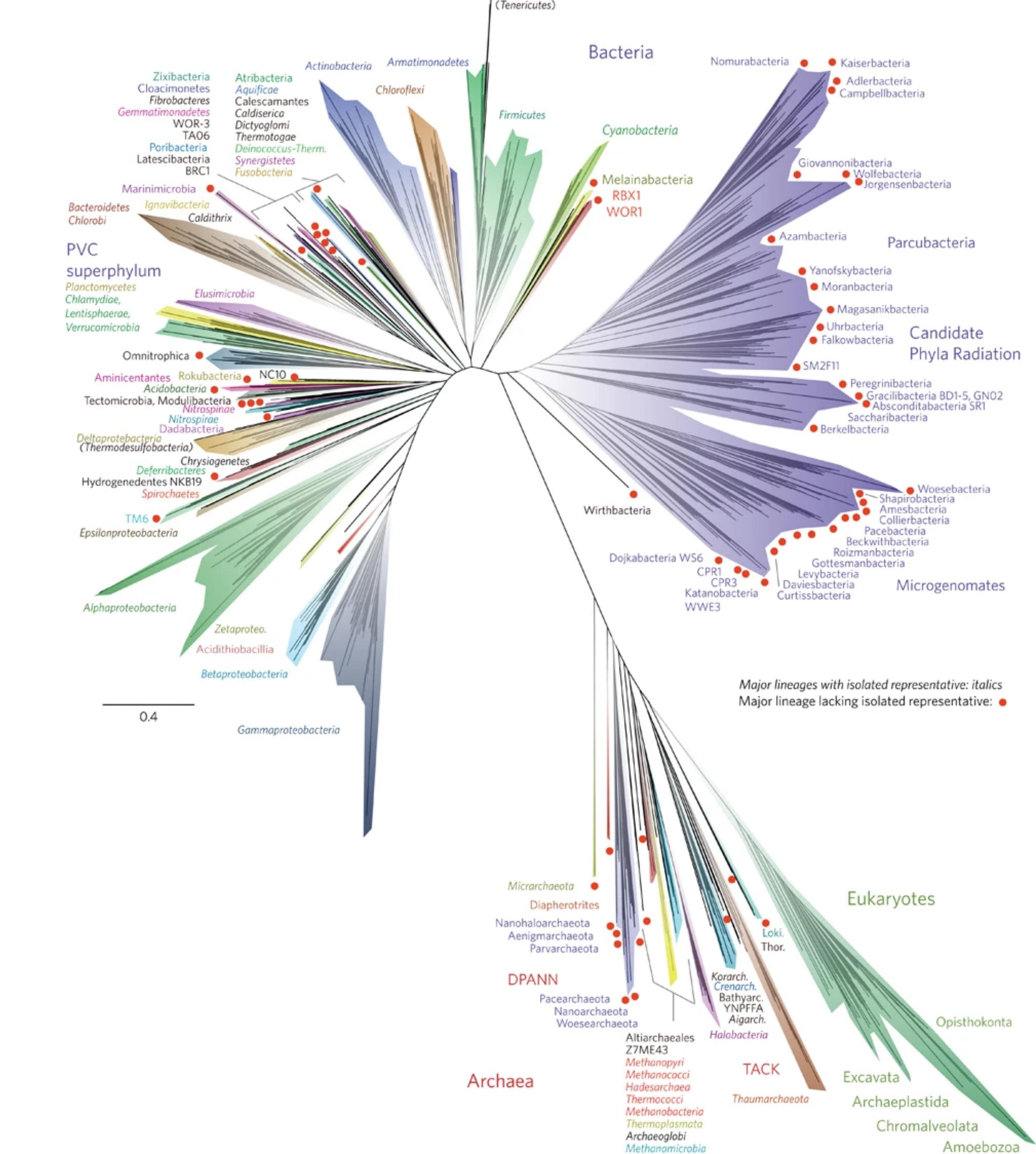


# **Quantitative Microbial Physiology**

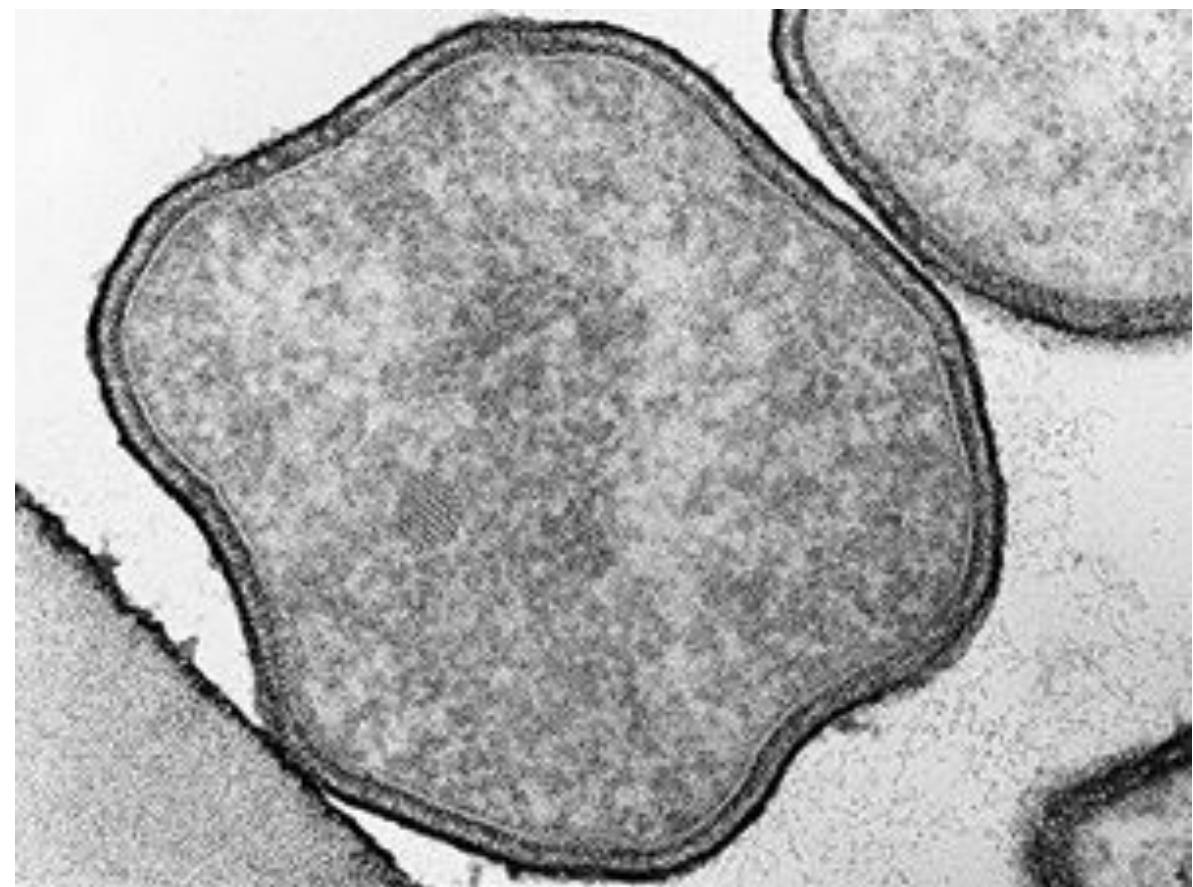
**Jacopo Grilli  
Lecture 1, Feb 17, 2025**

# Why microbes?

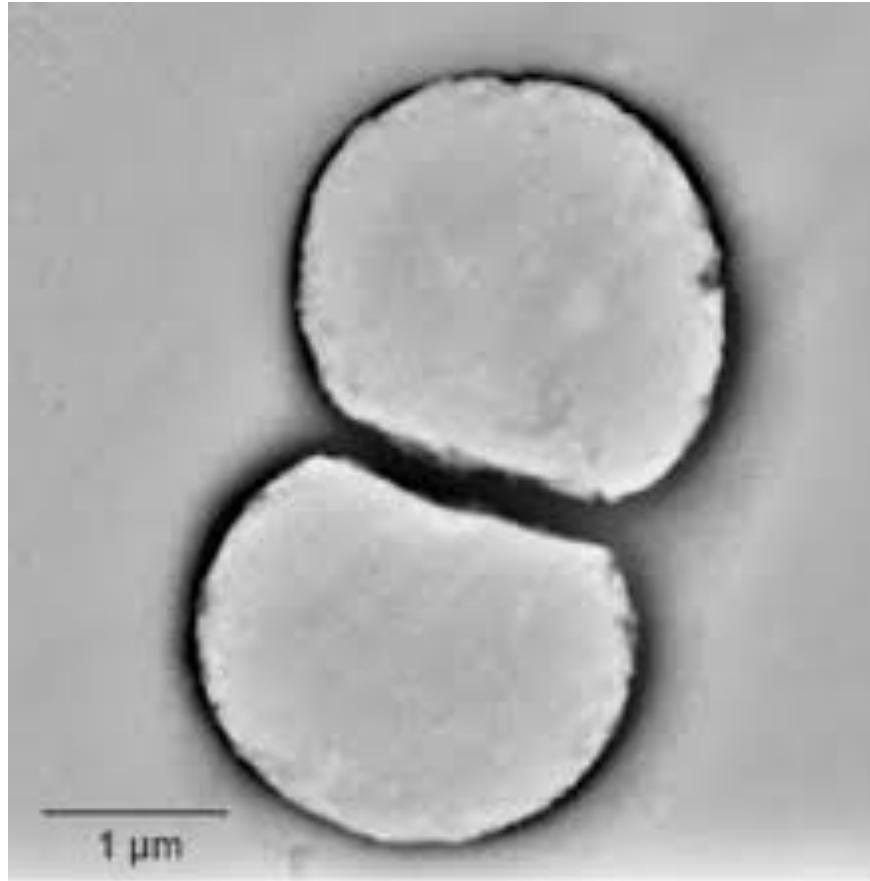
# Microbes are are extremely diverse



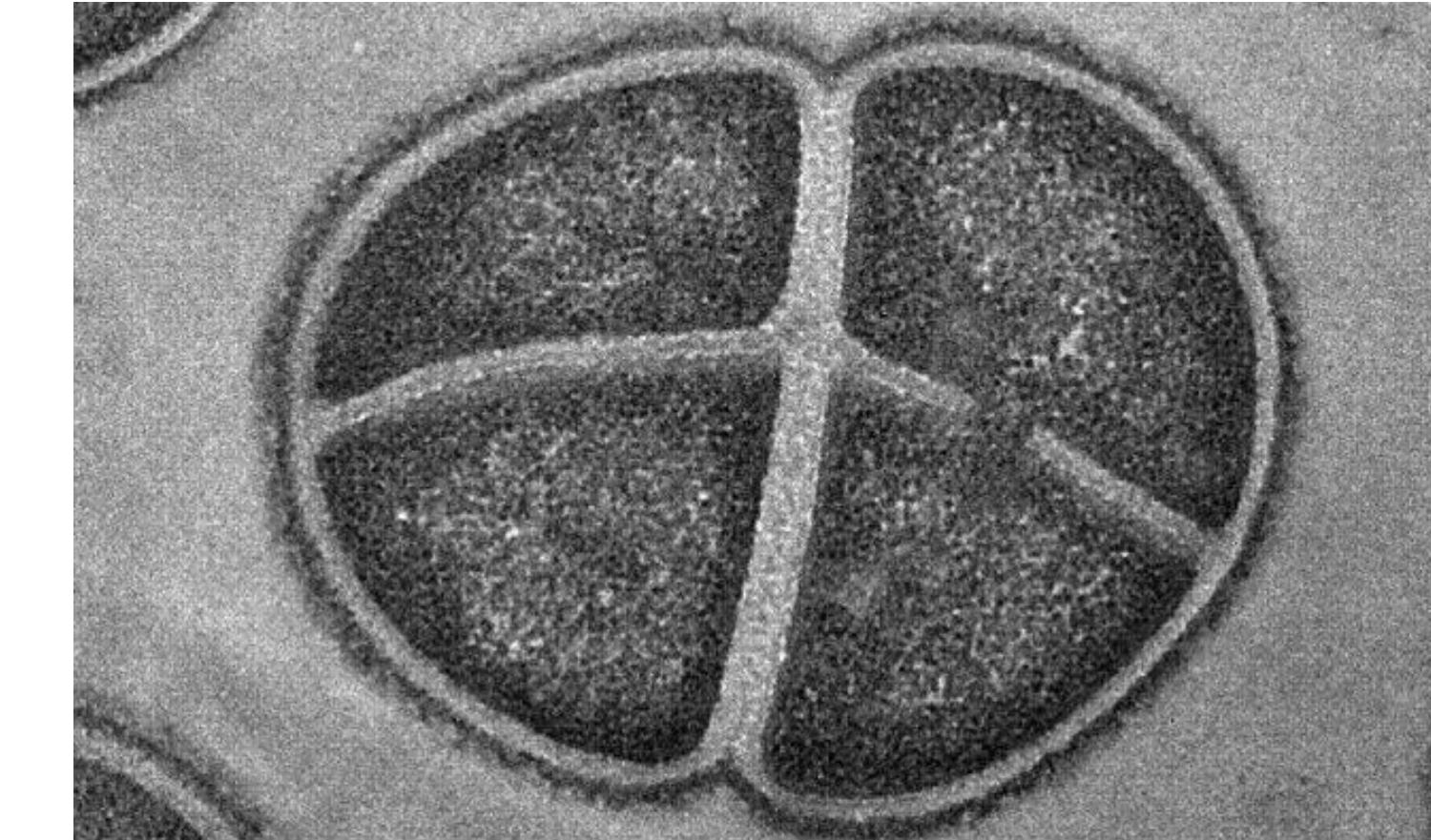
# Microbes are everywhere



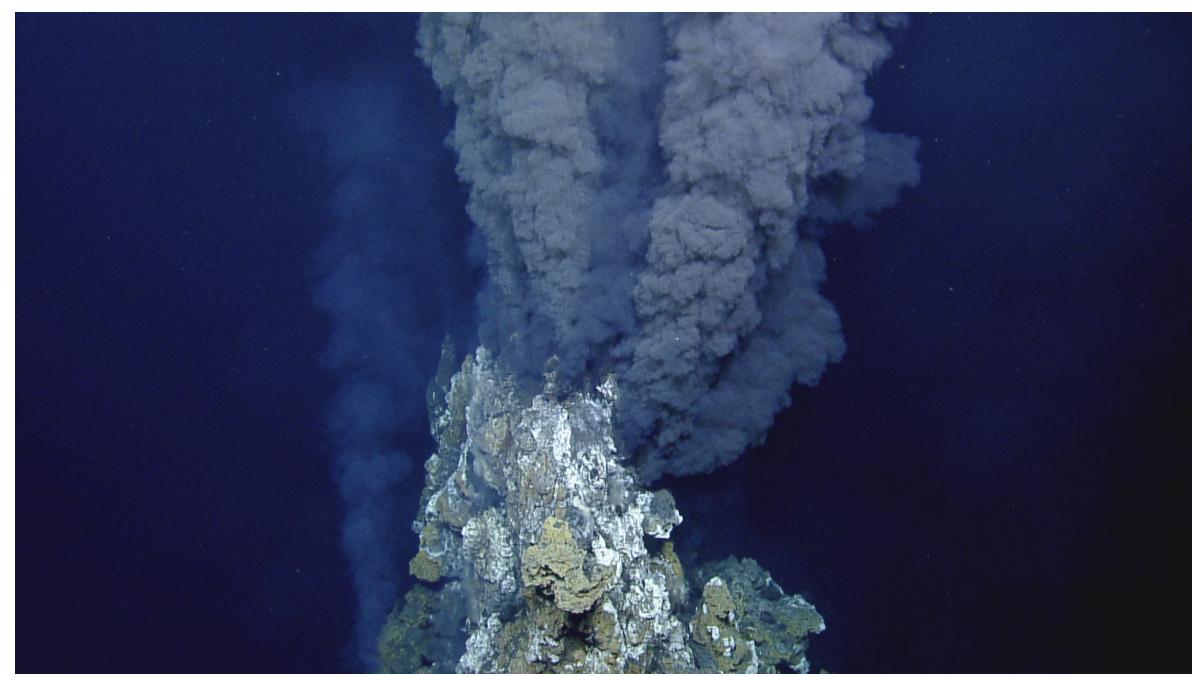
*Pyrolobus fumarii*  
optimal growth 106°C (60 mins)  
growth T in [90-113]°C  
in hydrothermal vents



