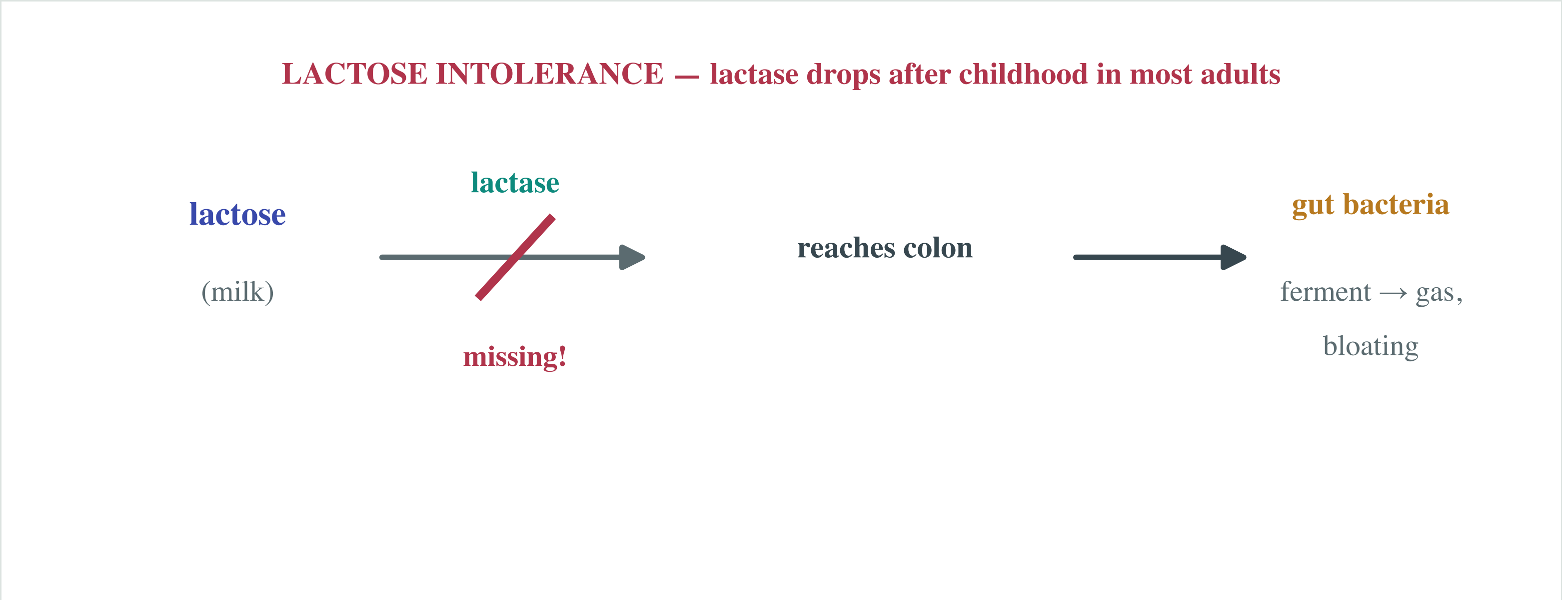
Maltose = Glc–Glc, **α(1→4)**; **lactose** = Gal–Glc, **β(1→4)**; **sucrose** = Glc–Fru, joined **anomeric-to-anomeric**. That last link locks **both** anomeric carbons – so sucrose is the one that's **non-reducing**.



💡 **KNOW ALL THREE:** the sugars, the linkage, and does it still reduce?

Lactose intolerance

To absorb lactose you need **lactase** to cut it. In most adults lactase **fades after childhood** – so lactose sails on to the **colon**, where bacteria ferment it into **gas and bloating**. Not an allergy: just a missing enzyme.



5 · Polysaccharides – Storage, Structure & Recognition

"Scale up to thousands of sugars: starch and glycogen for storage, cellulose for strength, and the sugar coats that ID your cells."

