1. **Pick up** Name Folder

- Pick up name folder and set it up at seat.

2. **Sit** with your lab group.

- laptops almost closed (avoid distracting)

3. **Clicker** Attendance

- Launch your Top Hat, and get ready to click.

In order for the 8 green photons to be absorbed, they would need to be initially absorbed by carotenoids in order for the energy to be passed down. Two ATP and two NADPH would be made if these 8 photons were absorbed, using the conversions previously used in last week's question. In one run of the calvin cycle, 6 NADPH and 6 ATP are required to generate 1 G3P molecule, so no G3P would be produced from 8 photons, or 2 ATP/2 NADPH.

LAST YEAR'S BEST ANSWER on HOMEWORK


Laptops closed (unless TopHat)

Announcements

1. ***CATME GEA1 feedback*** *is starting, please…*
2. ***Verbal Final*** *coverage of topics can start after exam, attempts before discuss digestion, skip it.*
3. ***TARDIS*** *pass=* ***ReDo*** *via time travel, also* ***Status Report Talk (is ReDo)*** *replaces Proposal talk grade IF you (solo or with others) email me by Thursday.*
4. ***Exam I****: Next Monday. Can bring 3x5 inch card with handwritten notes on both sides. If time at end can show you possible question formats on exam.*

Week 5

(Preparing for) **Monday's lecture:**

Budgeting homework time (70 min): Chapter 11 section 11.1 is long with many figures that require thinking and notetaking. The first 2/3's of it is the most important part and just reading that part, which is 3800 words, should take 21 minutes or longer. The data figures are important while those that are just drawings, like 11.3, 11.6, 11.7, 11.9, are not. Of course, when done properly, when you pause to review figures, try Integrating Questions, and take notes, this assignment will take you more like 70 minutes. **Special Allowance**: Your group can divide up the Trifectas for this lecture.

1. _______ **For Monday's lecture,** read **Chapter 11: Photosynthesis**, section 11.1 "Why is paraquat used in America but illegal in Europe?" and as you read it on your computer be sure to take handwritten notes in your lecture notebook. Please read carefully and take good notes for the first 2/3s of the section (which is about 3800 words). You can stop taking notes when you come to the yellow box of Integrating Questions #11-14. Then just read the last 1/3 of the section for deeper thought and better understanding.

2. _______ **Try to answer some Integrating Questions and Review Questions.** As you read the ICB textbook always attempt to test yourself a little, answer at least one of each set.

3. _______ (Trifecta): **Prepare to explain (aloud) Figures 11.1B, 11.2A, B, C, 11.4, 11.5, and 11.8A in class**. *Special Allowance today*: If you wish your group can designate who will be responsible for each figure and thus split up the responsibility and reduce the load (Purpose, Methods, Findings).

4. _______ **Advanced**: Take a peek at section 8.3, in particular study Figure 1. Take a sneak peek at "Chapter 11: Photosynthesis", section 11.2.

Chapter 11 (ICB) 2-6-2023 Photosynthesis (ICB book)
section 1

11.1 Why is paraquat used in America but illegal in Europe?

Context. Plants + Animals have many similar enzymes. so herbicide(s) might be targeted to plants only BUT...?

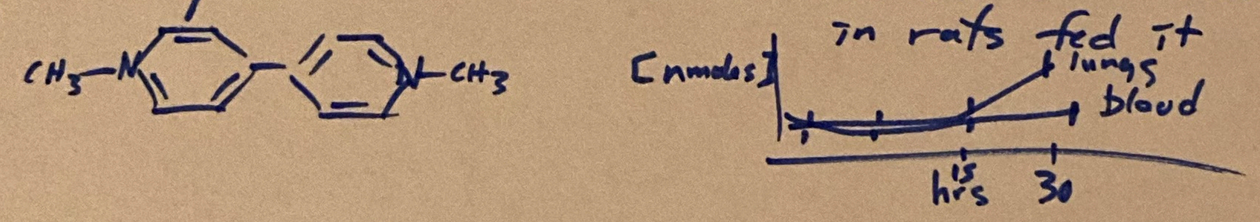
Photosynthesis light rxns are lots like Respiration so herbicide could kill mitochondria too?

L.O.s → Describe how plants capture energy from sunlight + convert E.
• Distinguish three parts of PHS + explain chemical + physical processes

Paraquat

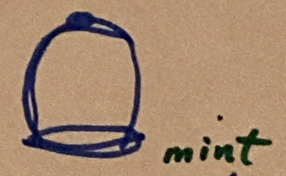
In 2003 EU began using Paraquat/herbicide to kill weeds by 2007 EU stopped use. Paraquat poisoning via oral or skin

Figure 11.1| Paraquat structure + accumulation in blood/lungs



difficult getting out of lungs once there

Understanding Photosynthesis



(1774) british Priest Joseph Priestly – testing air |Fig 11.2A| candle + plant + sunlight
Purpose: study components in air
Methods: air tight container, light candle (remotely) → burns out (few minutes) → not relight
Findings but with sprig of mint + sunlight (few days) → can relight candle!

(1882) german Theodor Wihelm Engelmann – testing algae vs rainbow of light |Fig 11.2B|
Purpose: what happened to plants when hit by sunlight?
Methods: rod-shaped algae (plant) mobile O_2-lovin bacteria (B. termo)
had novel high tech microscope by friend the famous Carl Zeiss!
↳ used prism to split light into rainbow
Findings: bacteria moved toward BLUE + RED light areas on living algae (absorbance spectrum)

(1937) british Robin Hill (@ Cambridge) |Fig 11.2C|
purpose: ID which part of plant cell does PHS?
Method: blender vs spinach leaves + centrifuge → chloroplasts isolated

ICB 11.1 (cont.) PHS
Robin Hill showed isolated chloroplasts could do PHS → evolve O_2 → *light dosage dependent

IQs 1–4 | 1. Paraquat poisoning → how location of accumulation problematic?
→ predict it is water soluble?
2. Priestly trifecta, mint produced what molecule?
3. Engelman trifecta 4. Hill trifecta "Hill reaction" Colin's boxes + lights
Paraquat's charge important – likely substituting for PQ

Fig 11.3| — Anatomy of Chloroplast + PS

IQs 5–9| 1. colors Chl absorbs, eye sees it as? why plants look green if have yellow/red pigments
Note: thylakoids can be stacked or unstacked dynamically

(1954) american Daniel Arnon (UC Berkeley)

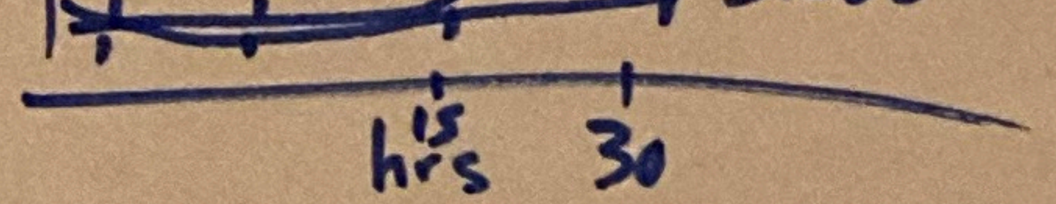
Figure 11.4| Purpose: measuring the rate of a. splitting H_2O, b. making ATP, c. fix CO_2
Methods: • use an inhibitor at different concentrations → dose-response curves *
• exposed isolated chloroplasts
• detected amount O_2 produced
Findings: H_2O splitting not affected BUT ATP + CO_2 fix were impacted but different dose-response
→ suggested all three seperate
Q: If reviewing Arnon's paper, ask for additional experiments?

(1973) german Hans Heldt → ATP production

Figure 11.5|
Purpose: study mechanism behind ATP production at thylakoid mem
Methods: • Track pH inside (lumen/space) + outside (stroma) thylakoid with pointy micro electrodes simultaneously of a single chloroplast
• Turn off/on light/dark
Findings: light ON → stroma loses H+s (pH↑) + thylakoid gains them (pH↓), repeated

then Robin Hill → photobleaching supported two photosystems P680 P700
Reading-reviews linear z-scheme path + carriers of light rxns + cyclic sch
+ talks about movement/pumping of protons at cytochrome

Figure 11.8| ATP synthase "rotational catalysis"! purified Chloroplasts + light → ATP
chloroplasts, mitochondria + prokary ATP synthase



of lungs once there

Understanding Photosynthesis

(1774), british Priest Joseph Priestly – testing air [Fig 11.2A] candle + plant + sunlight

Purpose: study components in air

Methods: air tight container, light candle (remotely) → burns out (few minutes) → not relight

Findings but with sprig of mint + sunlight (few days) → can relight candle!

(1882) german Theodor Wilhelm Engelmann – testing algae vs rainbow of light [Fig 11.2B] x

Purpose: what happened to plants when hit by sunlight?

Methods: rod-shaped algae (plant) mobile O_2-lovin bacteria (B. termo)
had novel high tech microscope by friend the famous Carl Zeiss!