*Picromyces torridus*  
optimal growth 60°C and  
pH 0.7 (6 hours)  
in hot springs



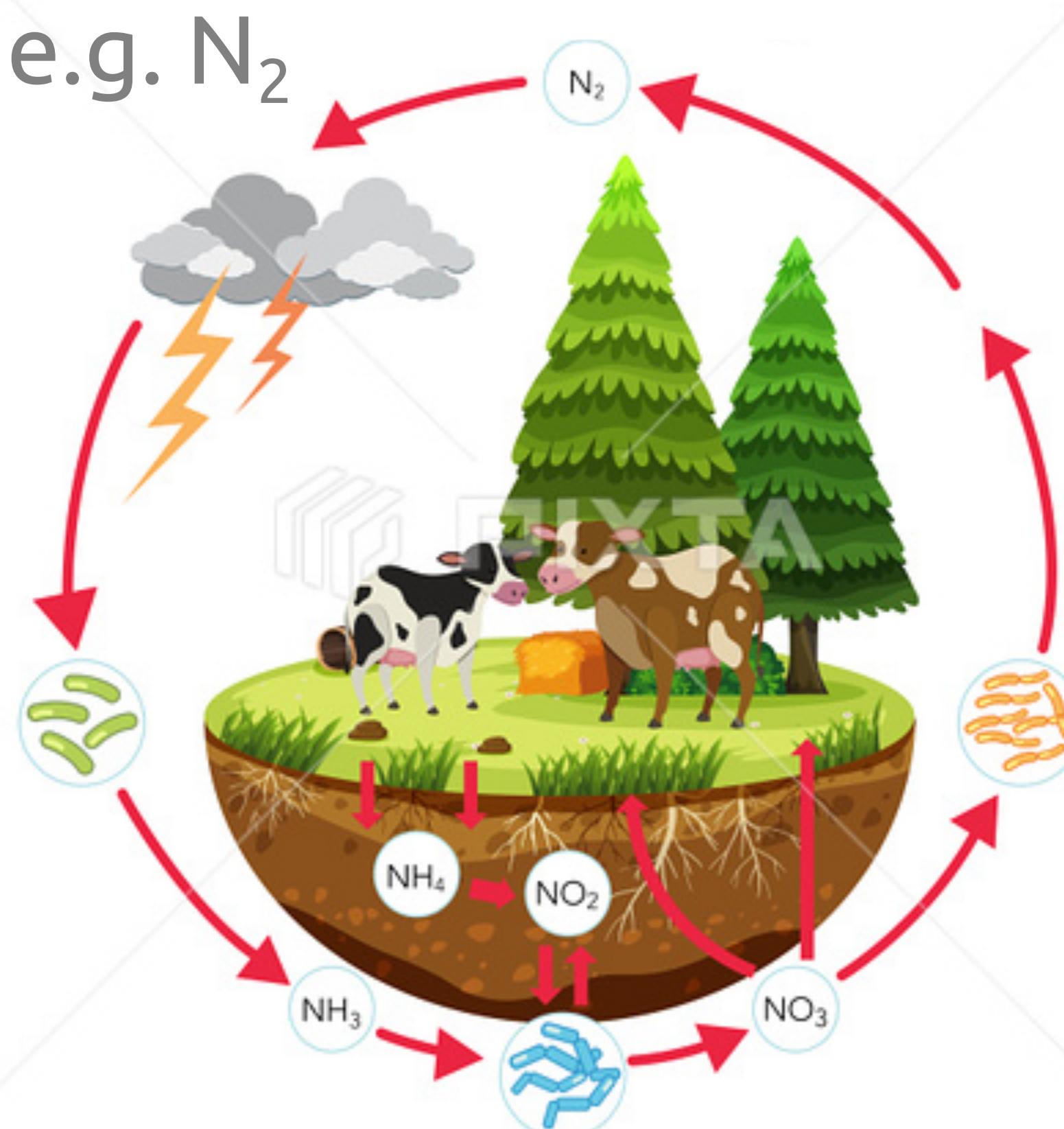
*Deinococcus radiodurans*  
survives easily 5000Gy of ionizing radiation  
cold, dehydration, vacuum (3yrs in outer space)  
found everywhere...



# Microbes are important

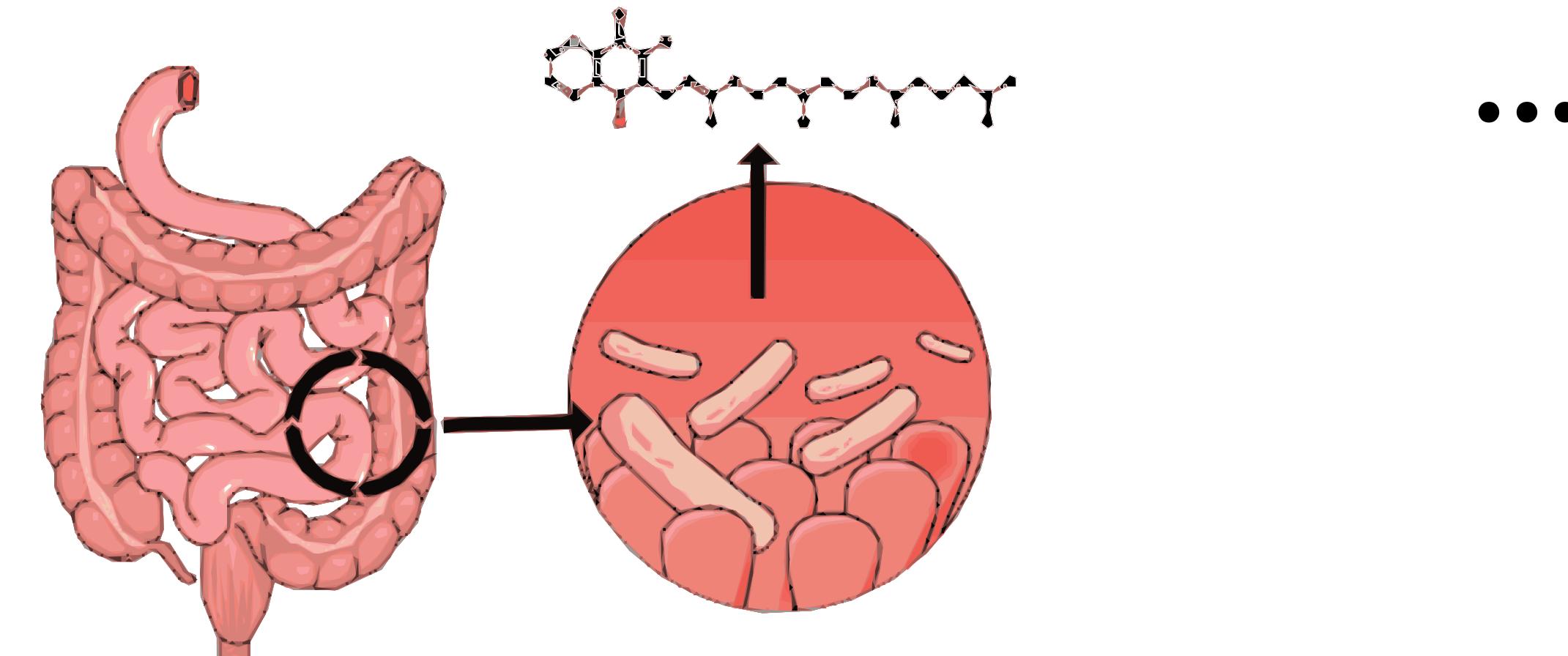
“Life would not long remain possible in the absence of microbes.”\*—L. Pasteur

biogeochemical cycles



host health/functioning

e.g. vitamin K<sub>2</sub>  
synthesis in gut



\*Gilbert JA, Neufeld JD

Life in a World without Microbes. PLoS Biol (2014)

# Main question

**what does an organism/cell has to do to be alive?**

# us: quantitative physiology

## *Cell physiology*

is the biological study of the activities that take place in a cell to keep it alive  
(and their dependency on the environment)

## ***Quantitative cell physiology***

is the biological study of the activities that take place in a cell to keep it alive  
(and their dependency on the environment) **with numbers and equations**

# **what I want to convince you of**

Microbes (biological systems) do interesting and extremely complex things

There exist quantitative biological laws

It is possible to build quantitative, predictive theory in biology

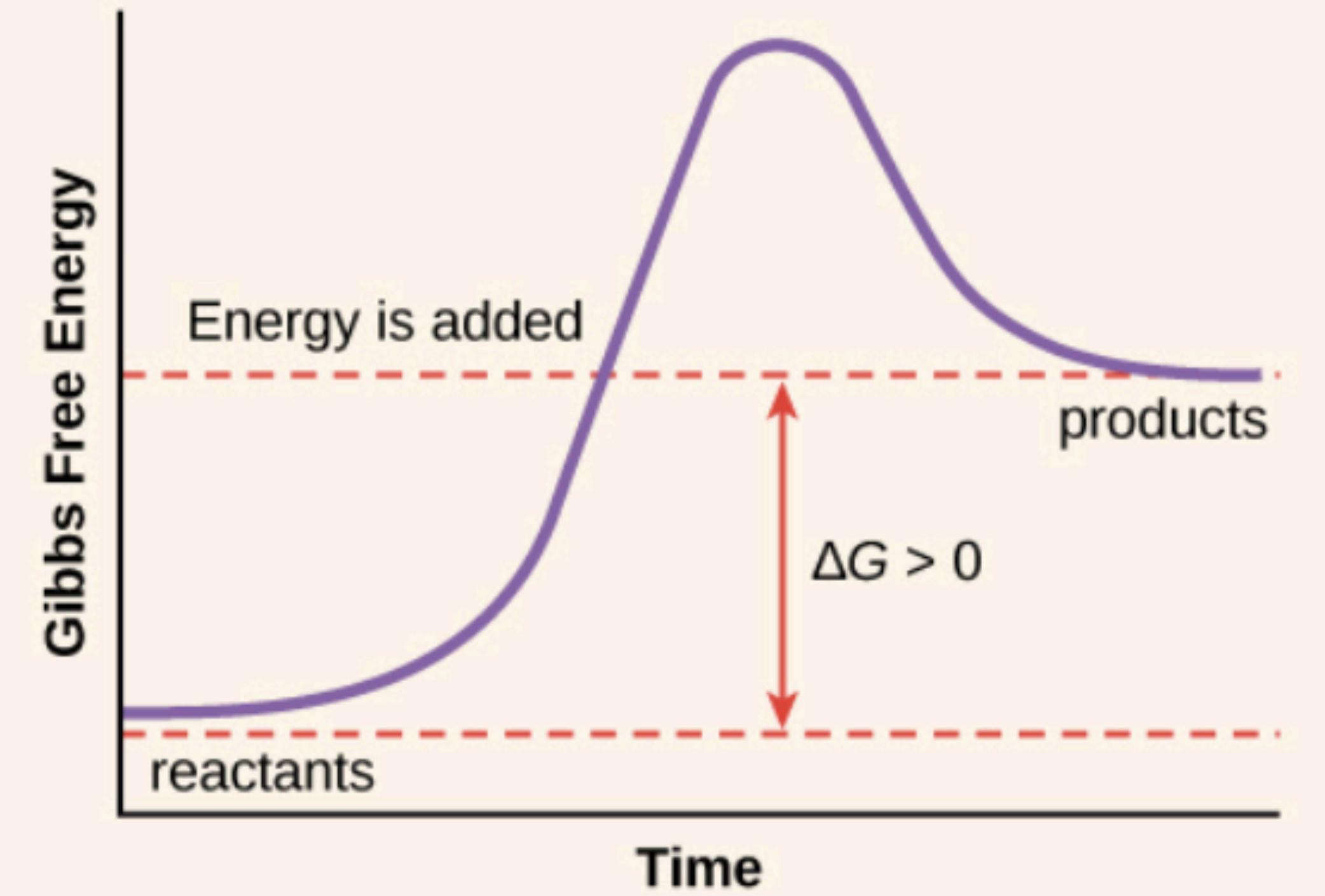
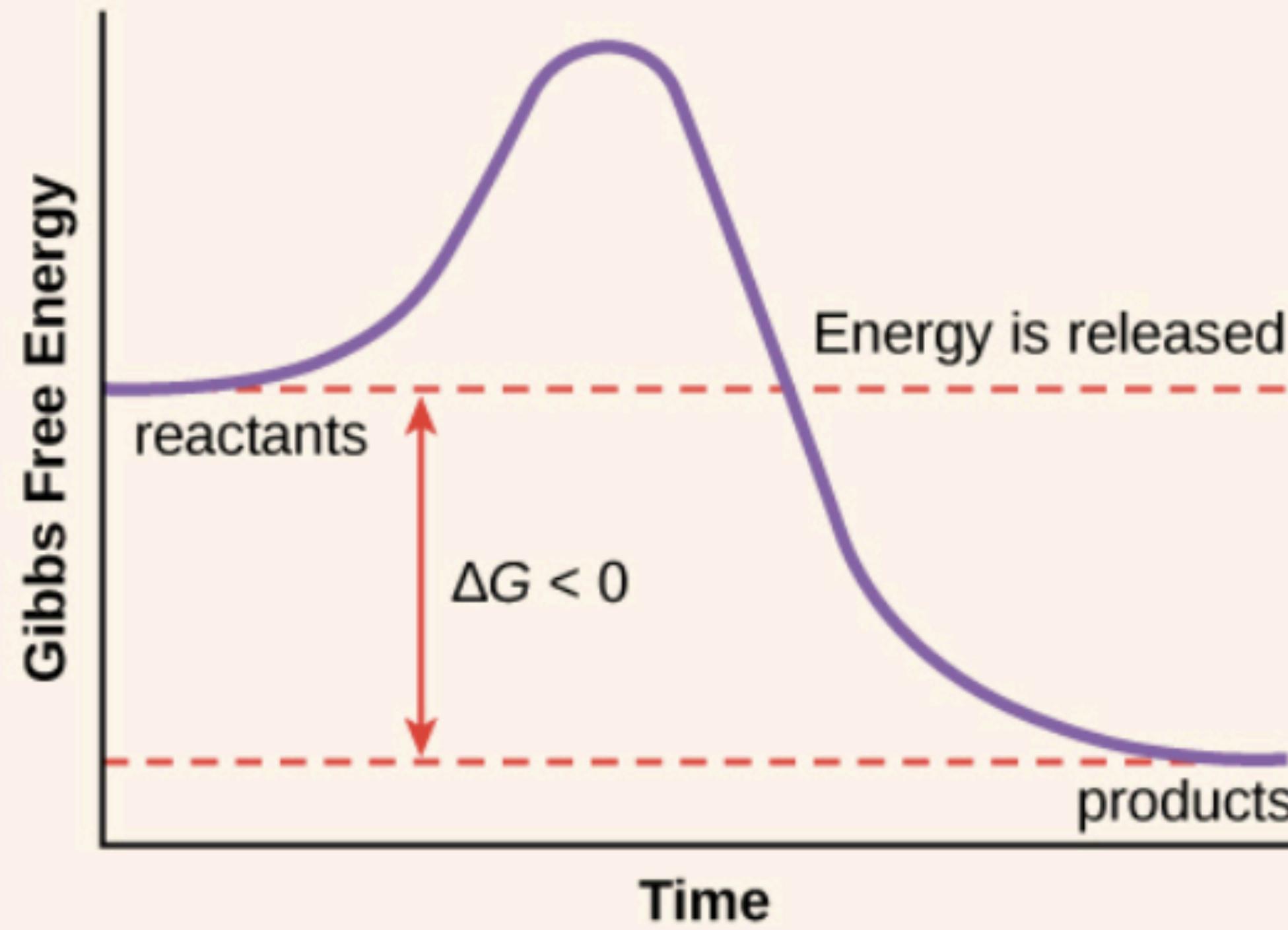
# **to start: microbial physiology in a nutshell**