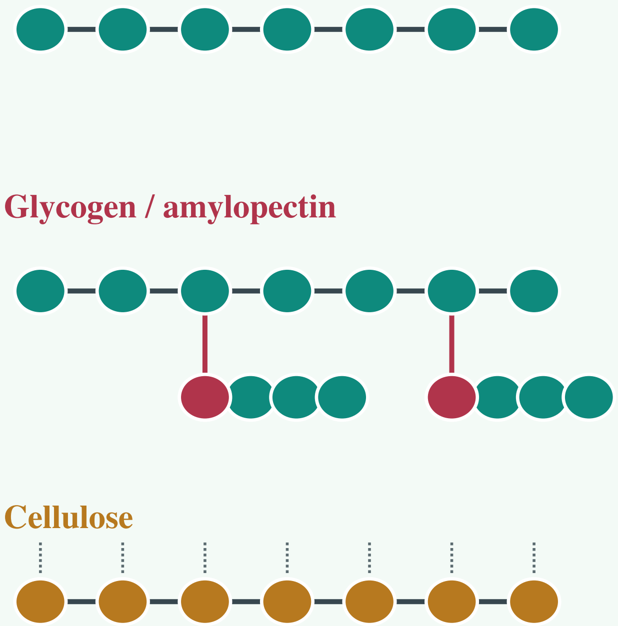
Same glucose, very different jobs

String glucose together and the **linkage** decides everything. **Starch** and **glycogen** use **α(1→4)** chains with **α(1→6)** branches – easy to build and break for fuel. **Cellulose** uses straight **β(1→4)**, H-bonded into fibers we **can't digest**.

Amylose (starch)