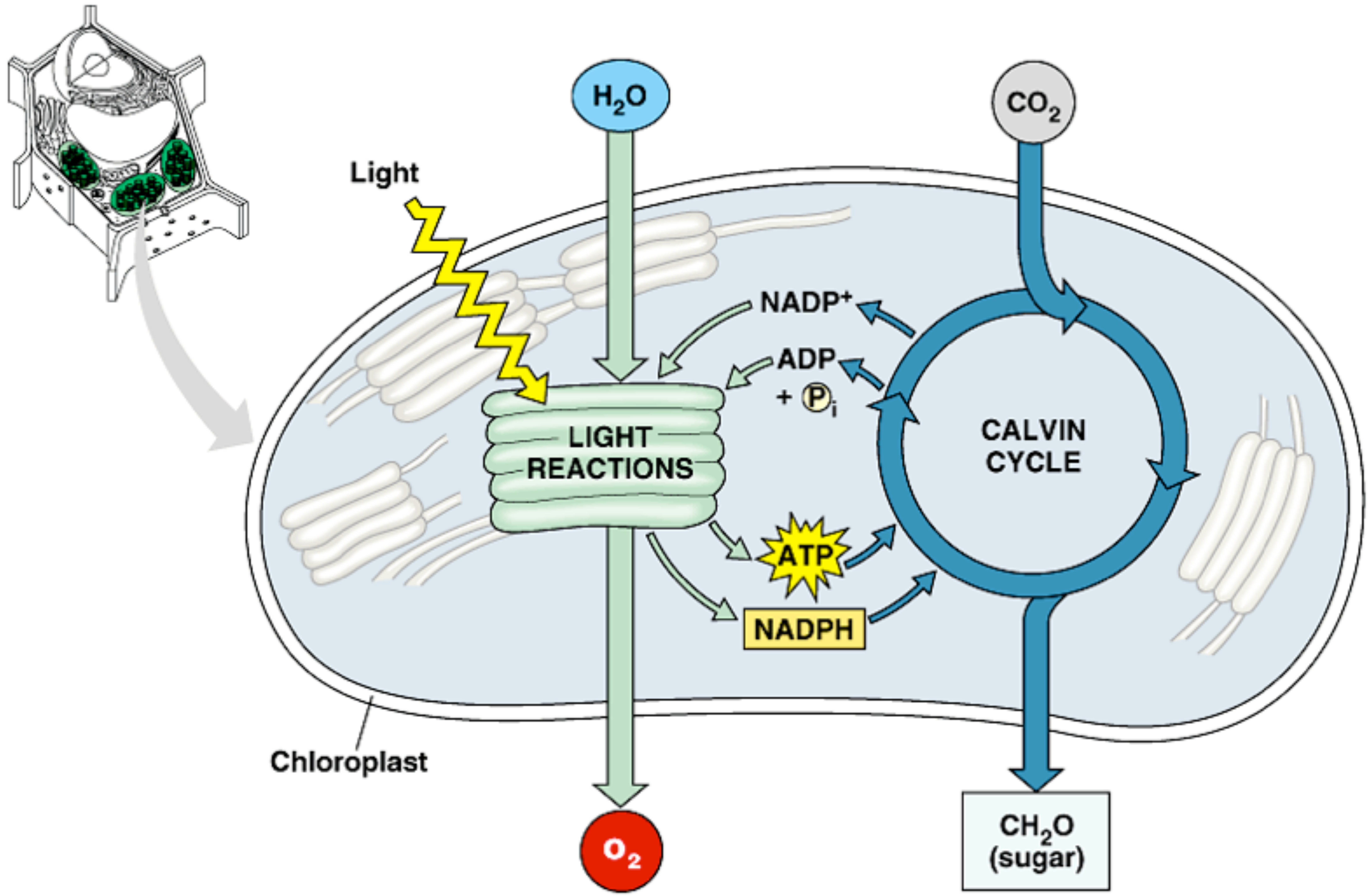
Findings: bacteria ↳ used prism to split light into rainbow living!
moved toward BLUE + RED light areas on algae (absorbance spectrum)

(1937) british Robin Hill (@ Cambridge) [Fig 11.2C]

purpose: ID which part of plant cell does PHS?

Method: blender vs spinach leaves + centrifuge → chloroplasts isolated

Back to Photosynthesis…



Light
H_2O
CO_2
NADP+
ADP
+ Pi
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
Chloroplast
O_2
CH_2O (sugar)

Integrating Concepts in Biology

Chapter 11: **Photosynthesis**

11.1 Why is paraquat used in America but illegal in Europe?

by A. Malcolm Campbell, Laurie J. Heyer, & Christopher Paradise

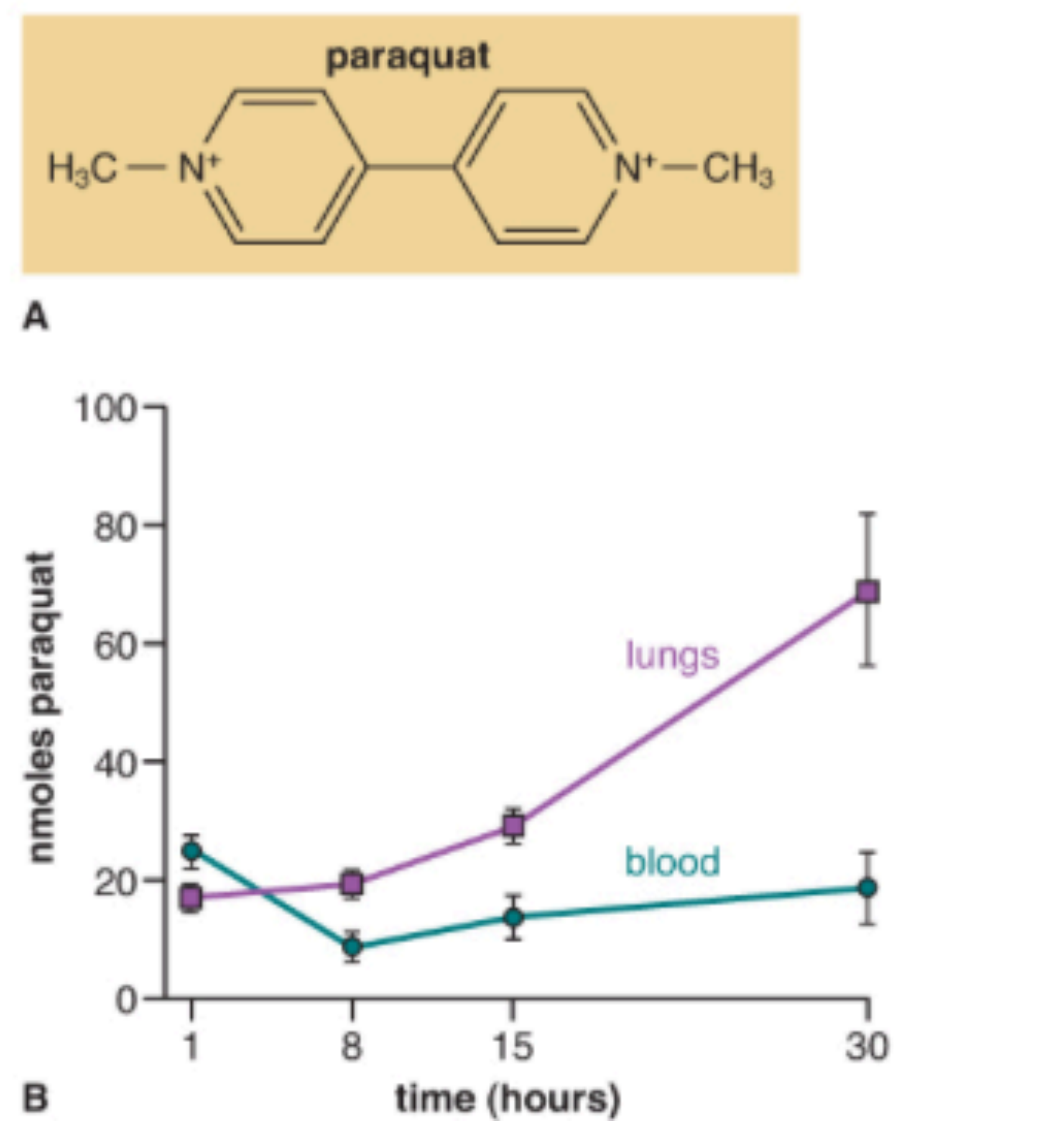
11.1 Why is paraquat used in America but illegal in Europe?

- Context: Plants and animals contain many similar enzymes. Herbicides are designed to kill only plants, but does our common eukaryotic ancestry put your health at risk too?
- Major themes: Biological systems use feedback mechanisms to regulate and maintain optimal conditions; time-dependent processes regulate biological systems; life requires organization, which is energy dependent; and a biological system's size and environment influence how it addresses physical and chemical challenges.
- Bottom line: Plant molecules that harvest light energy to make new chemical bonds are very similar to molecules in cellular respiration, which means that herbicides might be toxic to animals.

Biology Learning Objectives

- Describe how plants capture energy from sunlight and convert that energy into new forms of potential energy.
- Distinguish the three parts of photosynthesis, and explain the overall chemical and physical processes involved in each one.

In 2003, farmers in the European Union (EU) began using the most common herbicide on the planet—paraquat (Figure 11.1A). Paraquat is used in over 100 countries to kill unwanted plants, especially weeds that reduce crop yields. In 2007, an EU Court blocked the use of paraquat in Europe. Farmers in the EU are not allowed to use paraquat, because it "[f]ails to satisfy the requirement of protection of human health." Most cases of paraquat poisoning are due to oral ingestion, but some people have died due to absorption through the skin. How does paraquat work on plants? Can an herbicide kill plants and humans? Pathologists quantified the level of paraquat in lab rats that had consumed potentially lethal doses of the herbicide (Figure 11.1B). Physicians can try to lower the harm of ingested paraquat, but lowering the blood level of paraquat is easier than stopping the accumulation in lungs. To understand how paraquat works in plants and how this might affect humans, you need to understand photosynthesis first.



Biology Learning Objectives

- Describe how plants capture energy from sunlight and convert that energy into new forms of potential energy.
- Distinguish three independent parts of photosynthesis, and explain the overall chemical and physical processes involved in each one.