**In 5 slides (+ some equations)**

*150 pages in Brock Biology of Microorganisms (with no equations)*

# 0: There exist chemical reactions



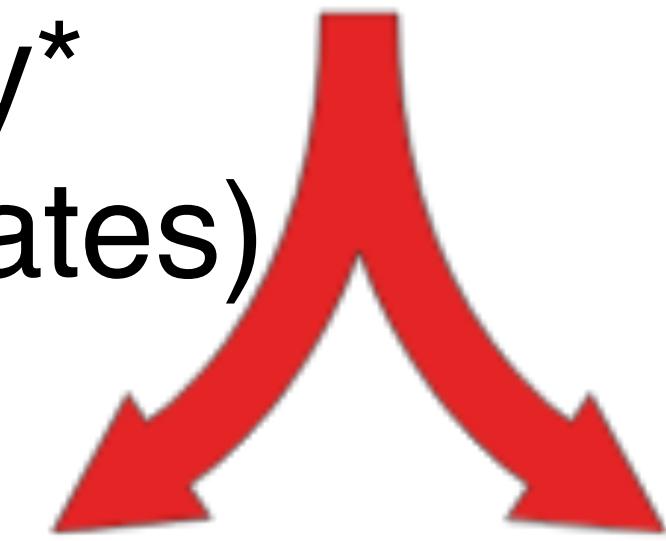
# 1: Cells perform reactions to get energy and produce new material



**Catabolism**

release energy\*

from stuff (substrates)



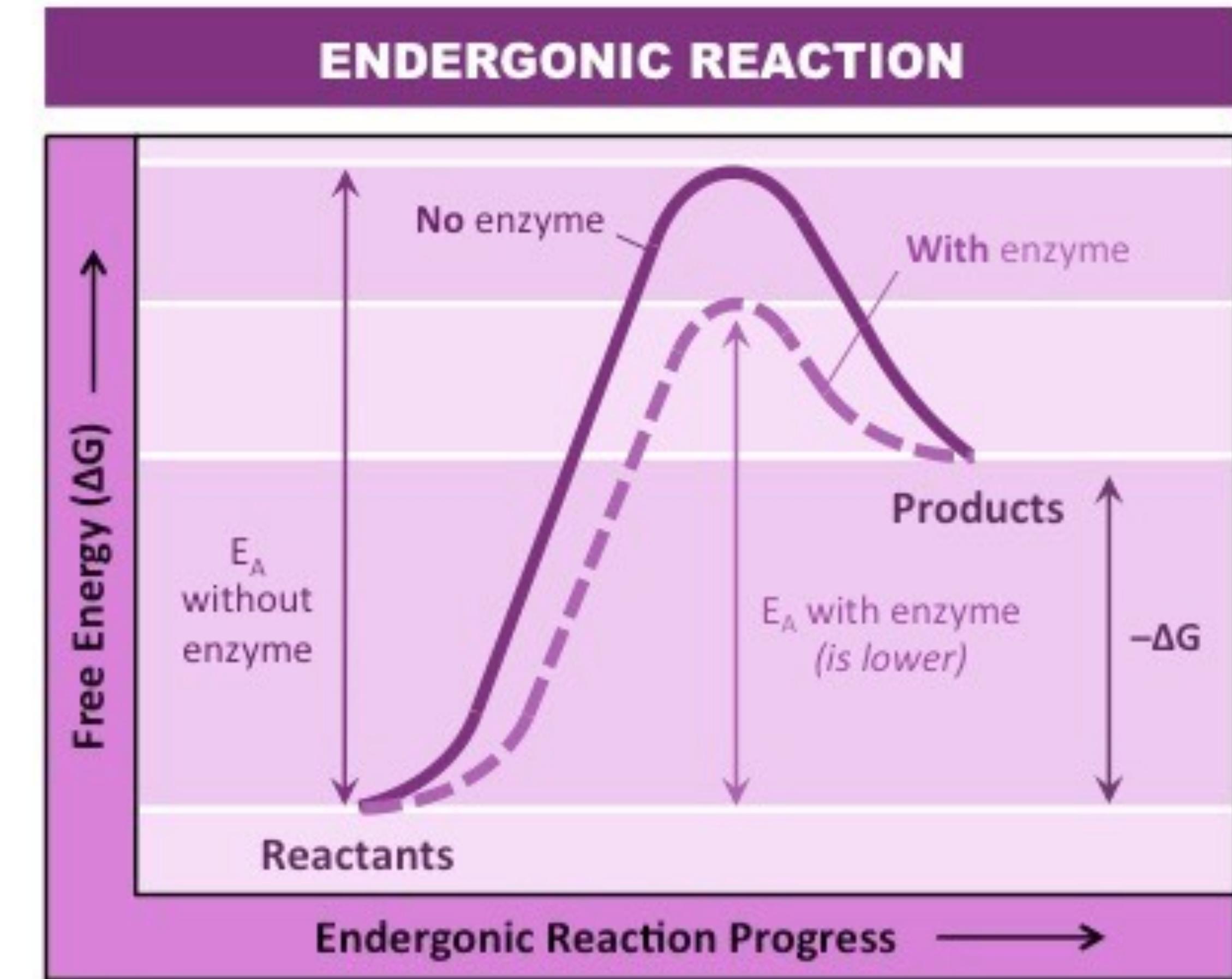
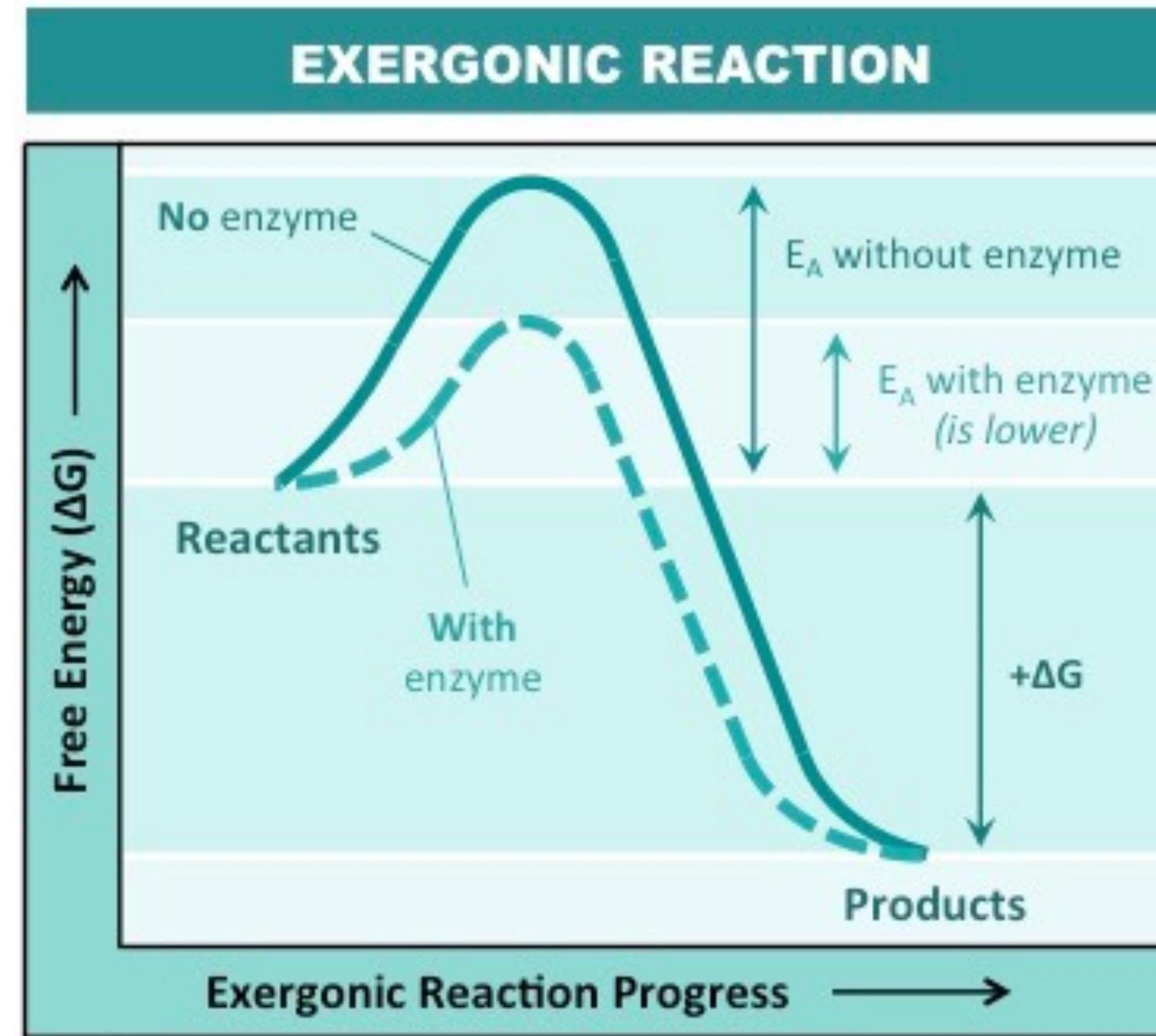
**Anabolism**