Glycogen / amylopectin

Cellulose



linear α(1→4) — coils into a helix

α(1→4) chains + α(1→6) branches

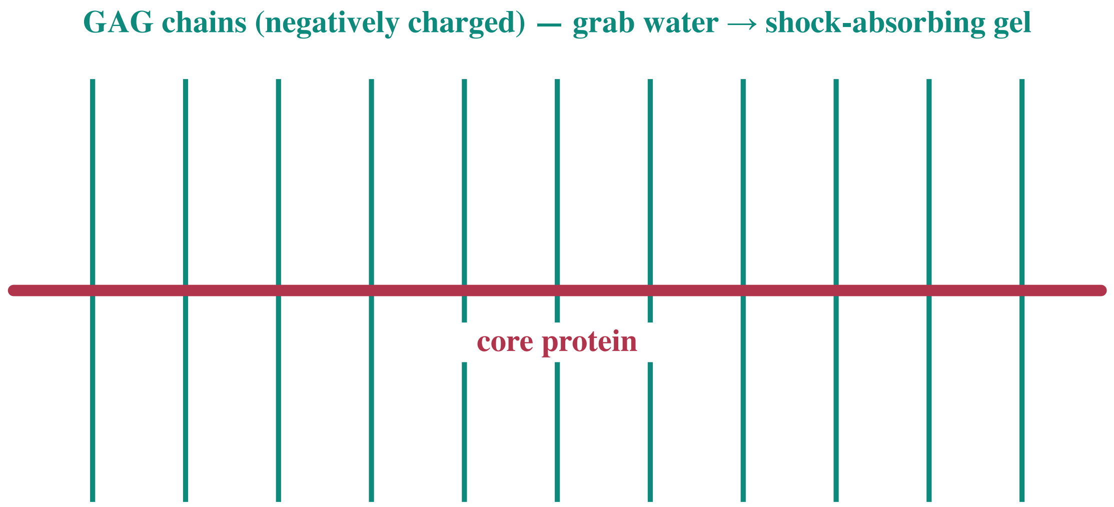
many ends = fast glucose release

straight β(1→4) — H-bonds into tough fibers

we can't digest β — no enzyme for it

Sugars that cushion: cartilage

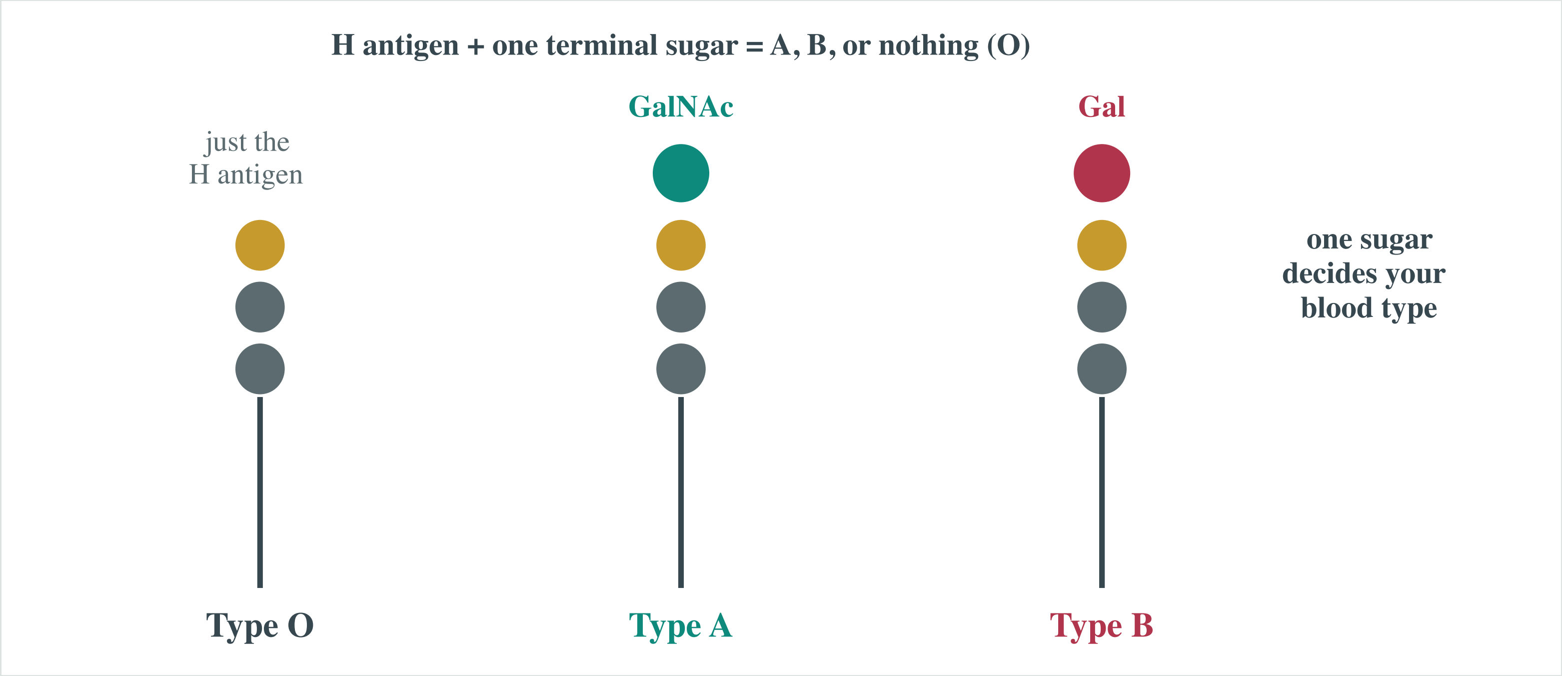
Not all sugar is fuel. In **cartilage**, a core protein bristles with **glycosaminoglycan (GAG)** chains – a molecular **bottlebrush**. Those chains are **negatively charged**, so they pull in water and swell into a **shock-absorbing gel** that cushions your joints.



aggrecan in cartilage: the bottlebrush that cushions your joints

Sugars that ID you: blood type

Your **ABO blood type** is a **sugar**. Red cells carry a short glycan ending in the **H antigen**; add one terminal sugar and you're set – **GalNAc → type A**, **galactose → type B**, **neither → type O**. Transfuse the wrong one and the immune system attacks that sugar.



Can you…?

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- ☐ explain reducing sugars, glycosidic bonds, and the major di- and polysaccharides (maltose, lactose, sucrose, starch, glycogen, cellulose)?
- ☐ connect sugar chemistry to the body – glycation/HbA1c, lactose intolerance, cartilage GAGs, and ABO blood typing?

If any box stays empty, the practice site has a drill for it. 🧪