Trifecta

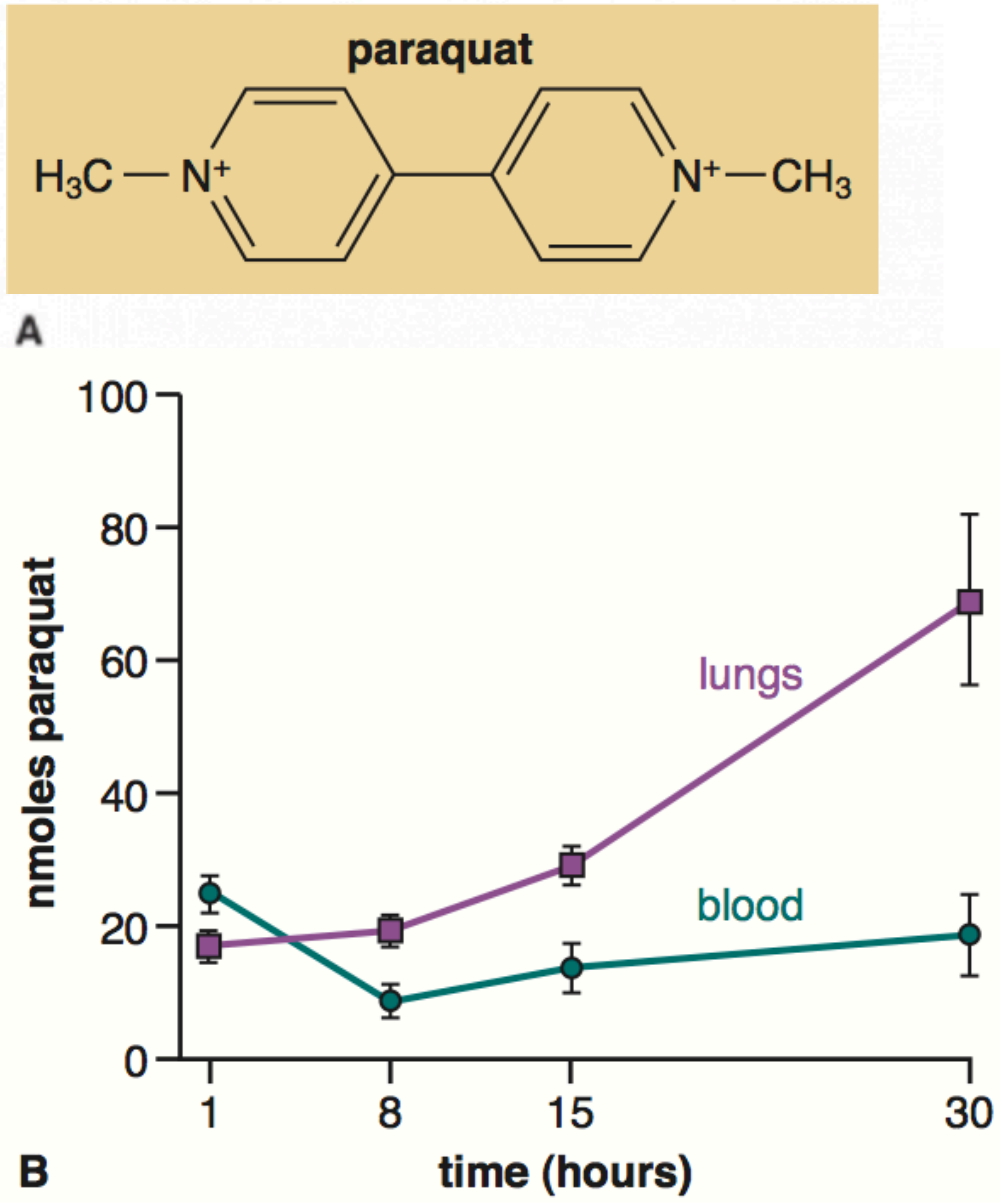
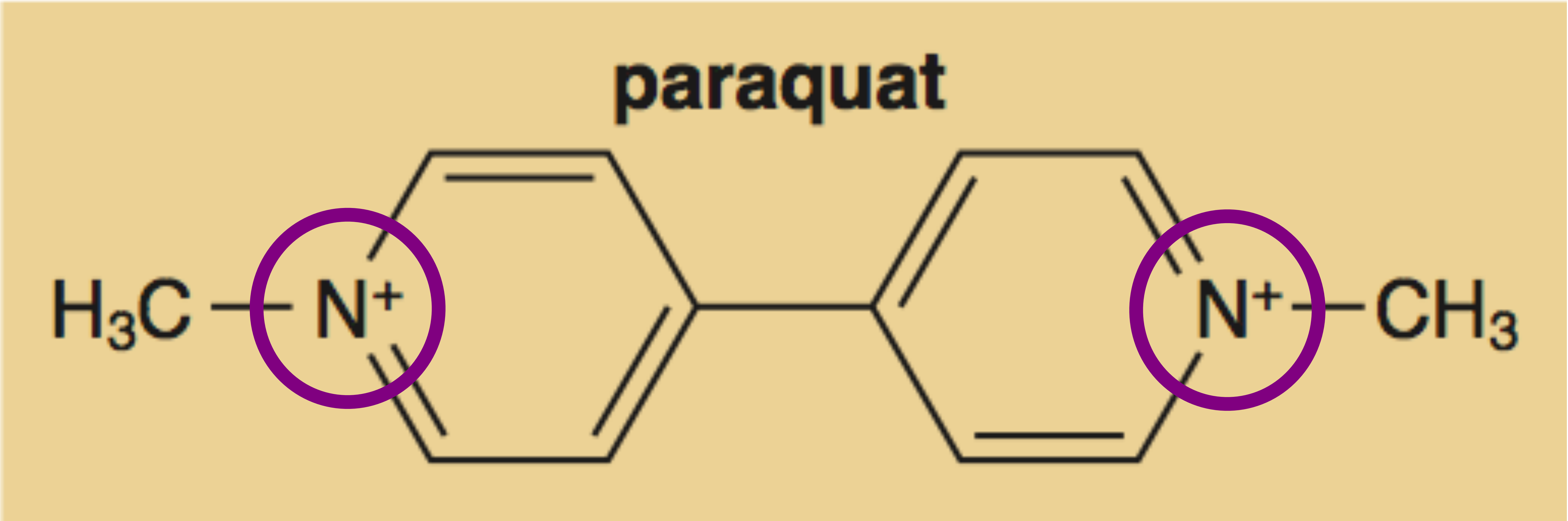


Figure 11.1 Paraquat and its mammalian consequences. **A,** Molecular structure of the herbicide paraquat. **B,** Paraquat levels in the blood (per mL) and lungs (per gram) of rats fed paraquat. Error bars are standard error; n = 5 rats per time point. Panel A from public domain, common knowledge. Panel B modified from LL Smith, 1985; his figure 1. Smith, L. L. 1985. Paraquat Toxicity. Philosophical Transaction of the Royal Society of London. Vol. B 311: 647 – 657. Reprinted with permission from The Royal Society. Copyright © 1985.

Legal in US, Illegal in EU – why?