use energy and stuff to  
produce new stuff



\*energy can be produced also from light

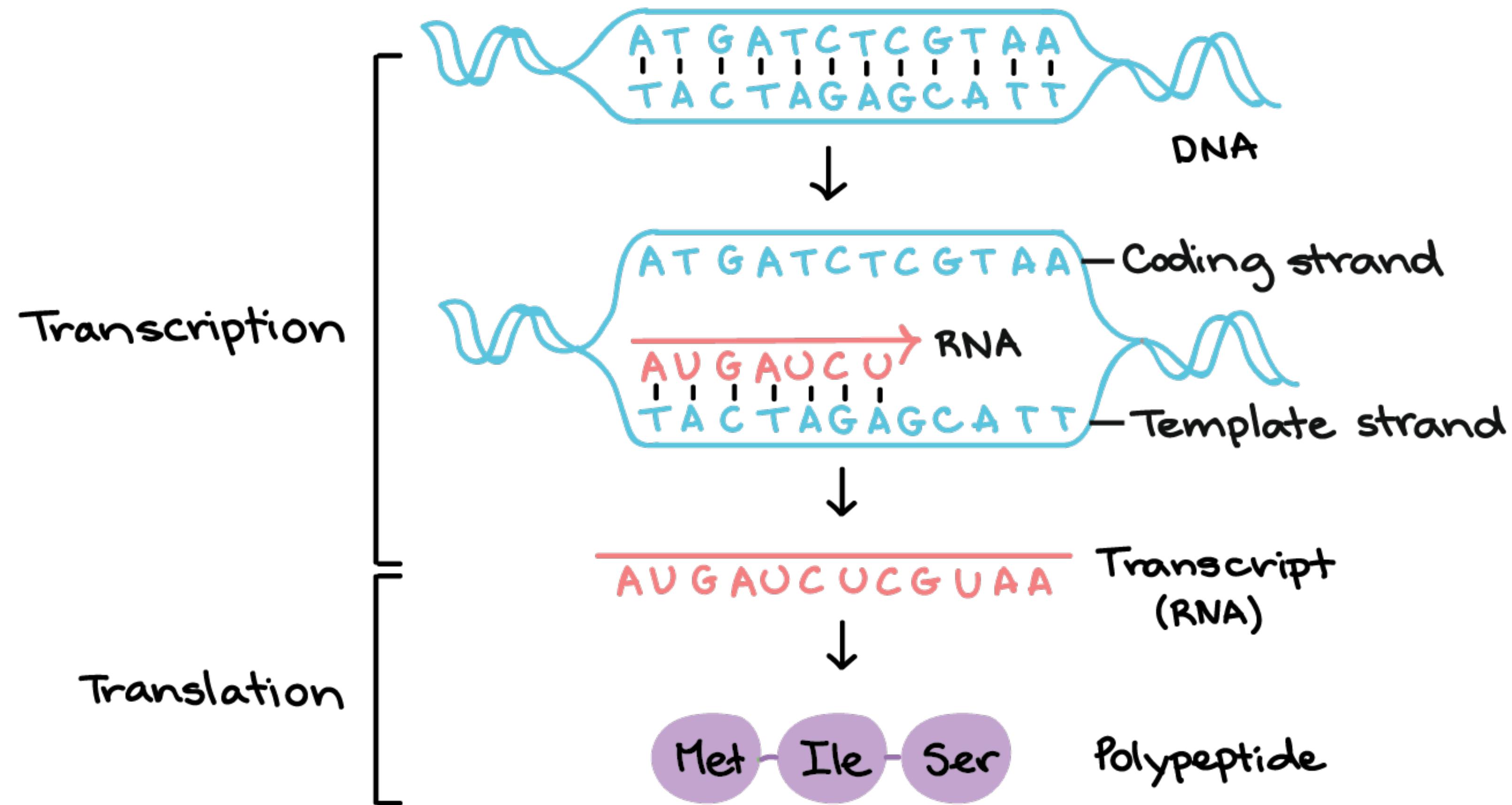
# 2: Enzymes exist and are specific



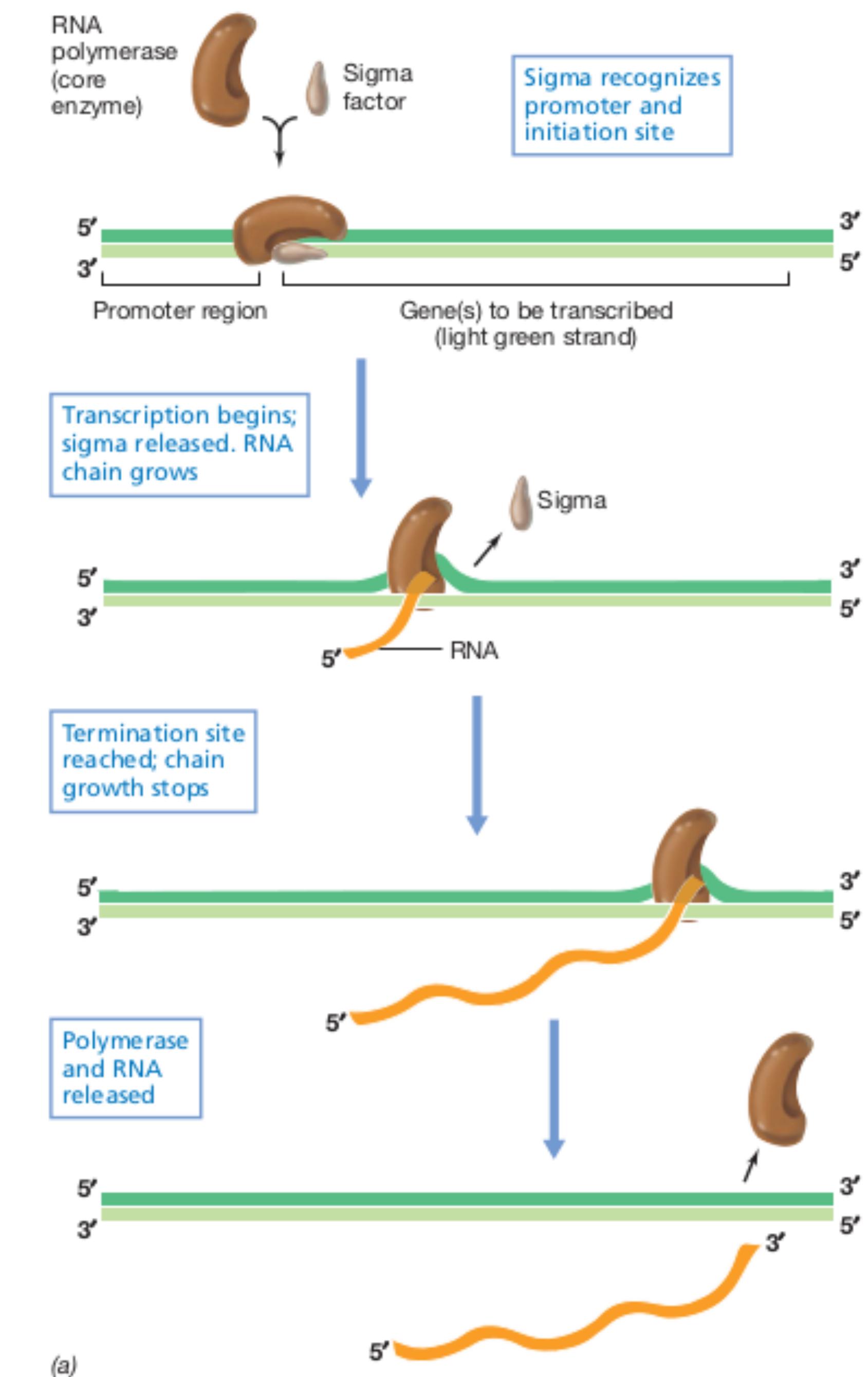
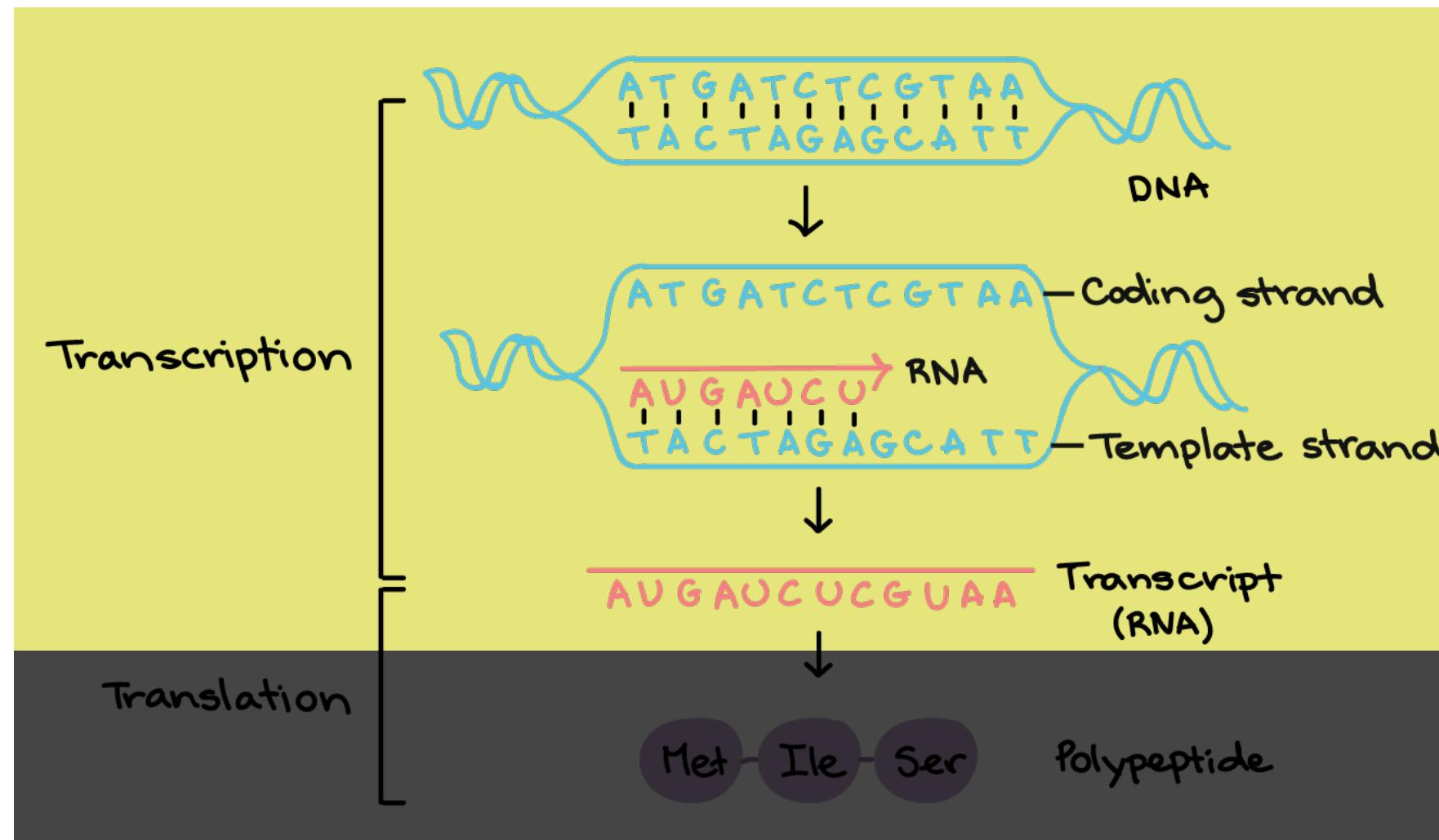
# 3: The instructions to build enzymes (and every other protein) are written in DNA



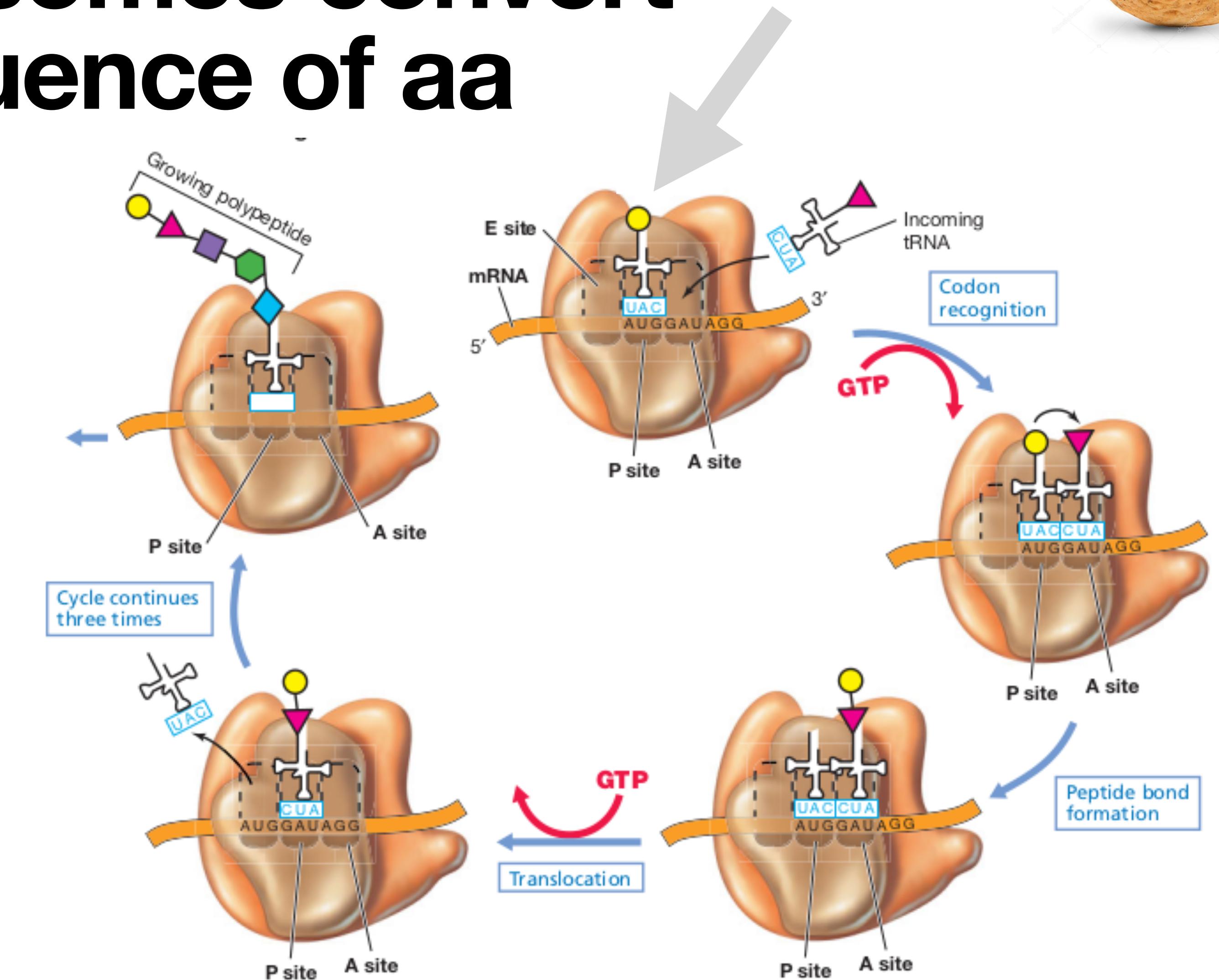
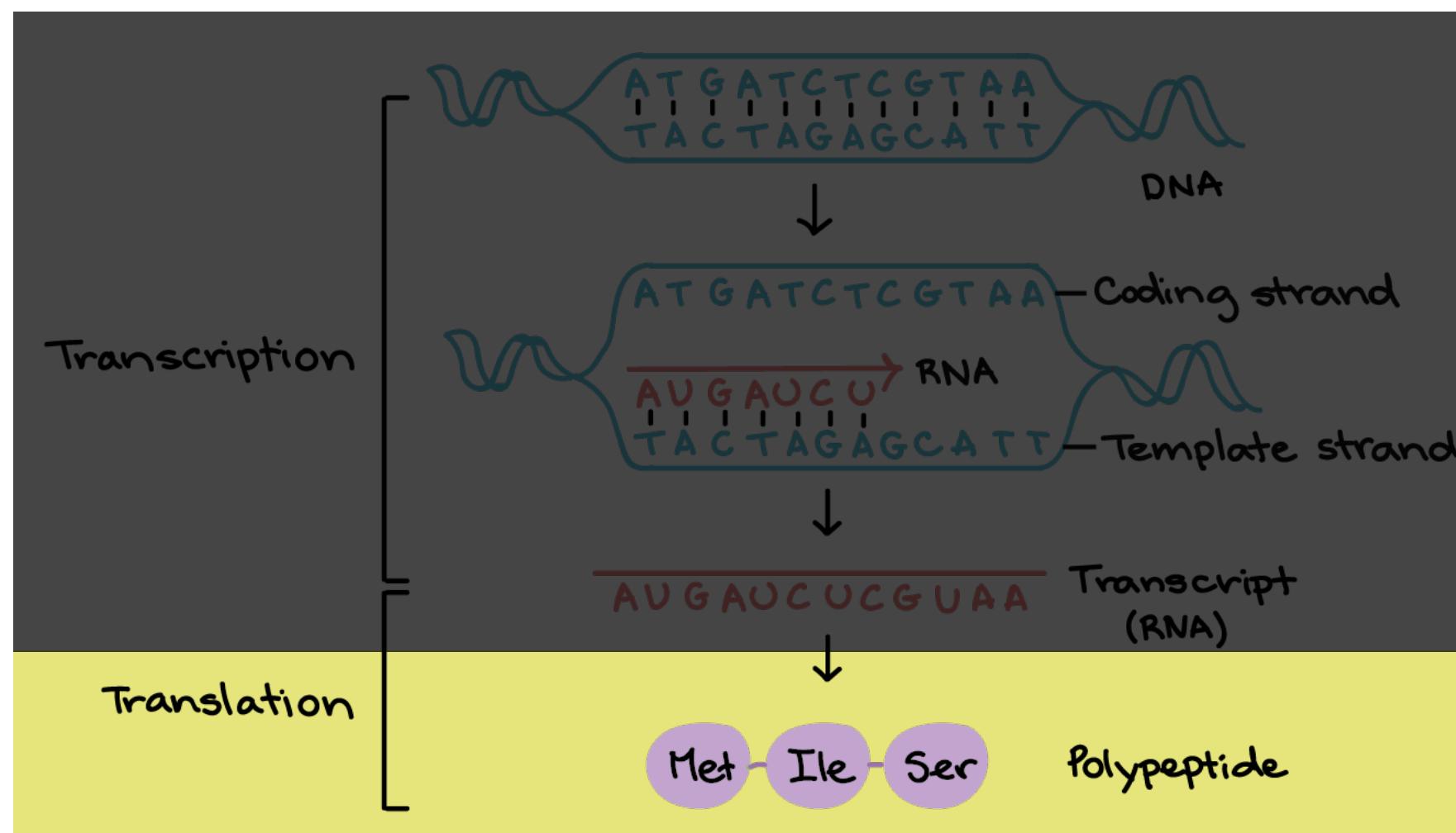
*Proteins are expressed in a two step process*



