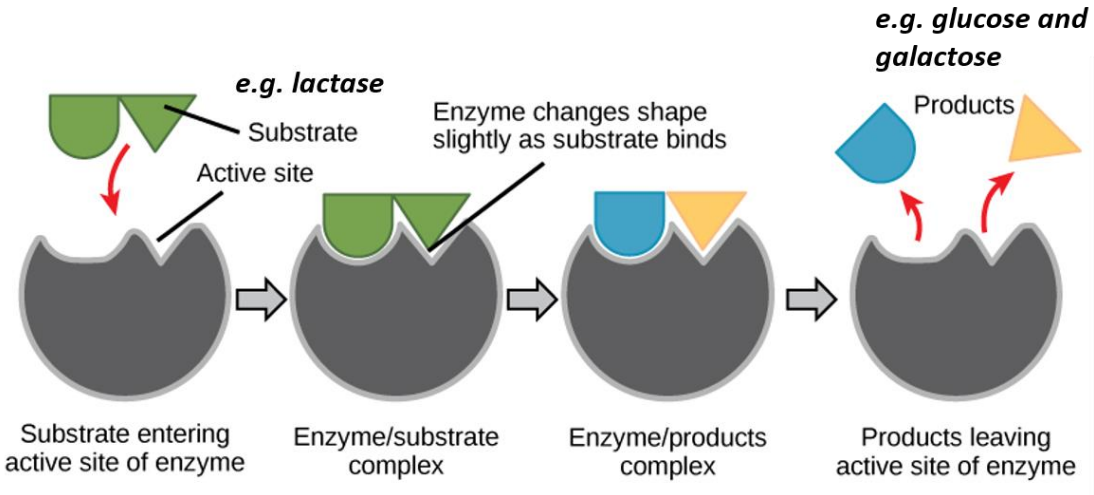
7. Lactase enzyme and lactose intolerance: Solutions

7.1 Enzyme lactase and lactose intolerance

What does lactase do and how?

In a way, enzymes are the main "workhorses" of metabolism: they catalyse all the life-sustaining chemical reactions, allowing them to proceed much faster than they otherwise would. You might have learned the basics of how enzymes work in your studies. Here we will consider a specific example, a well-known enzyme, lactase.



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7.2 Lactase in action in "real life"

Please see below a description of an experiment involving lactase and two different types of milk, as well as the photo results of the experiment. Answer the questions to interpret results.

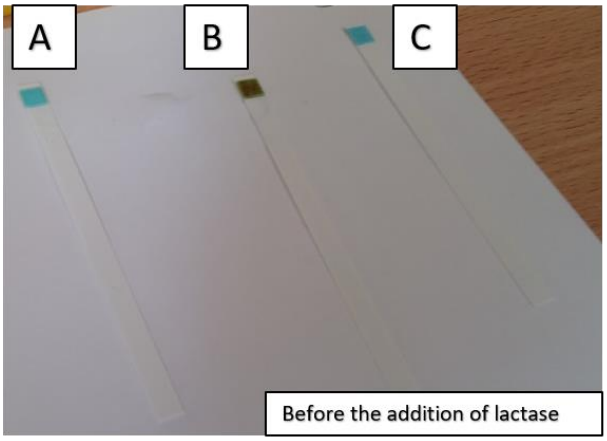
Materials:

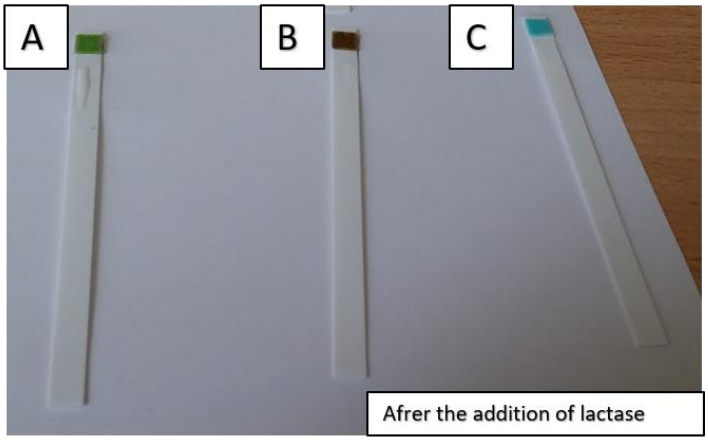
1) Sugar (sucrose) solution in water, 25g/L
2) Milk, ordinary semi-skimmed
3) Milk, lactose-free
4) Lactase solution, 20g/L
5) Glucose test strips