+2 charged molecule

Plastoquinone PQ ->

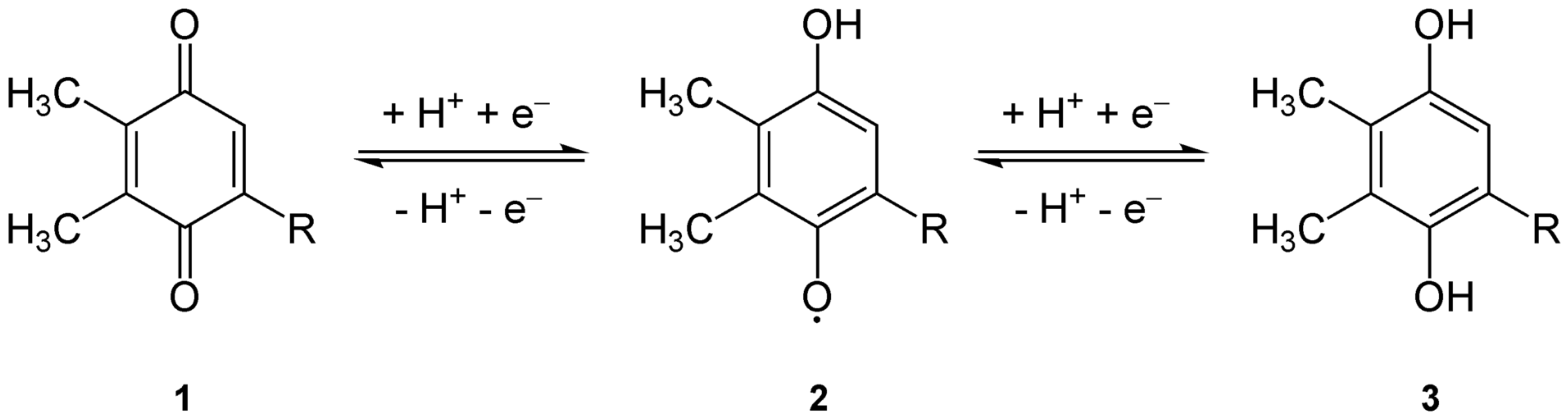


Fig. 11.1

B: modified from LL Smith, 1985

Paraquat Affects Mammals

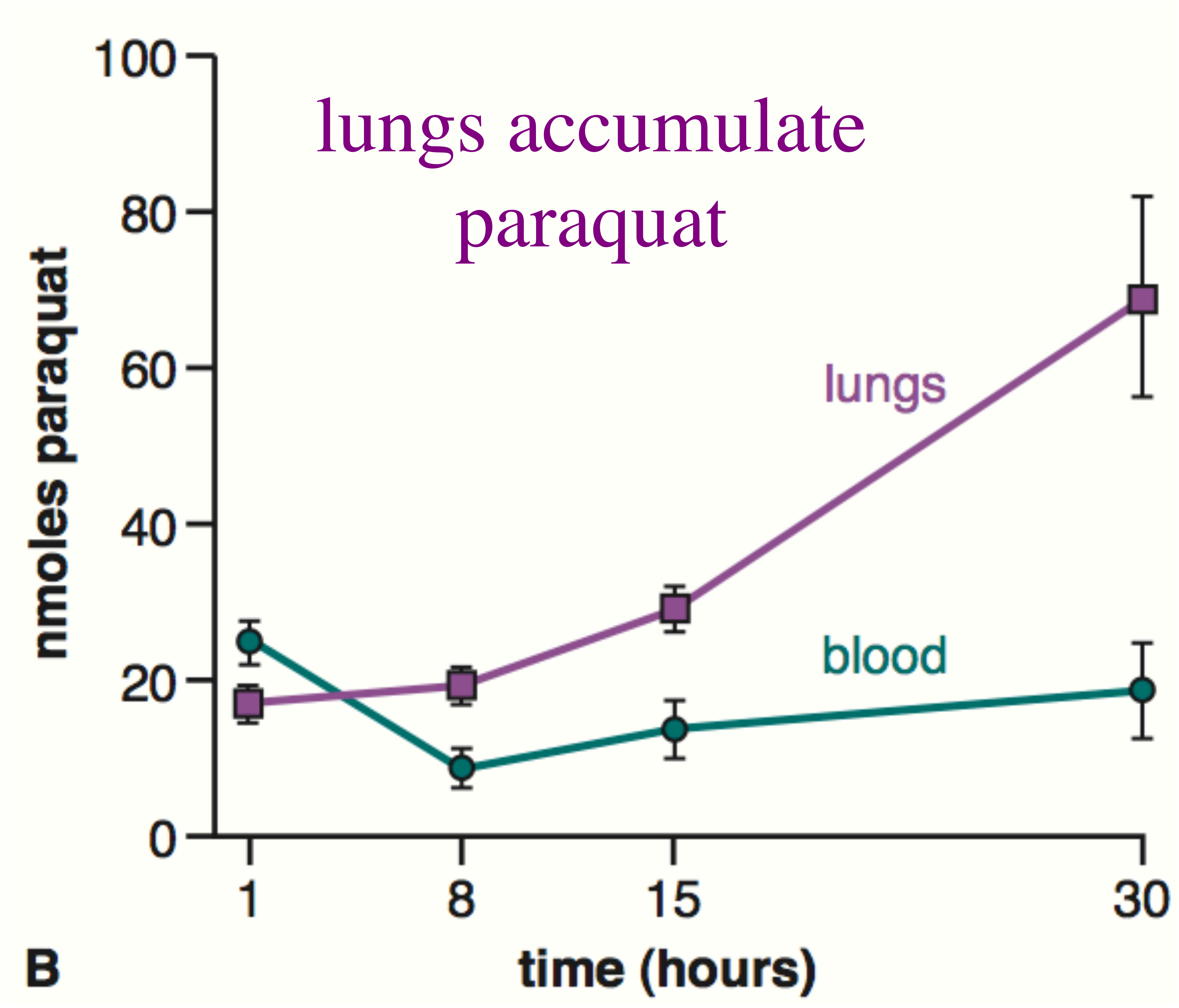


Fig. 11.1

B: modified from LL Smith, 1985

Trifecta

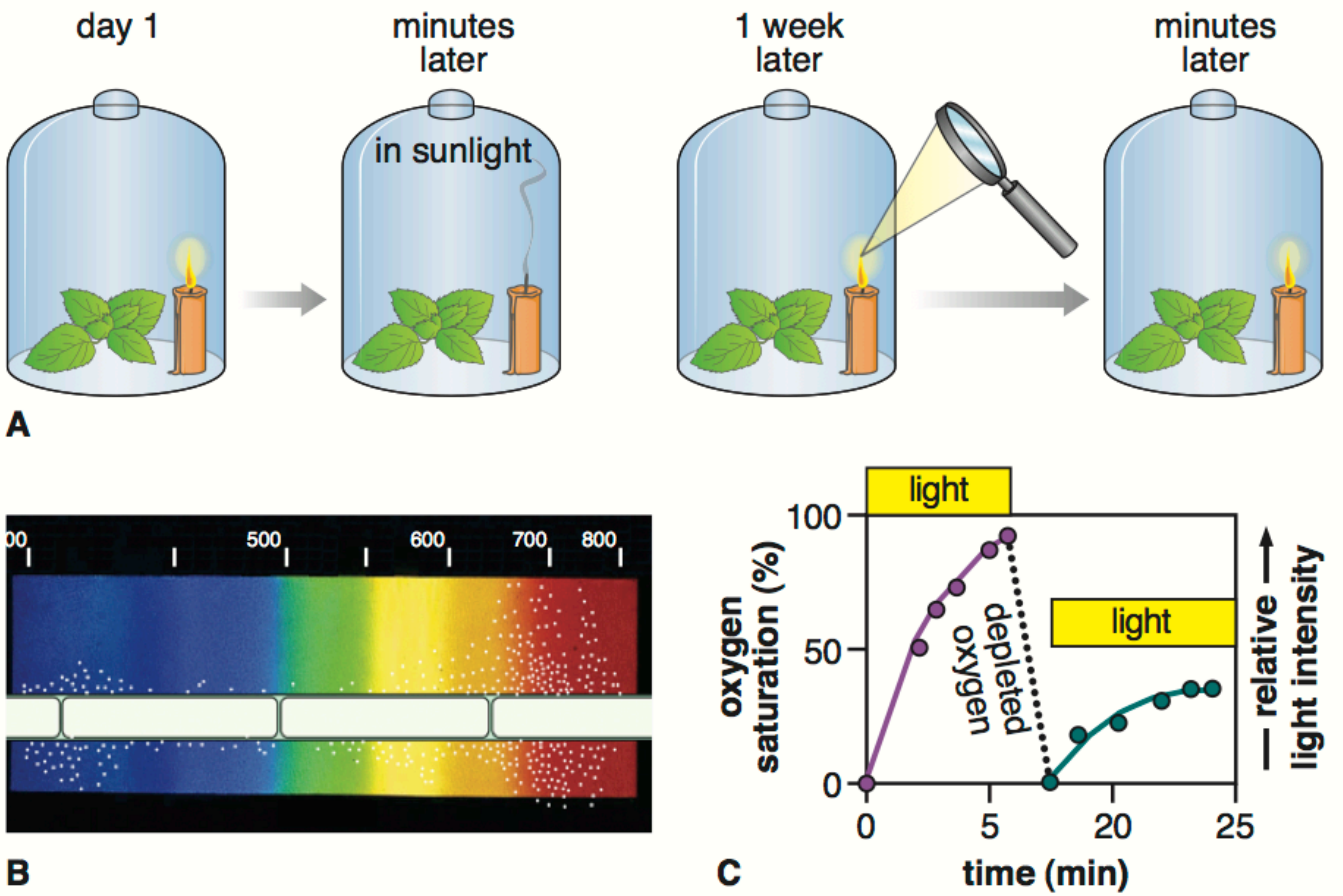


Figure 11.2 Plants produce oxygen. **A,** Priestley's 1774 experiment showing that plants in the sunlight can replenish depleted air. **B,** Engelmann's 1882 experiment showed oxygen-loving bacteria (white spots) moved to the portion of algae cells (horizontal rectangles) exposed to particular wavelengths of light. The original drawing was in black and white; color has been added for clarity. **C,** Hill's experiment measured oxygen production (y-axis, left side) from purified chloroplasts exposed to different intensities of light (yellow boxes, y-axis right side). Panel A original art based on Joseph Priestly's 1774 written description. Panel B modified from Engelmann, 1882, his figure 1. Kamen, Martin D. 1986. On creativity of eye and ear: a commentary on