# 3.1 Transcription from DNA to mRNA

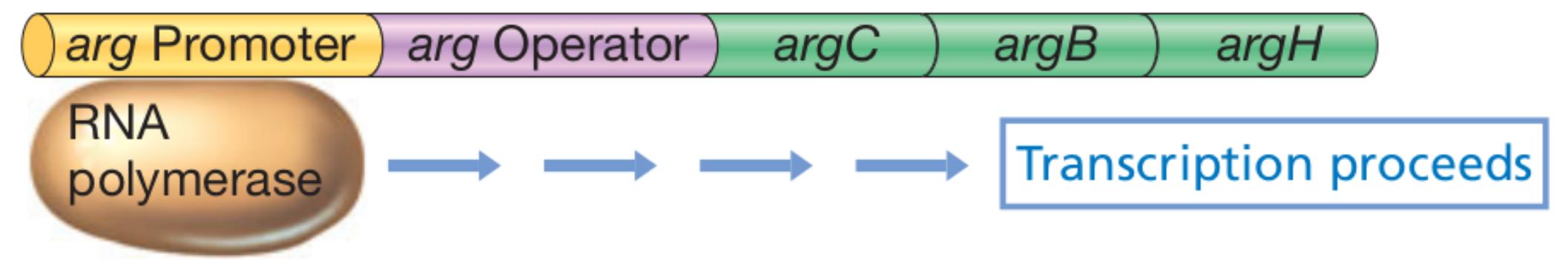


# 3.2 Translation: ribosomes convert mRNA info to a sequence of aa





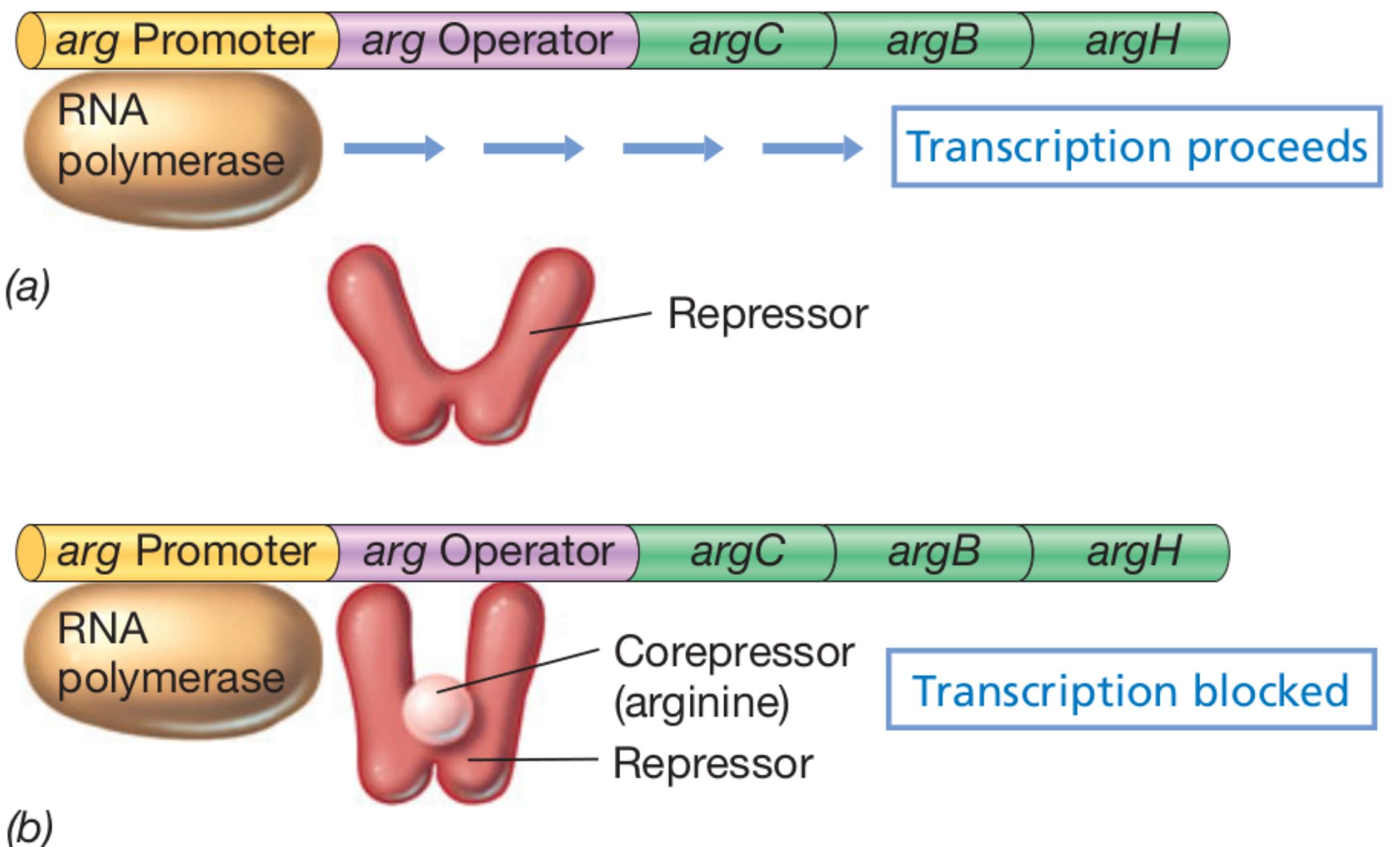
# 4: Regulation: cells regulate which protein express and how much





# 4: Regulation: cells regulate which protein express and how much

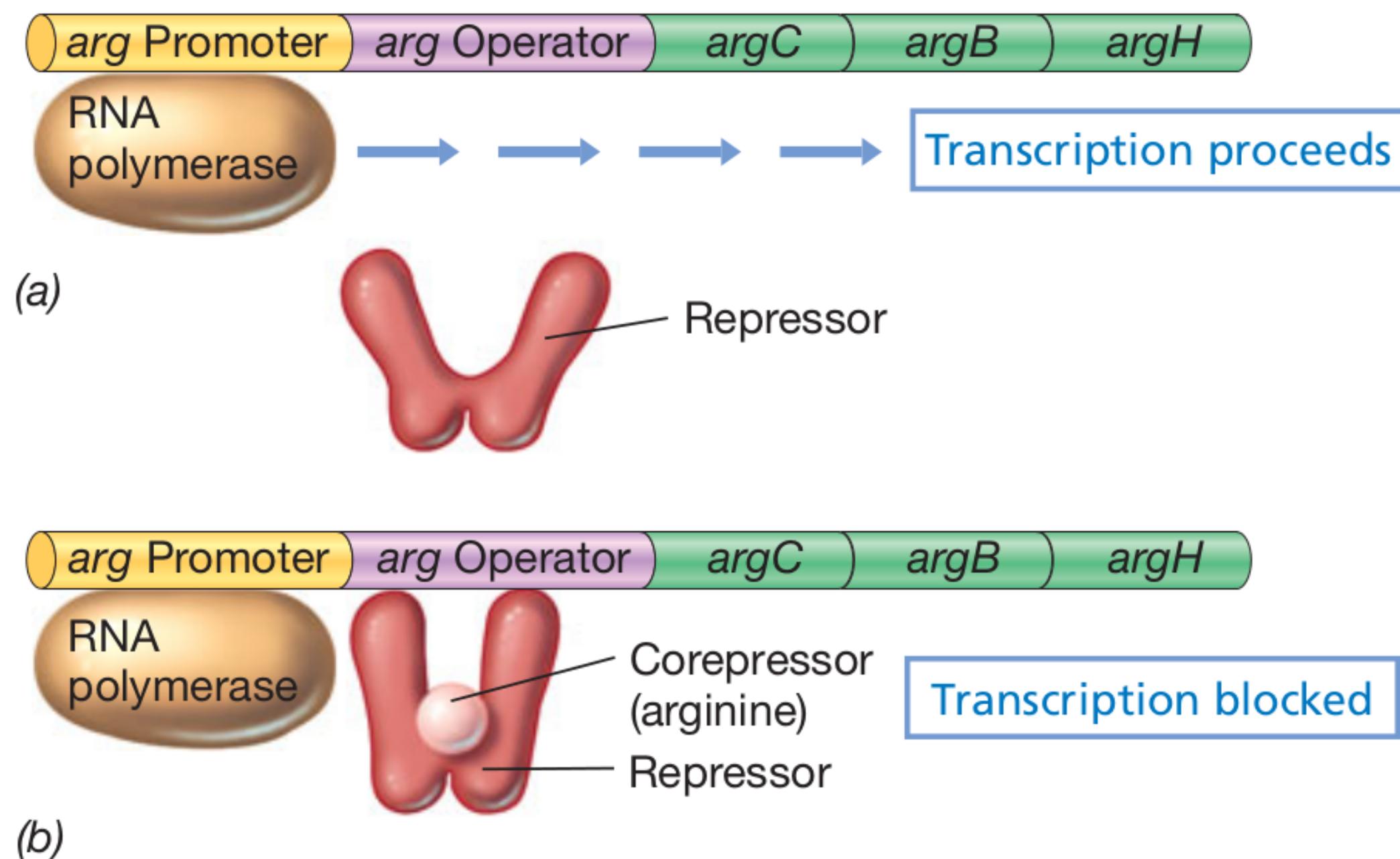
## *Repression* (e.g., arginine operon)



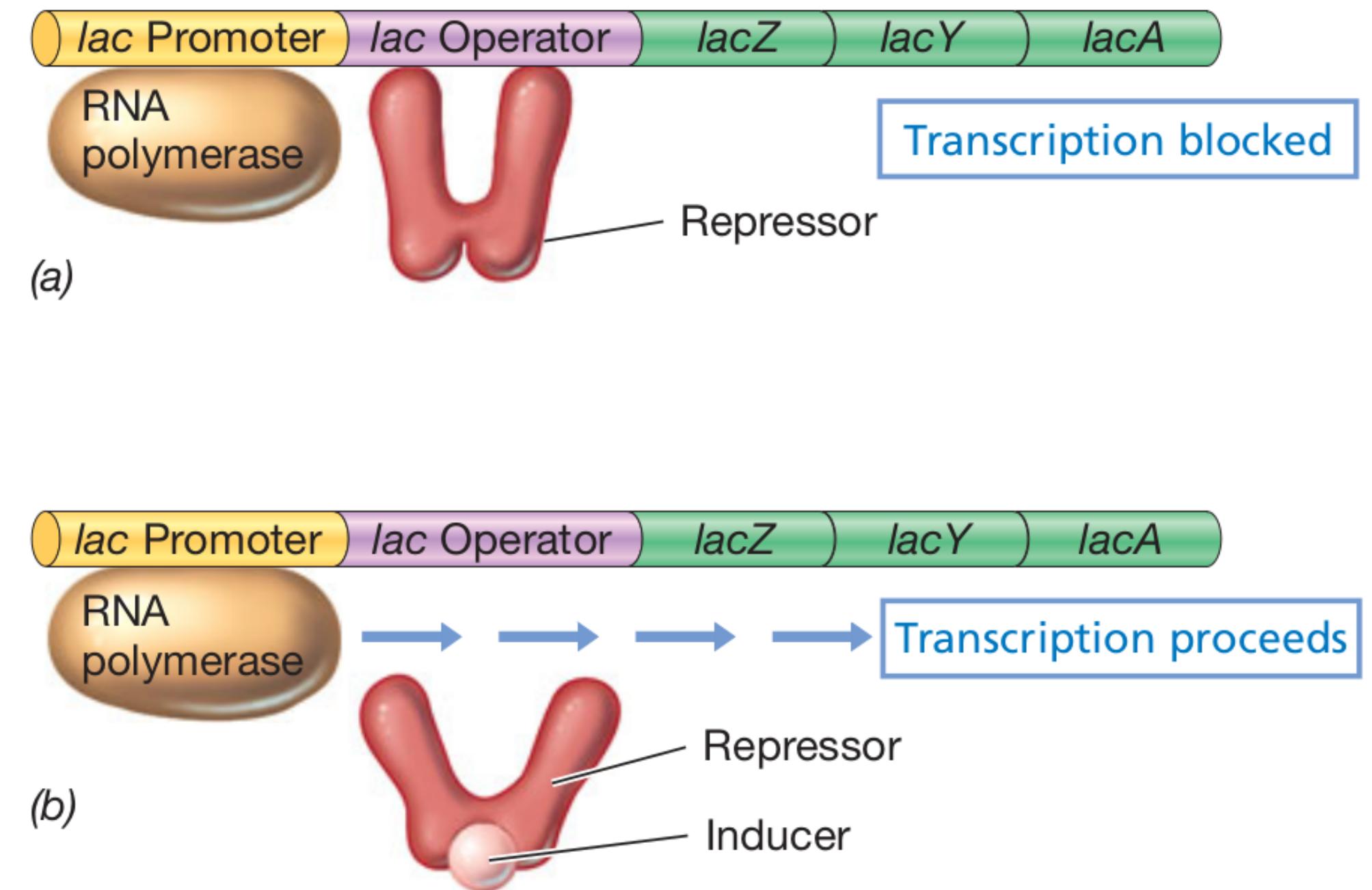
# 4: Regulation: cells regulate which protein express and how much