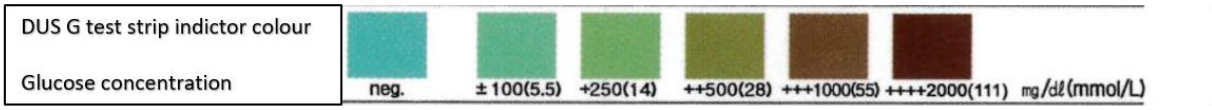
Experimental procedure:

1) 10ml of sucrose solution, ordinary milk and lactose-free milk were poured into separate test tubes.
2) A new glucose indicator test strip was submerged into each test tube for 30 sec. The strips were taken out onto a white piece of paper, and photos of them taken 1 min afterwards.
3) 1ml of lactase solution was added to each test tube and the solution gently mixed
4) Step 2) was repeated to measure glucose concentration after the addition of lactase.

Results:







1. Identify which sample (sucrose solution, ordinary milk or lactose-free milk) correspond to letters A, B, C.

A. *Ordinary milk*
B. *Lactose-free milk*
C. *Sucrose solution*

2. Interpret the results: for each sample. Why do you think we see these levels of glucose before and after the addition of lactase? Why do they change upon the addition of lactose in some cases and stay constant in others?

a) *For ordinary milk:*
(Hint question: which sugar(s) does milk contain – based on your knowledge and the experiment?)

Milk contains lactose, which is a disaccharide of glucose and galactose (as seen on the schematic in the first section). Before the addition of lactase, the glucose indicator was blue (negative), indicating that there is no free glucose in milk. Once the enzyme was added, it started breaking down lactose, "freeing up" the glucose. After 1 min of this reaction, about 300 mg/dL glucose was released.

b) *For lactose-free milk:*
(Hint question: How do you think this milk is made?)

The indicator strip shows that there is a high concentration of glucose in lactose-free milk, about 2 g/dL. This does not change upon addition of lactase. Manufacturers of lactose-free milk are using the same enzyme, lactase, to "chew up" all the lactose in cow milk – in this process, glucose is released (as we see from a)), and its concentration is at maximum because the manufacturers have to make sure that all the lactose is removed (broken down).

c) *For sucrose solution:*
(Hint questions: Why was sucrose solution chosen to be tested in an experiment focused on lactase? What does it tell us about the enzyme?)

There was no glucose in the sucrose solution, neither before nor after the addition of lactase. Like lactose, sucrose is also a disaccharide containing glucose as one of its monosaccharide components, that is why it was chosen as a control for this experiment (lactose = glucose + galactose; sucrose = glucose + fructose). The fact that the glucose was not released upon addition of lactase shows that this enzyme, like the vast majority of others, is substrate-specific. This means even though reactions of sucrose and lactose breakdown are very similar, and both release glucose, lactase can recognise and break down only its specific substrate, lactose.

Lactose intolerance: additional resources

As you know, lactose-free milk and other lactose-free dairy products are manufactured primarily for lactose intolerant people. Lactose intolerance, or lactase non-persistence, is an interesting case study both from a human metabolism perspective, as well as from a population genetics prospective. Visit these resources to explore this topic further:

1) A 5-min video cartoon on lactose intolerance, with great introduction on how lactase works, and why you get specific symptoms when it does not: https://www.youtube.com/watch?v=_i2cclGYPx0

2) A short article explaining lactase persistence and several population and evolutionary genetics findings on this topic:
https://www.ucl.ac.uk/mace-lab/gallery/lactase