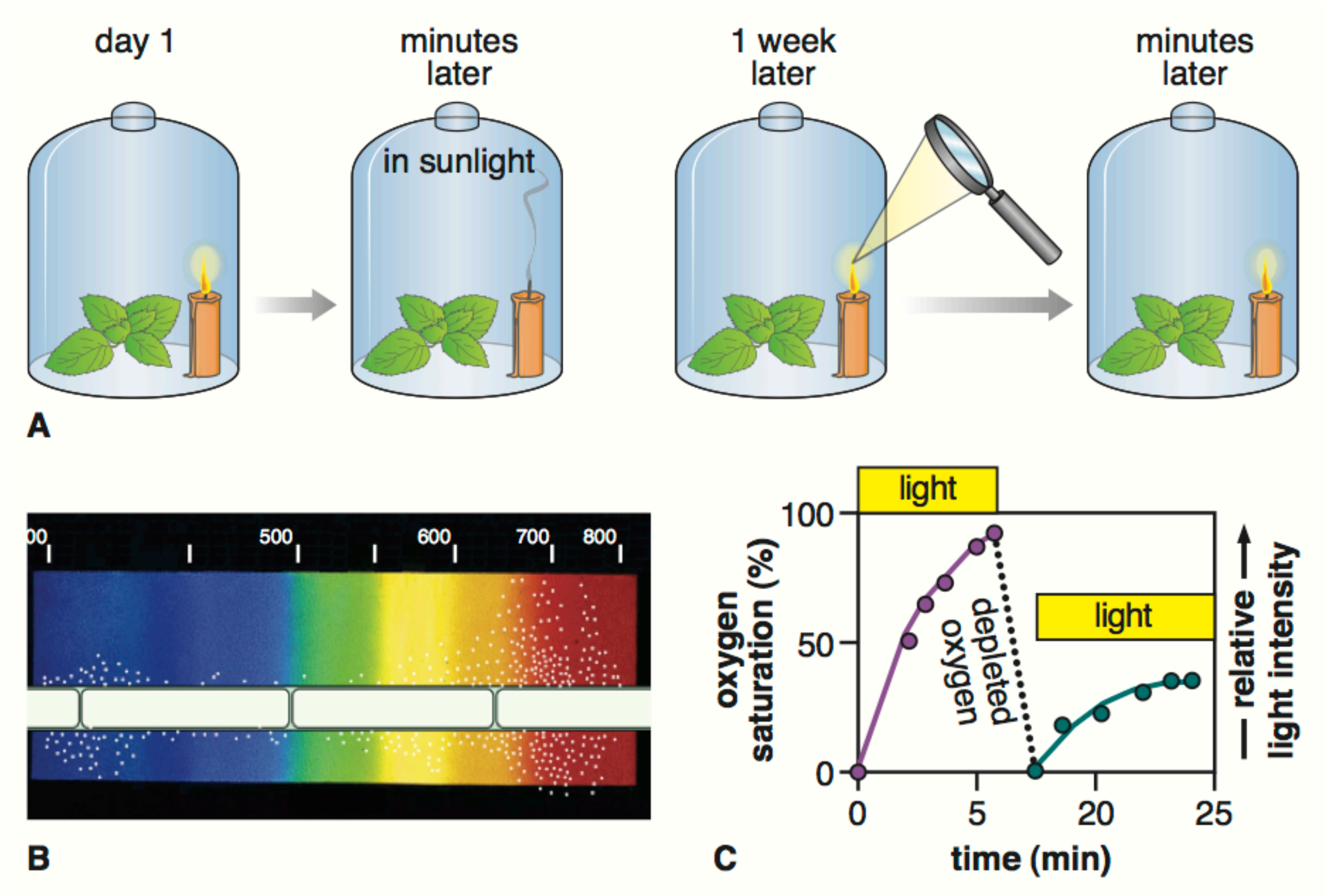


Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Trifecta

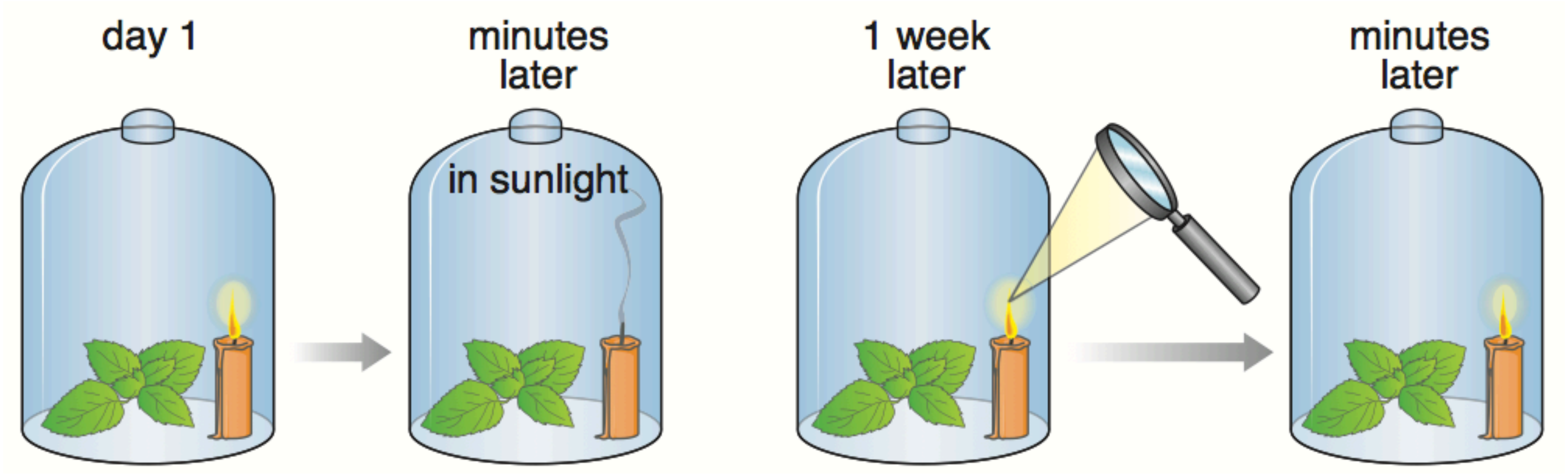


Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

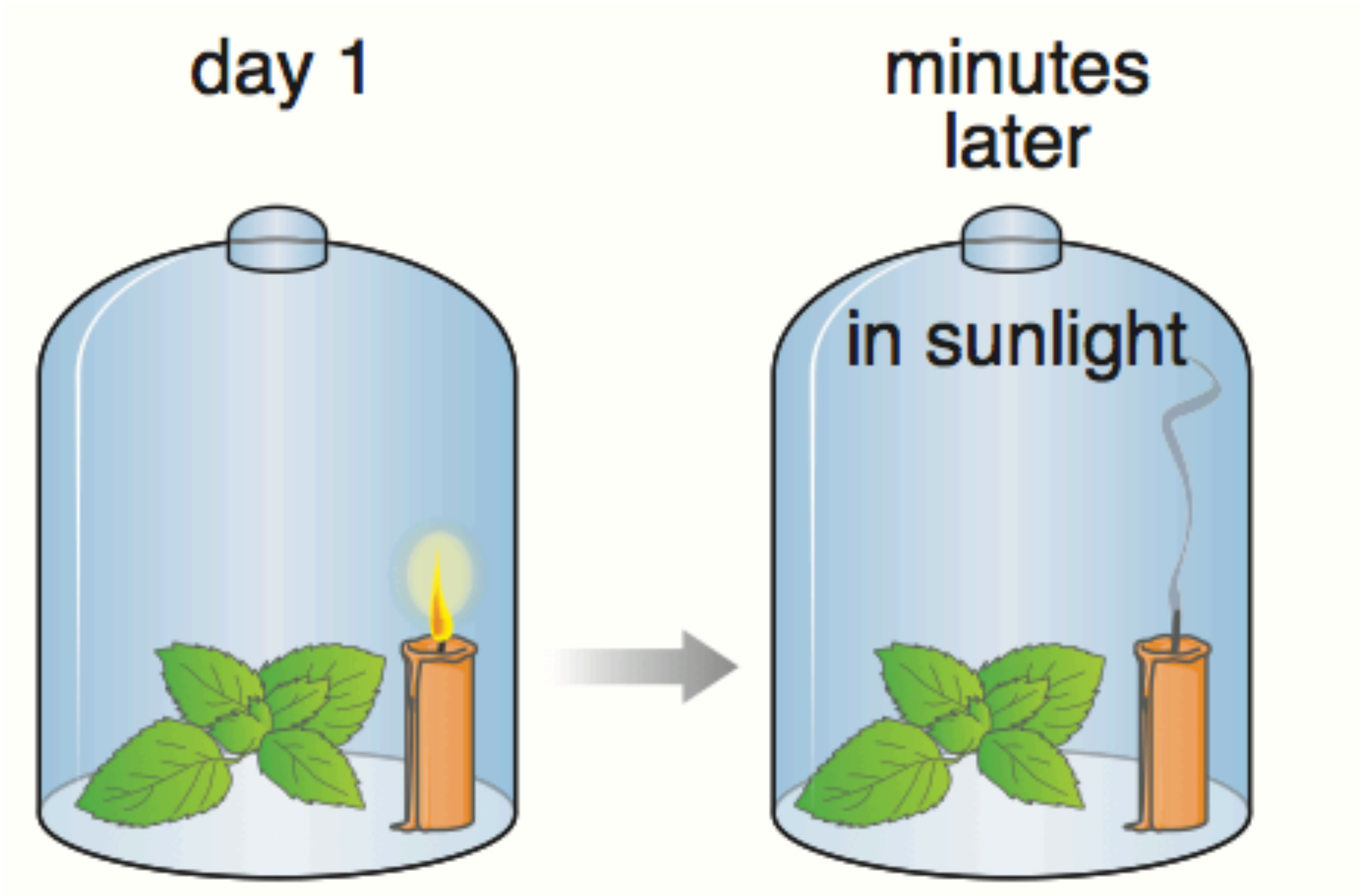
Experiments Determine Oxygen Source

light flame
under glass
with plant

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Experiments Determine Oxygen Source

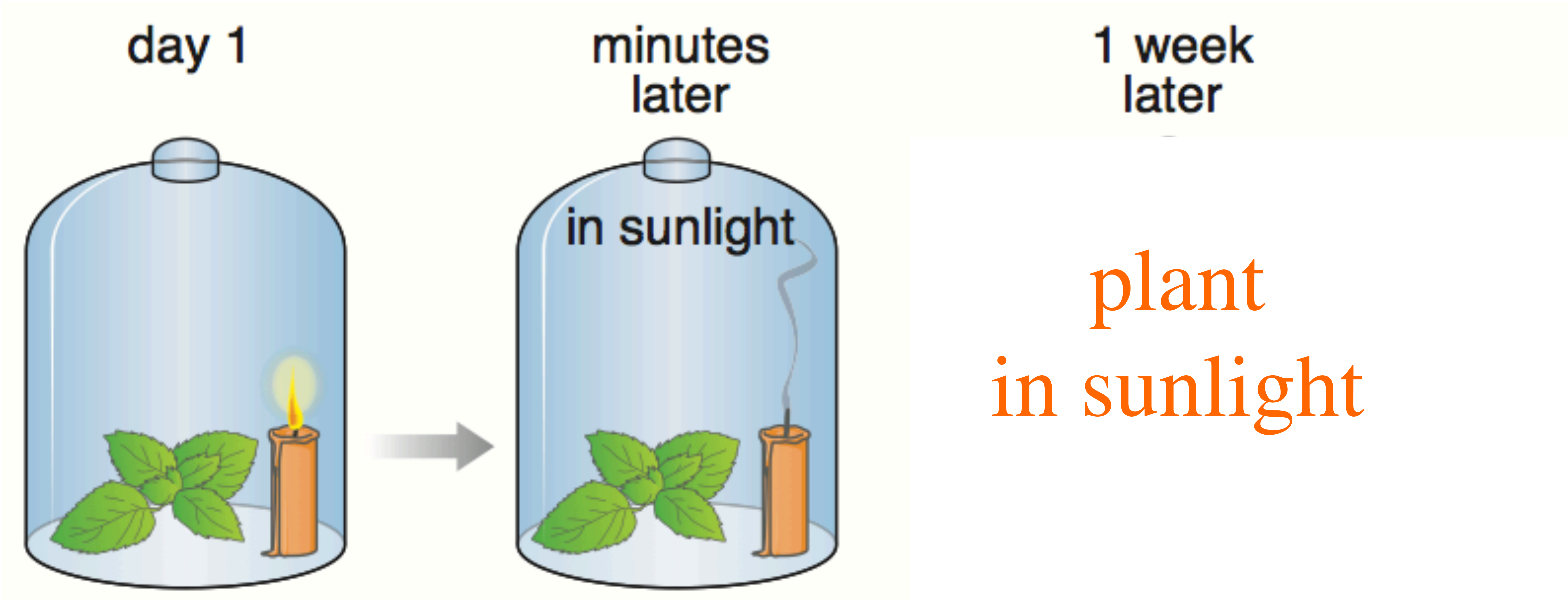


flame
burns
out

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Experiments Determine Oxygen Source

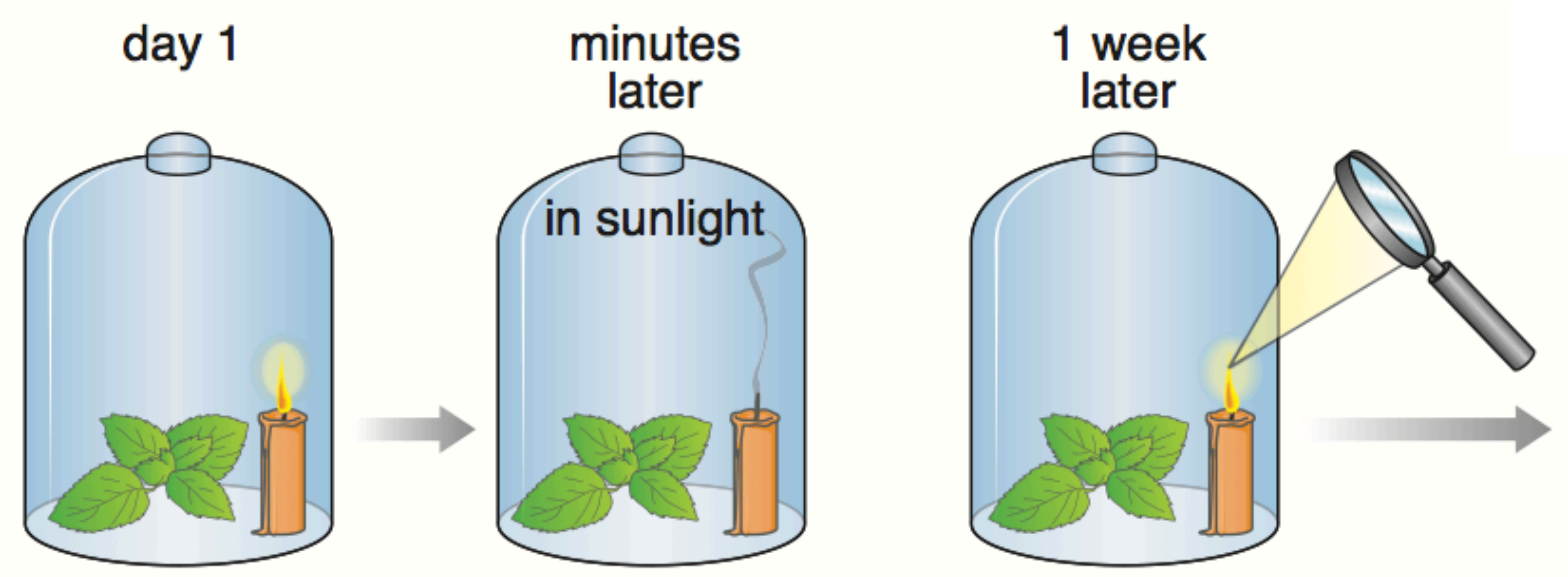


plant
in sunlight

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Experiments Determine Oxygen Source