## *Repression* (e.g., arginine operon)



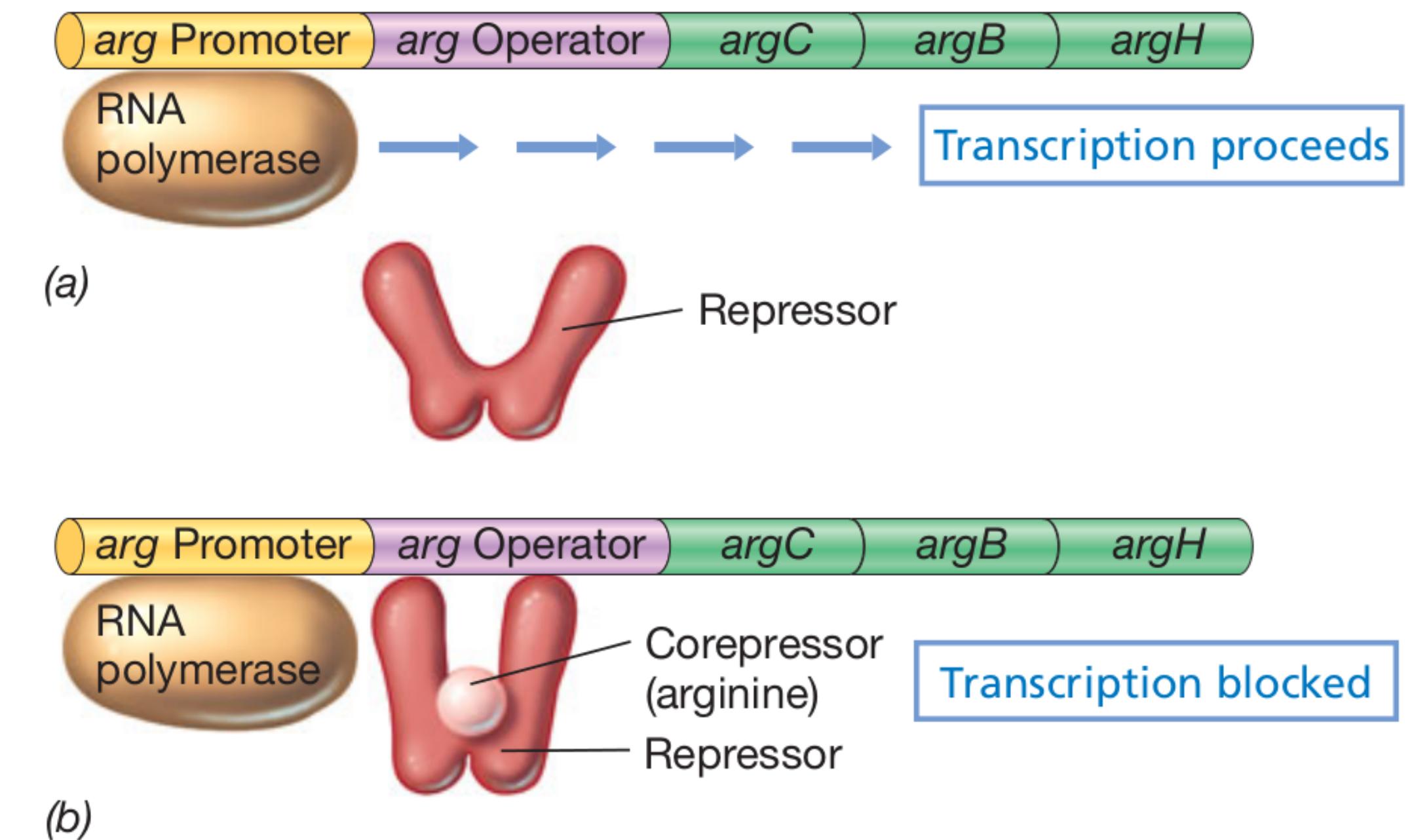
## *Induction* (e.g., lac operon)



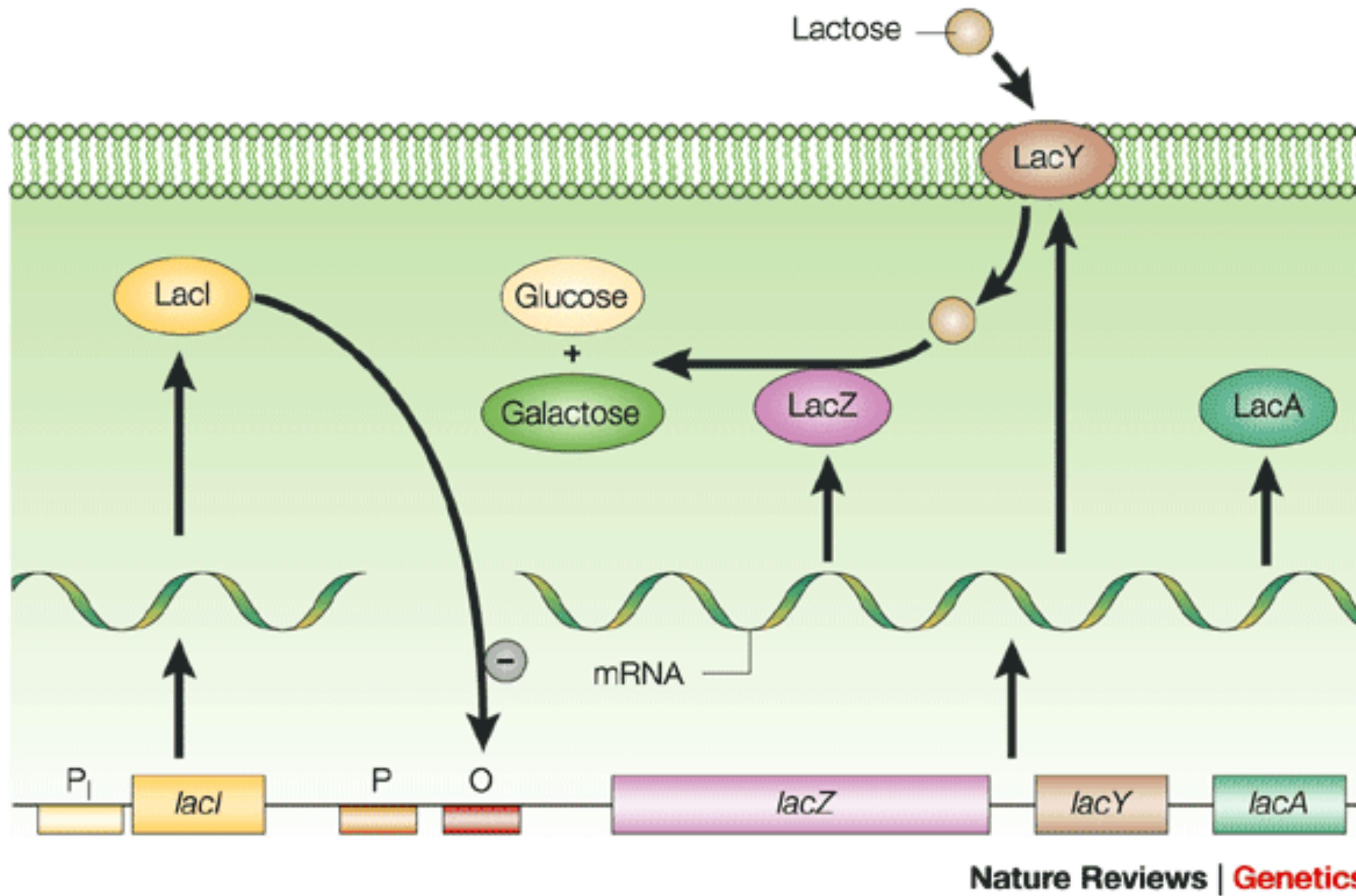
# 4: Regulation is the way cells take decisions (the example of the arg operon)



The problem from a cell perspective:  
Producing aminoacid arginine is costly  
**when should I produce it?**



# 4: Regulation is the way cells take decisions (the example of the lac operon)

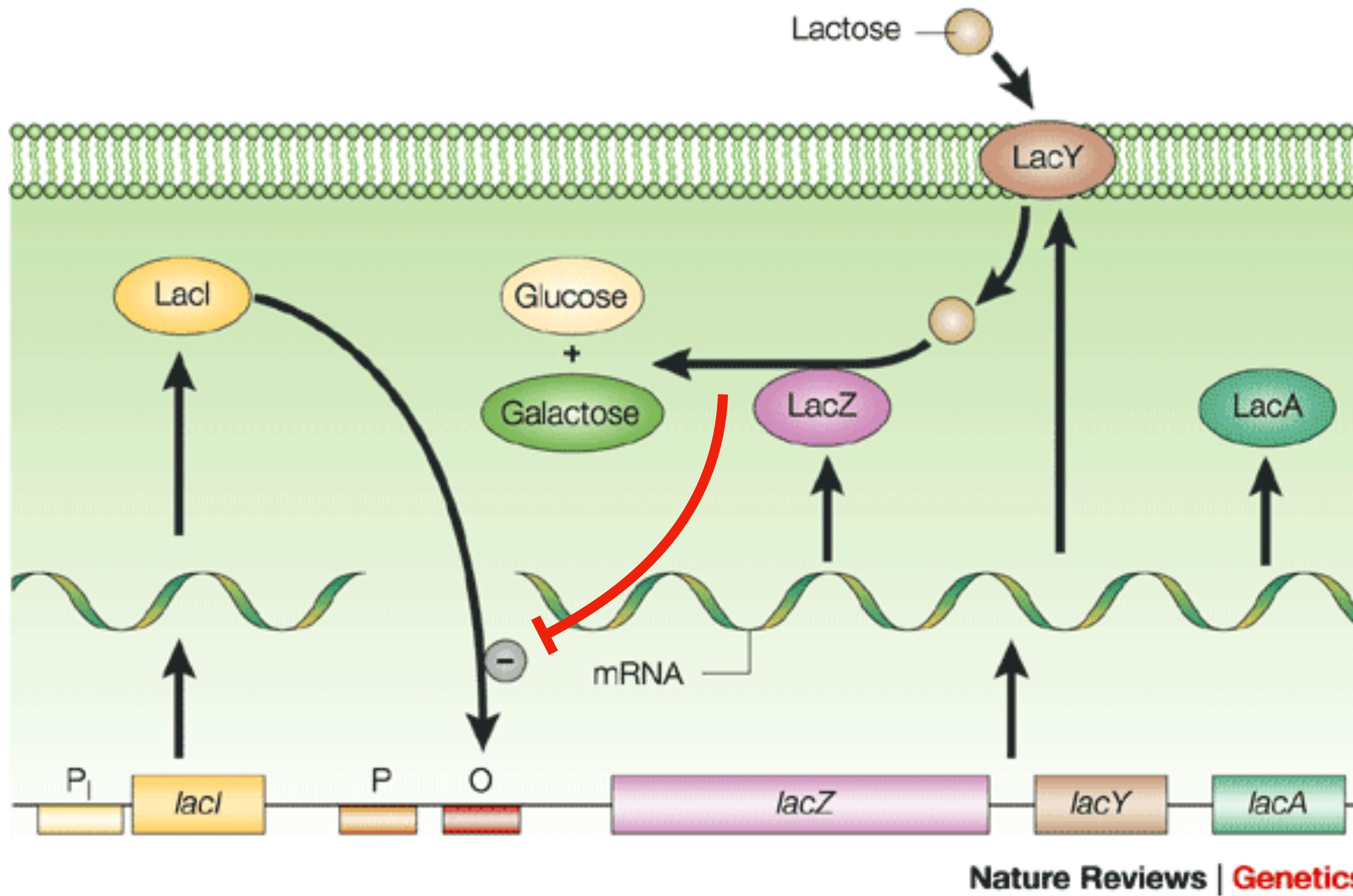


Nature Reviews | Genetics

Monod and Jacob  
Nobel prize in 1964



# 4: Regulation is the way cells take decisions (the example of the lac operon)



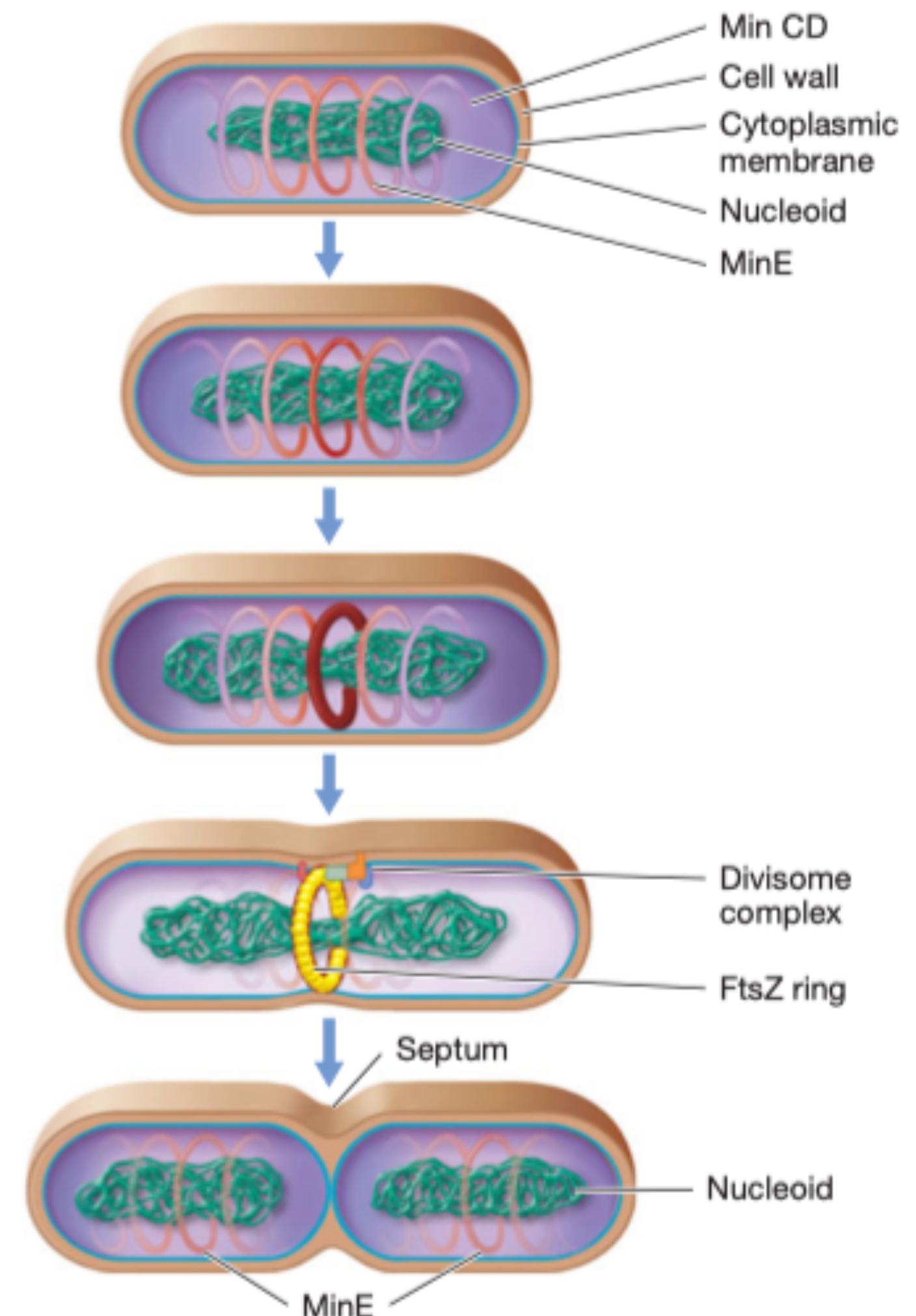
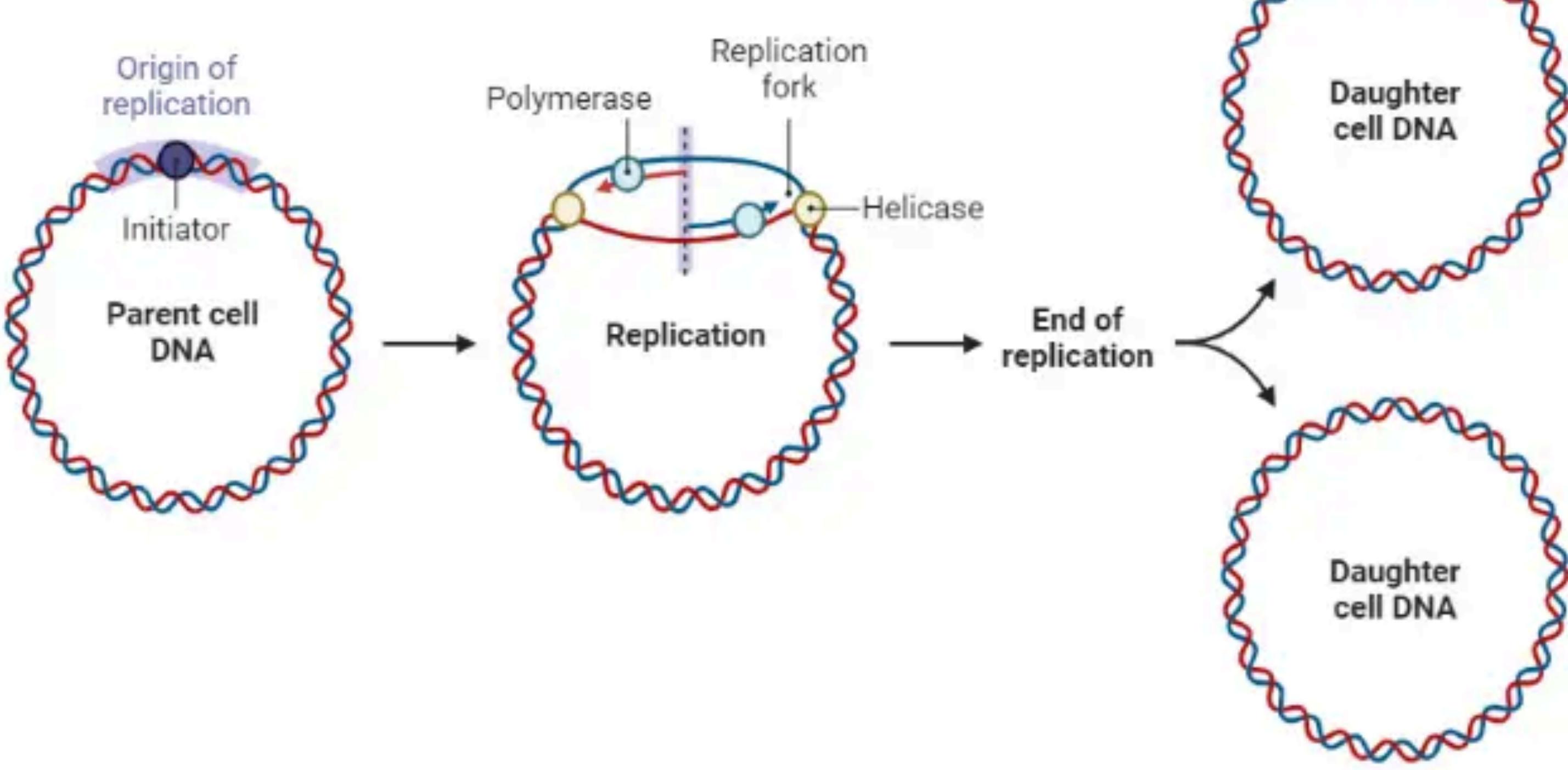
Nature Reviews | Genetics

Monod and Jacob  
Nobel prize in 1964



# 5: DNA is replicated and a cell divides

*“The dream of every cell is to become two cells” - F. Jacob*



More about this in Ariel Amir's lectures

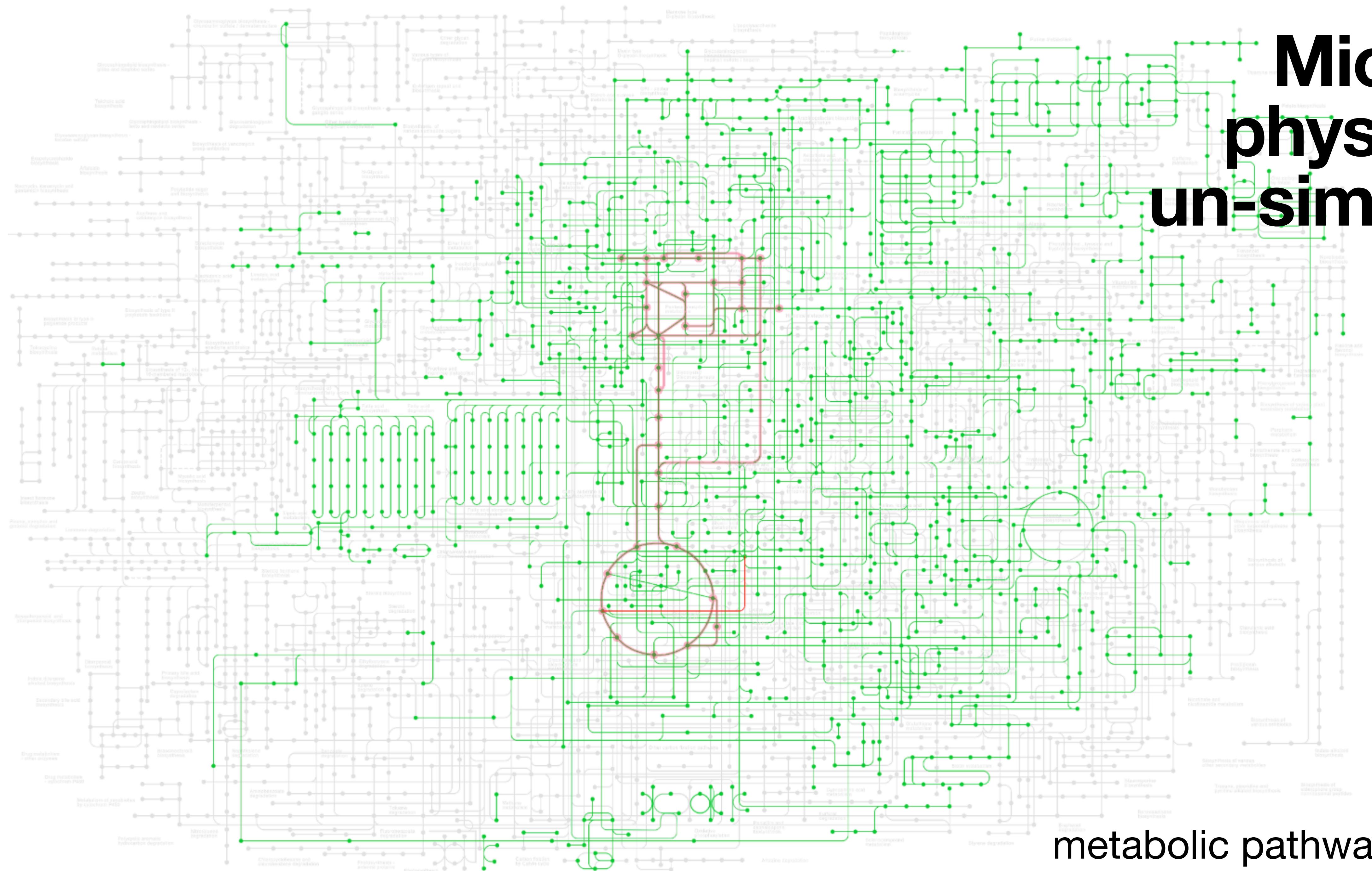
# Microbial physiology in a nutshell



1. Cells perform reactions to get energy and produce new material
2. Enzymes exist and are specific
3. The instructions to build enzymes (and every other protein) are written in DNA
4. Cells take decisions by regulating which proteins express and how much
5. Cells replicate DNA and become two cells

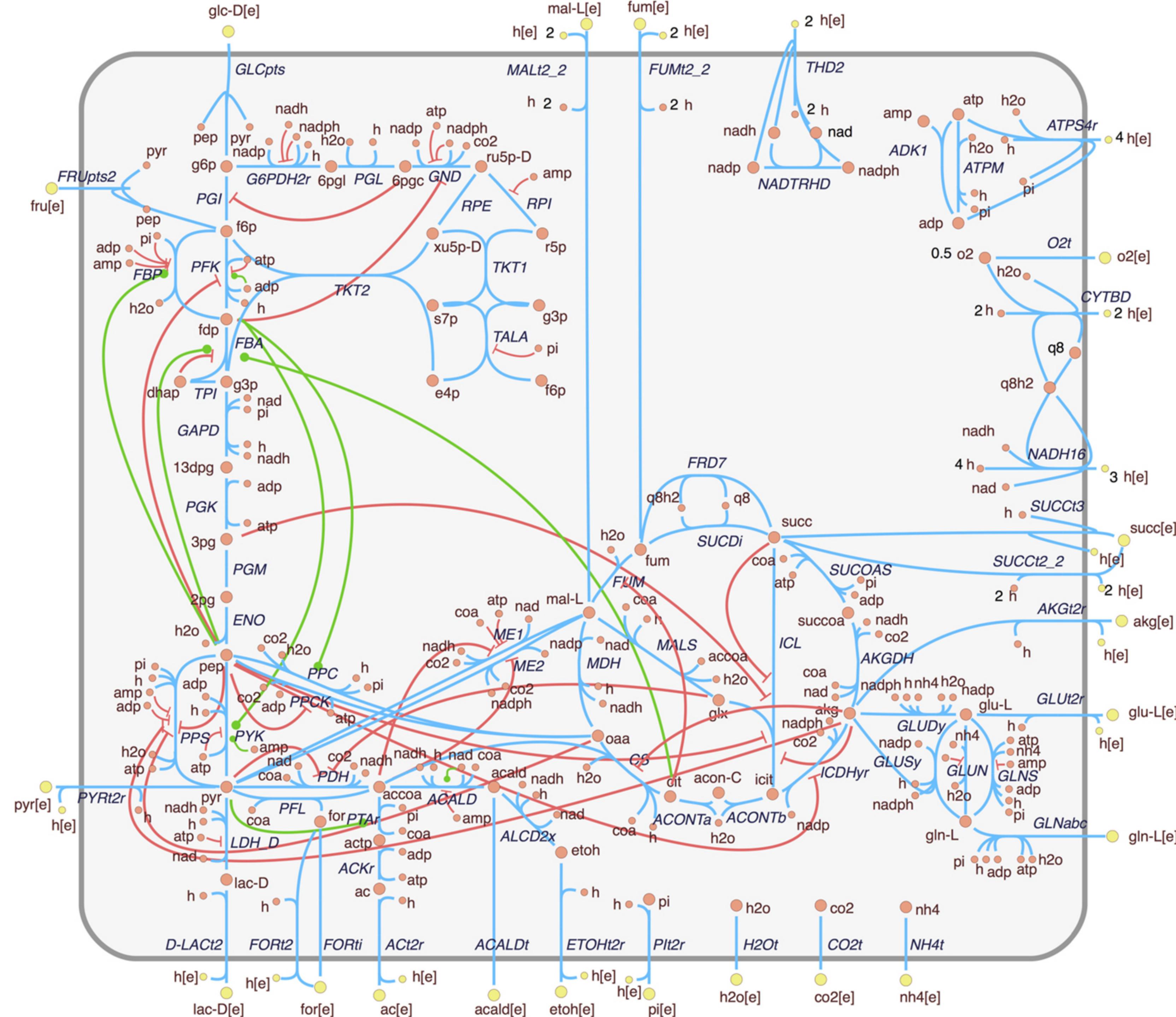
# **Microbial physiology un-simplified**