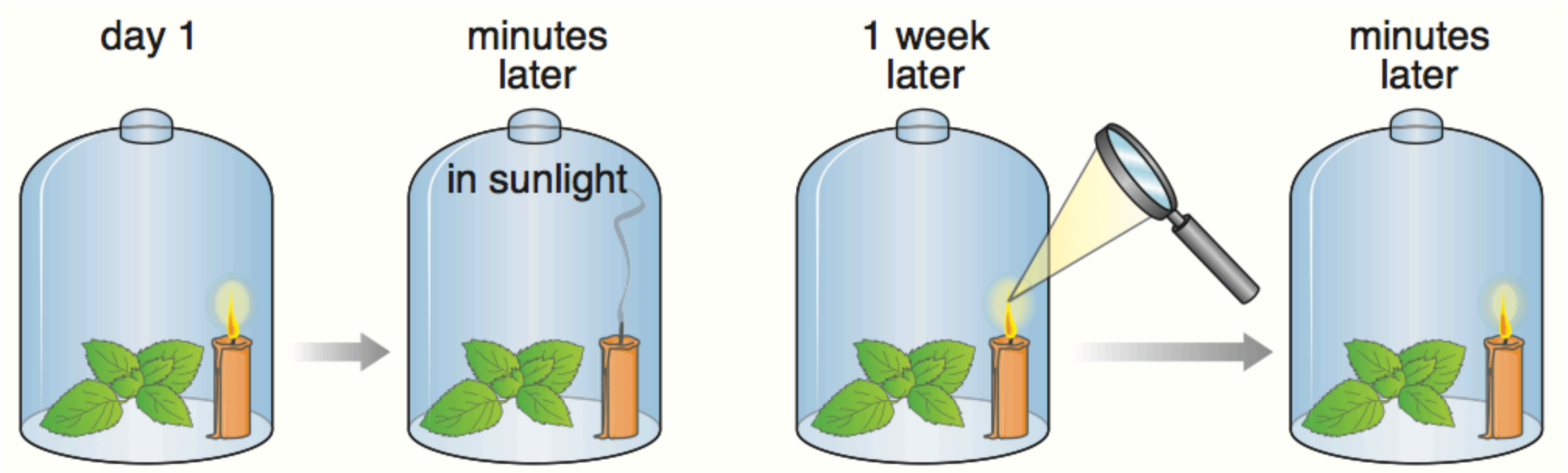


intensify
sunlight
on wick

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Experiments Determine Oxygen Source



flame
burns
again

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Trifecta

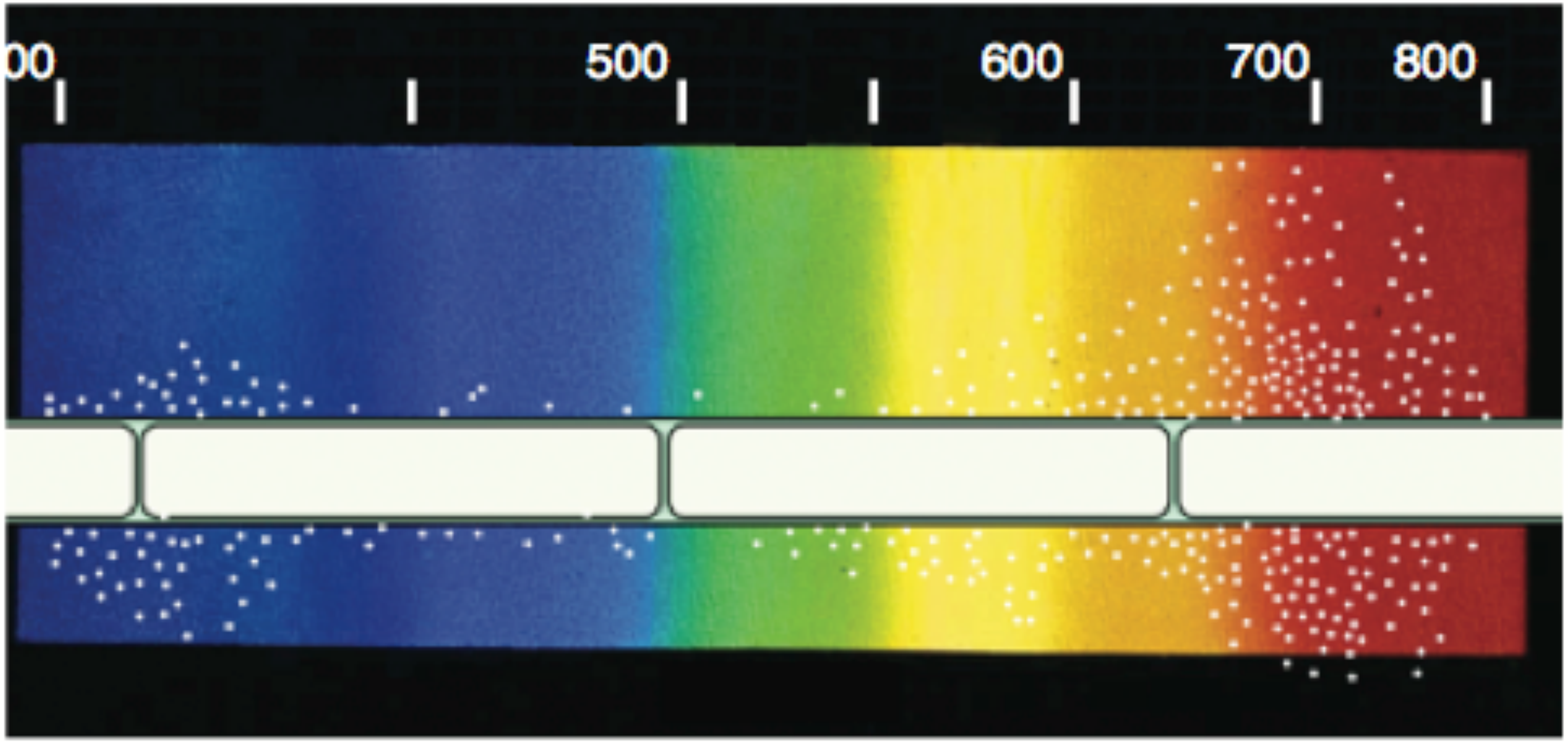


Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Biological Detection of Oxygen Source

green alga viewed through microscope

Fig. 11.2

Biological Detection of Oxygen Source

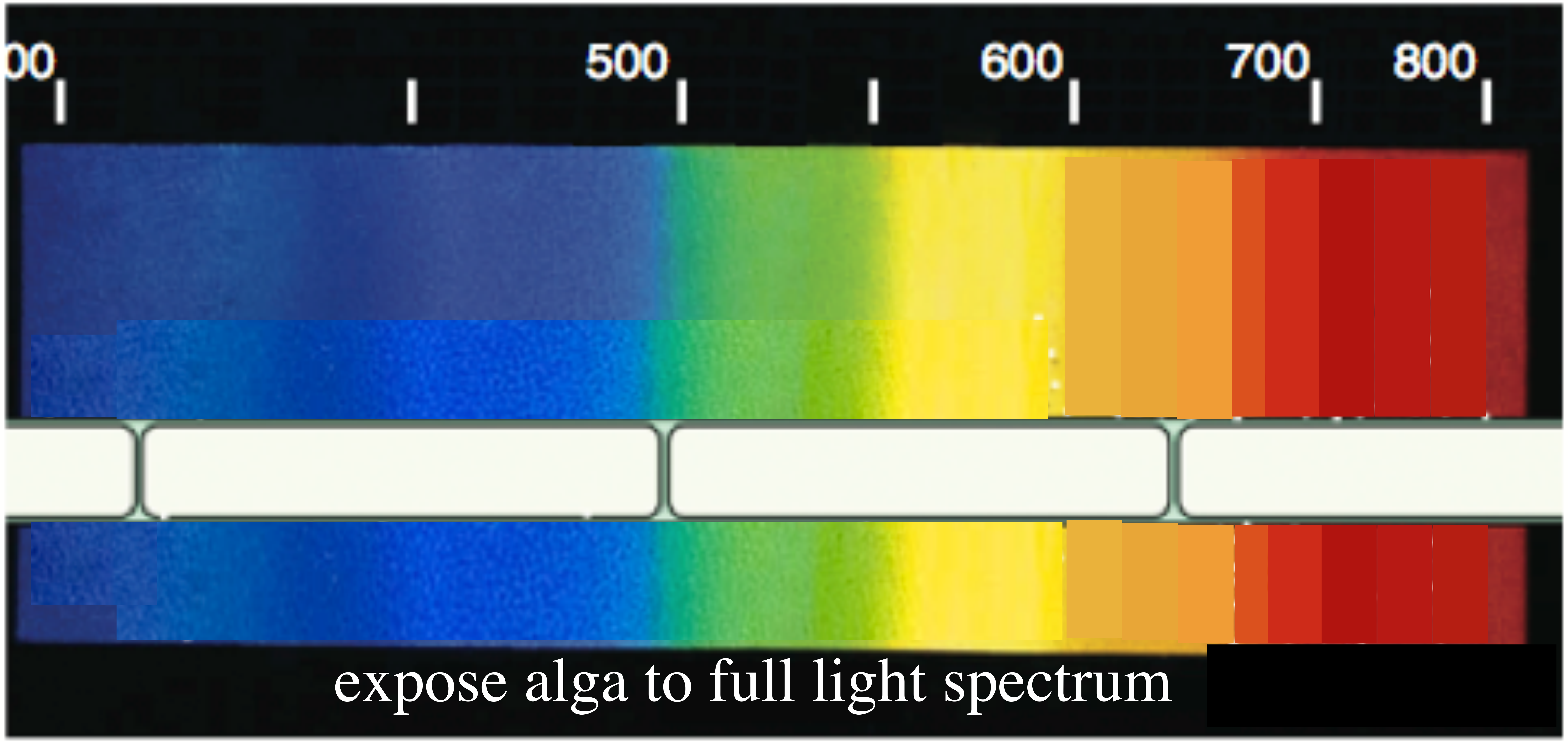
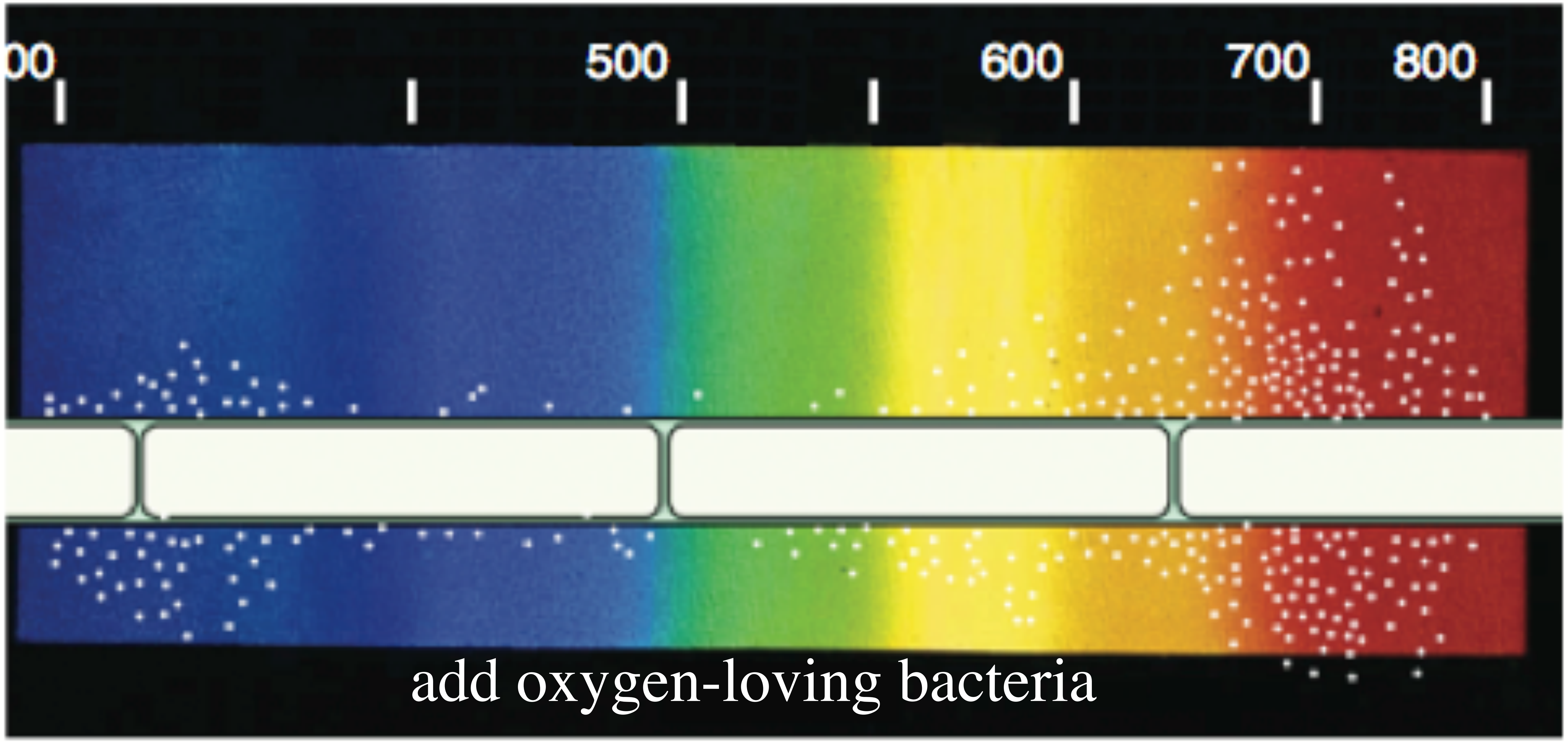


Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Biological Detection of Oxygen Source



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Biological Detection of Oxygen Source

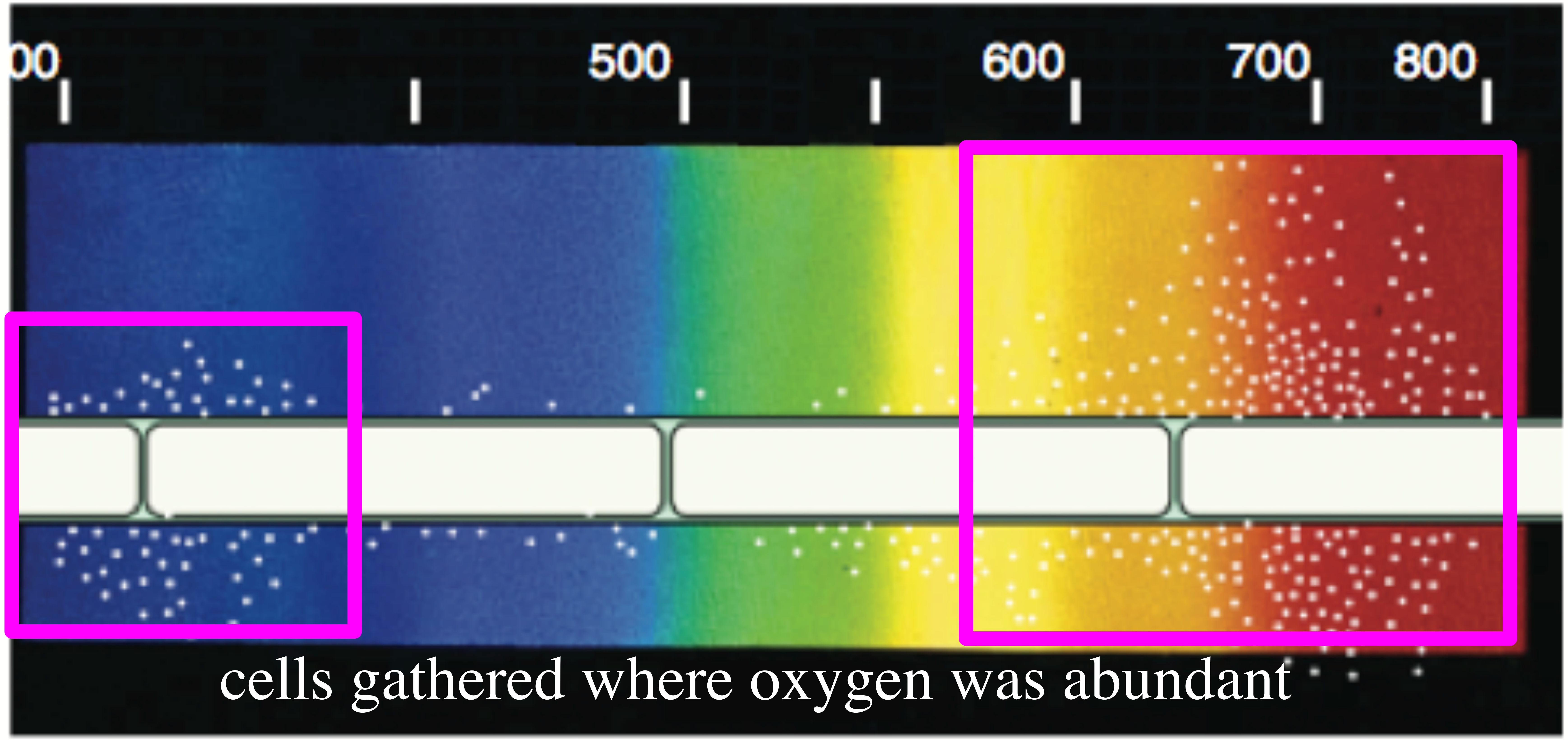

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Trifecta

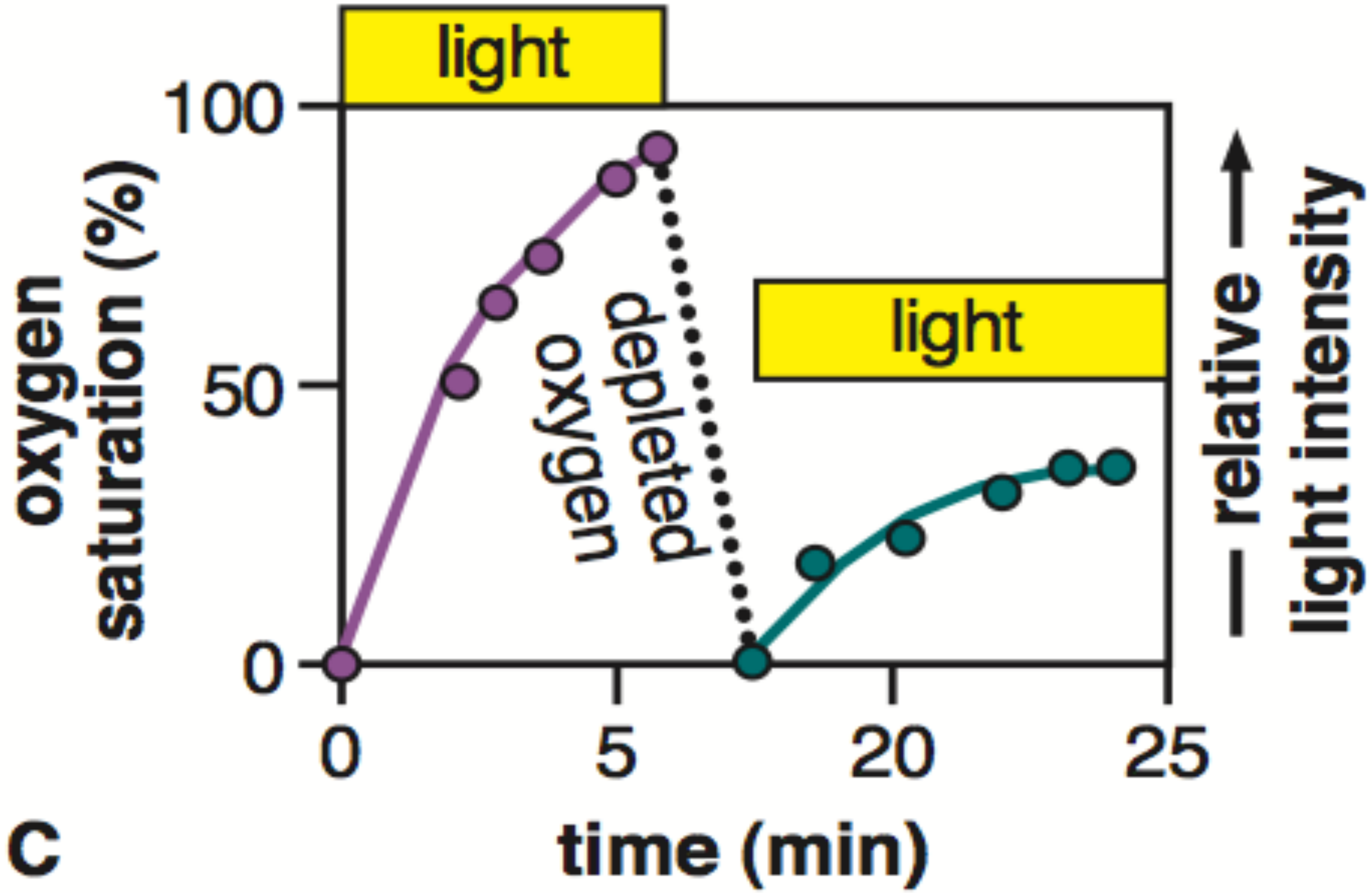

Fig. 11.2

Influencing Oxygen Production Rate

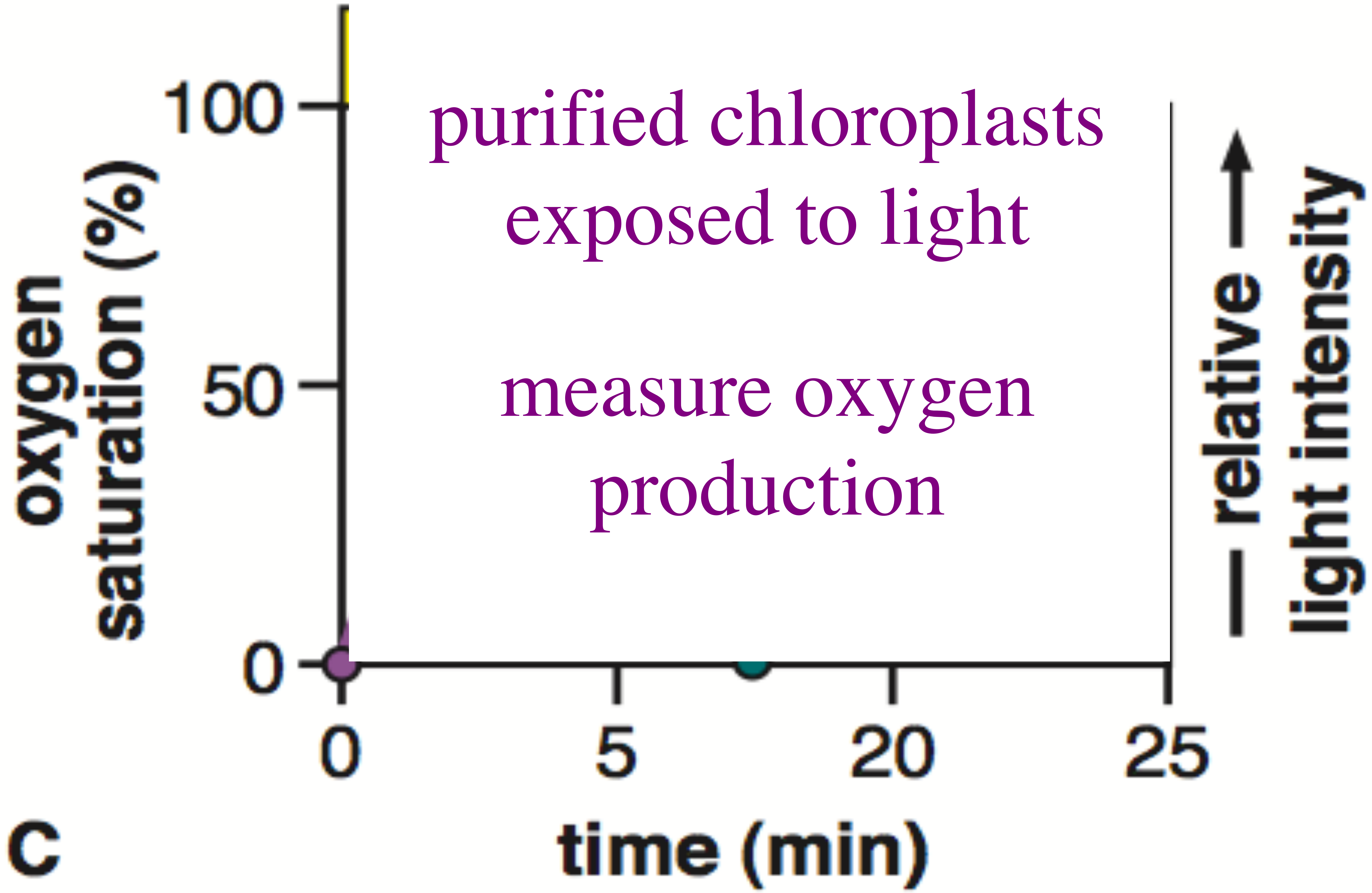