# metabolic pathways in *E. coli*

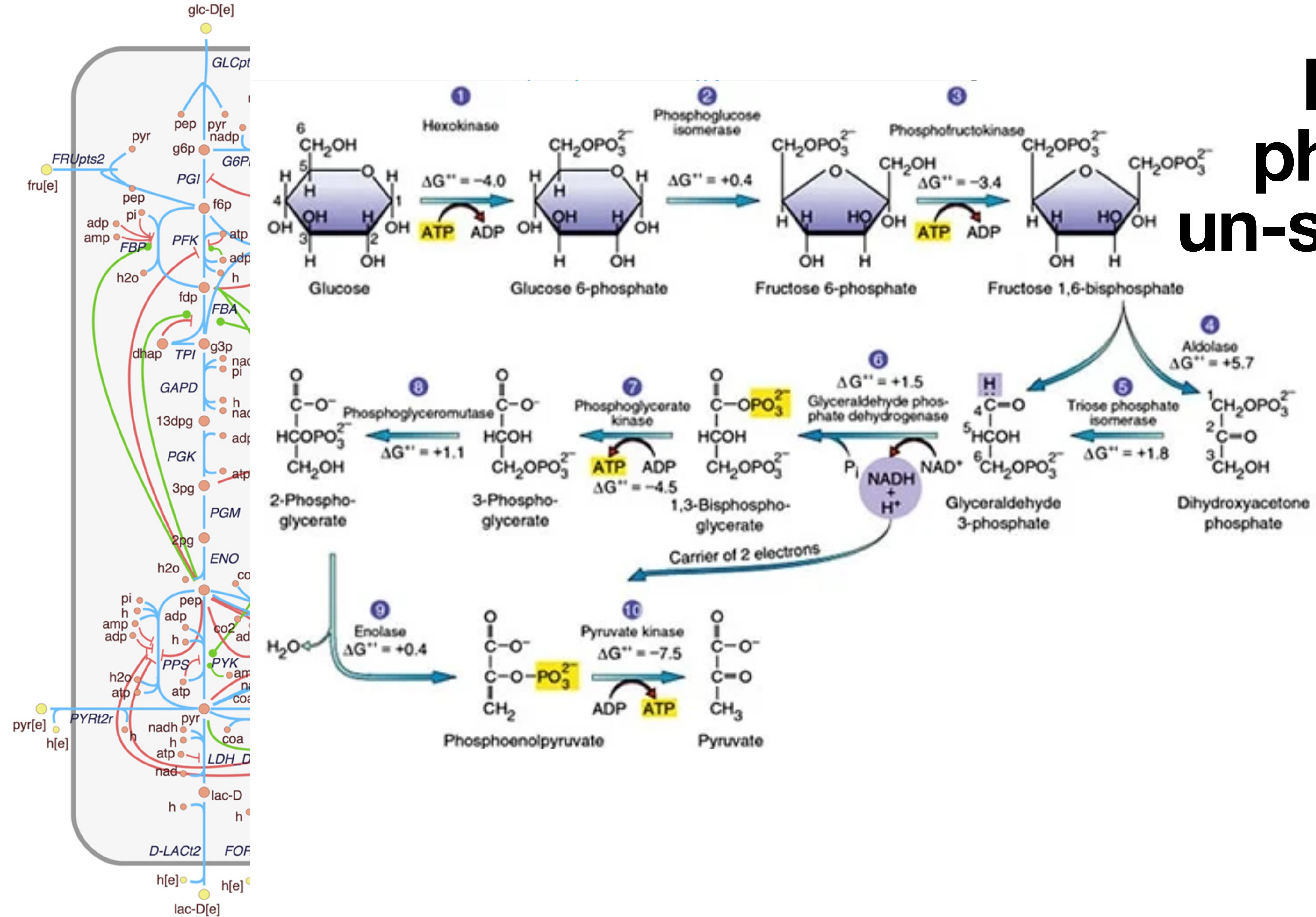


# Microbial physiology un-simplified

Regulation of central metabolism in E. coli  
 reactions  
 enzime activation  
 enzime inhibition

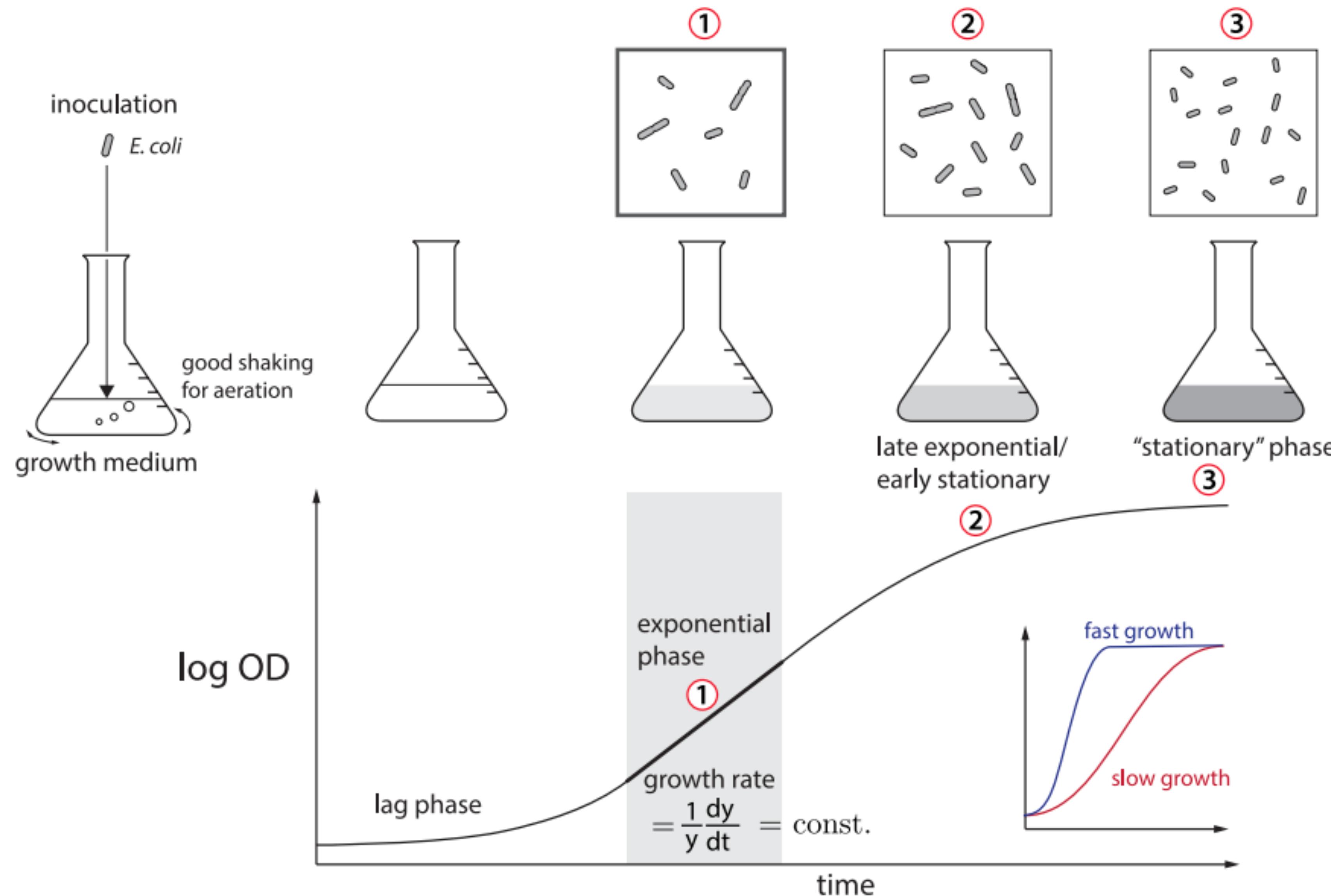


# Microbial physiology un-simplified

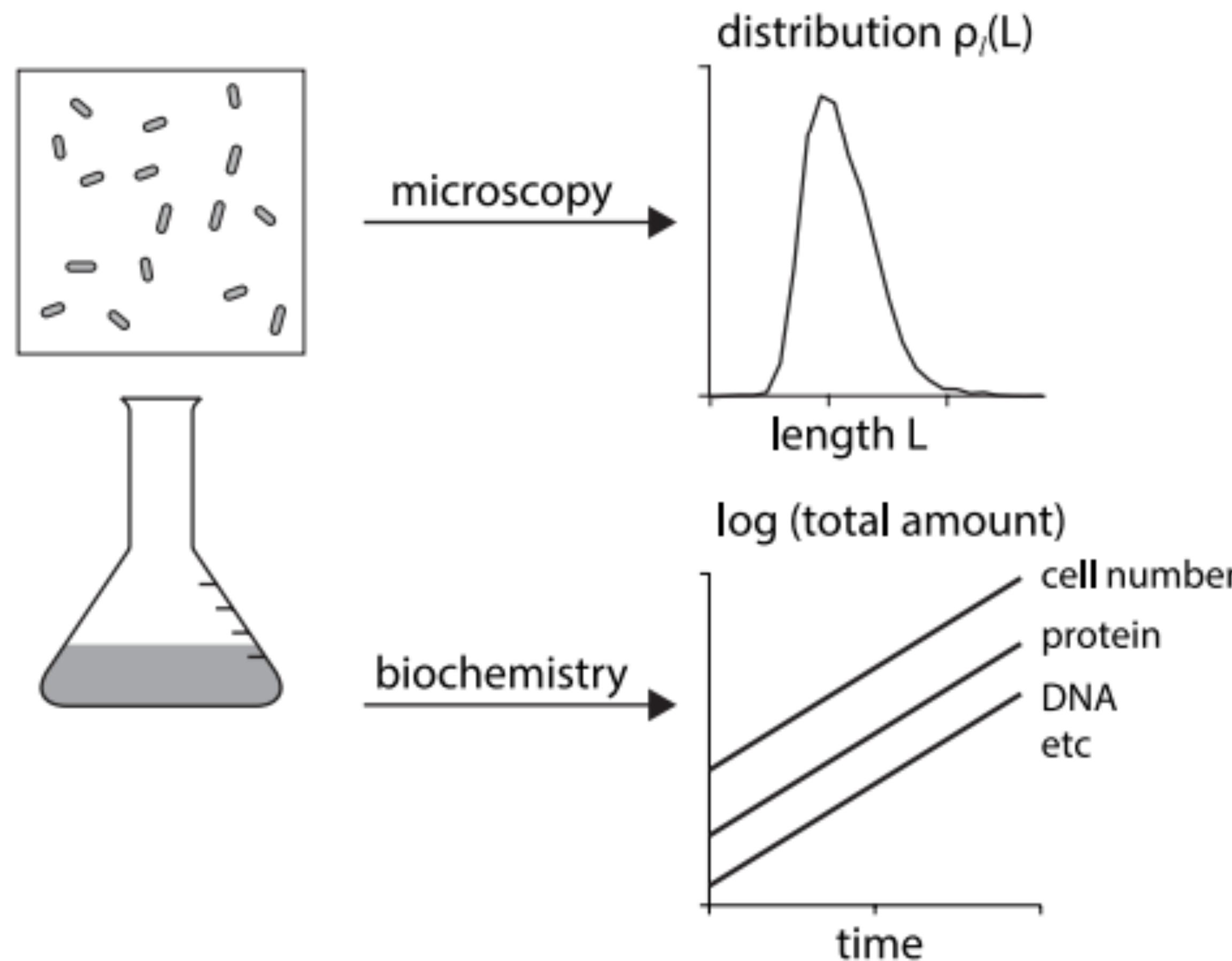


Glycolysis

# Growing bacteria in the lab

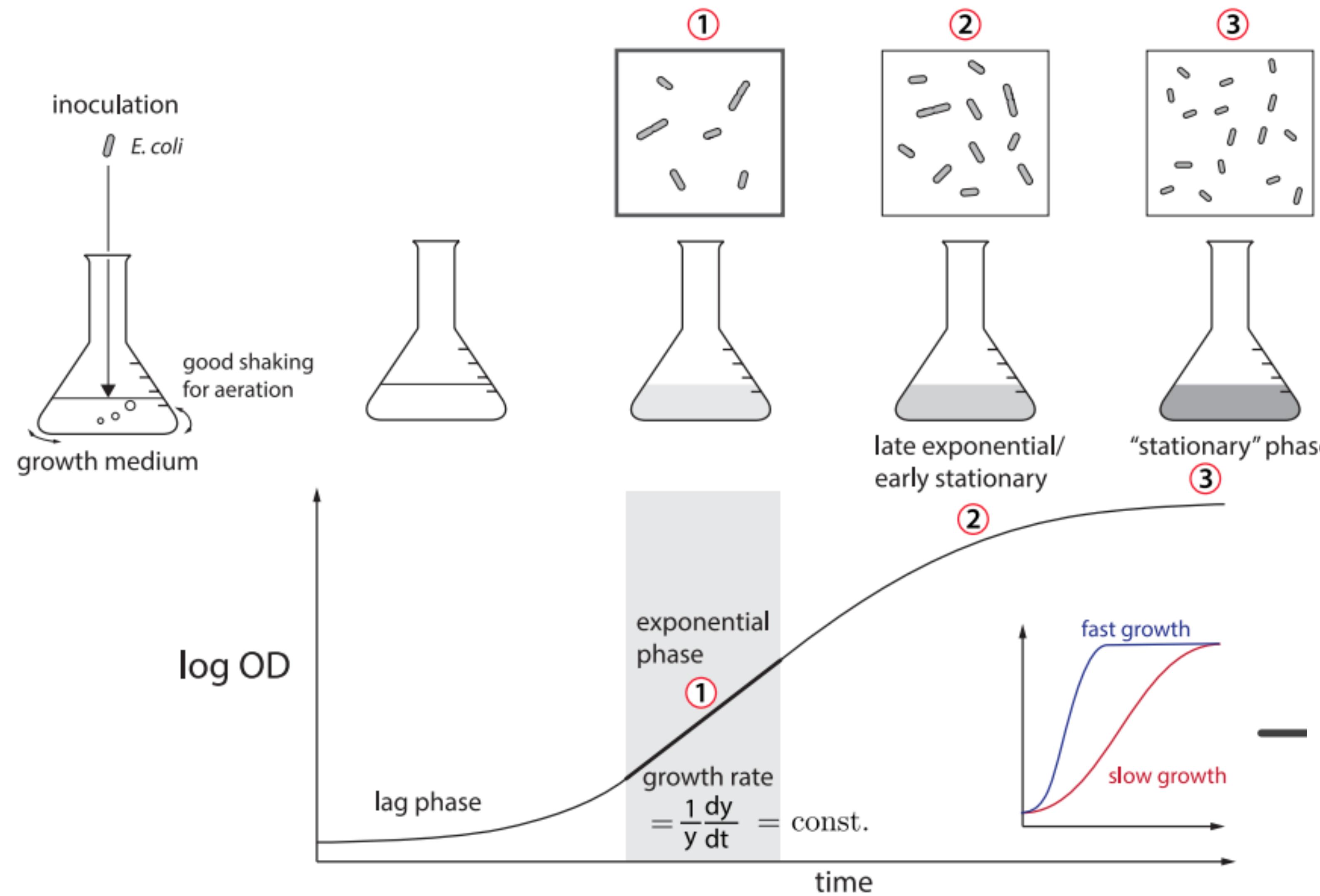


# what else can we measure?



# when is easier to study physiology?

physiology: biological study of the activities that take place in a cell to keep it alive



# References

*Jun et al., 2018 Rep. Prog. Phys. 81 056601*

*Brock Biology of Microorganisms*