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Influencing Oxygen Production Rate

intense light,
O_2 accumulates

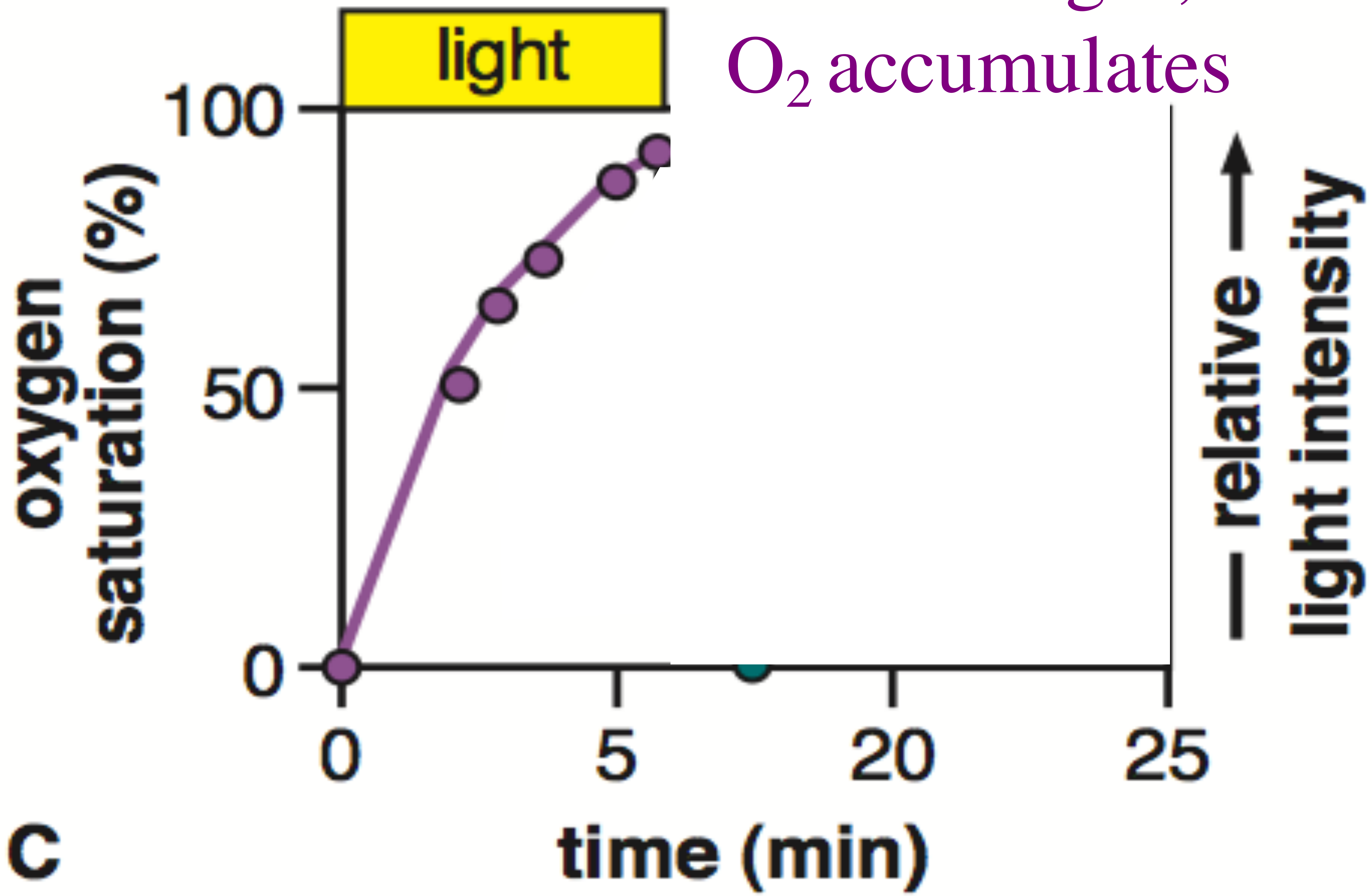

Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Influencing Oxygen Production Rate

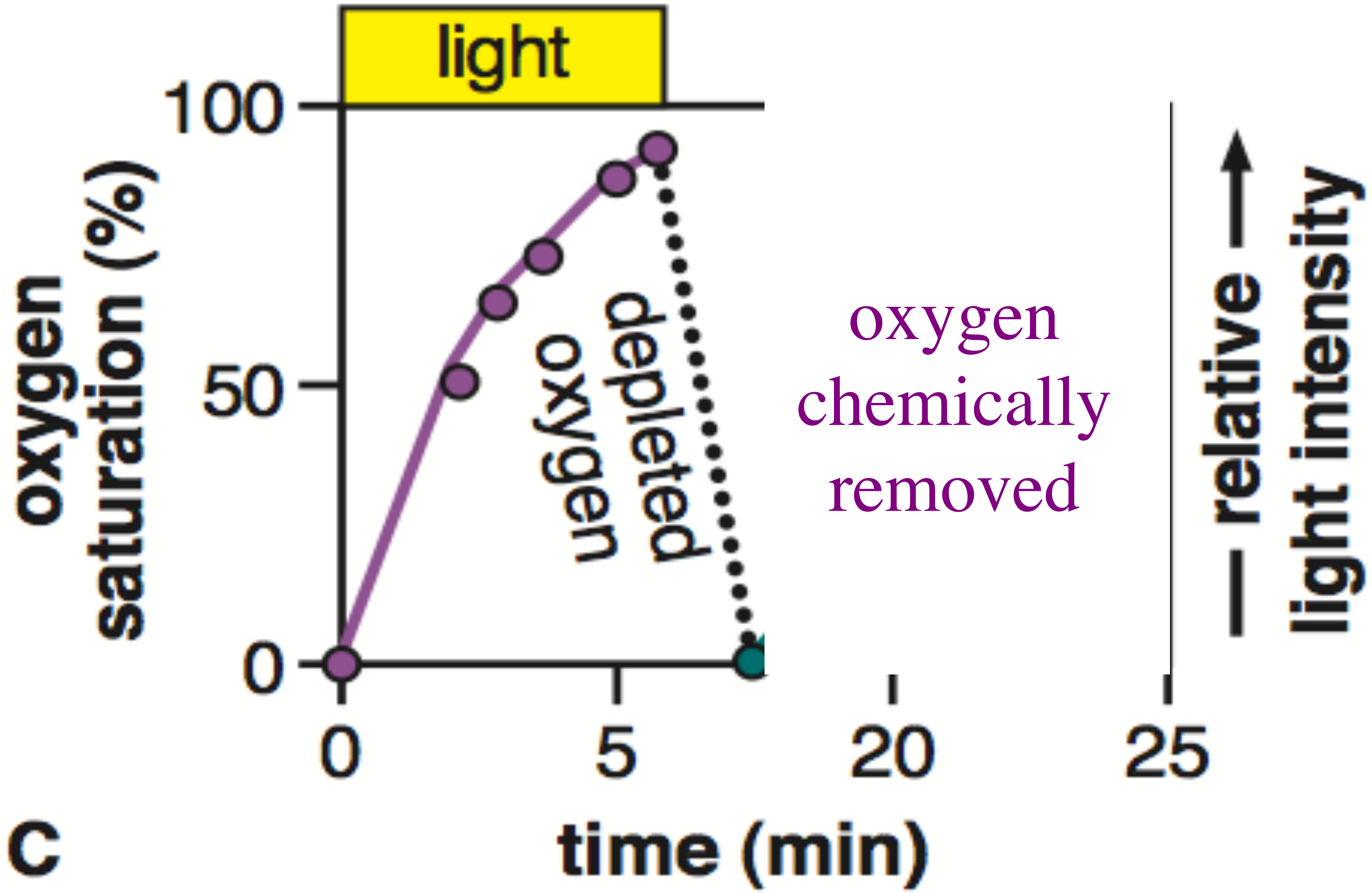

Fig. 11.2

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Influencing Oxygen Production Rate

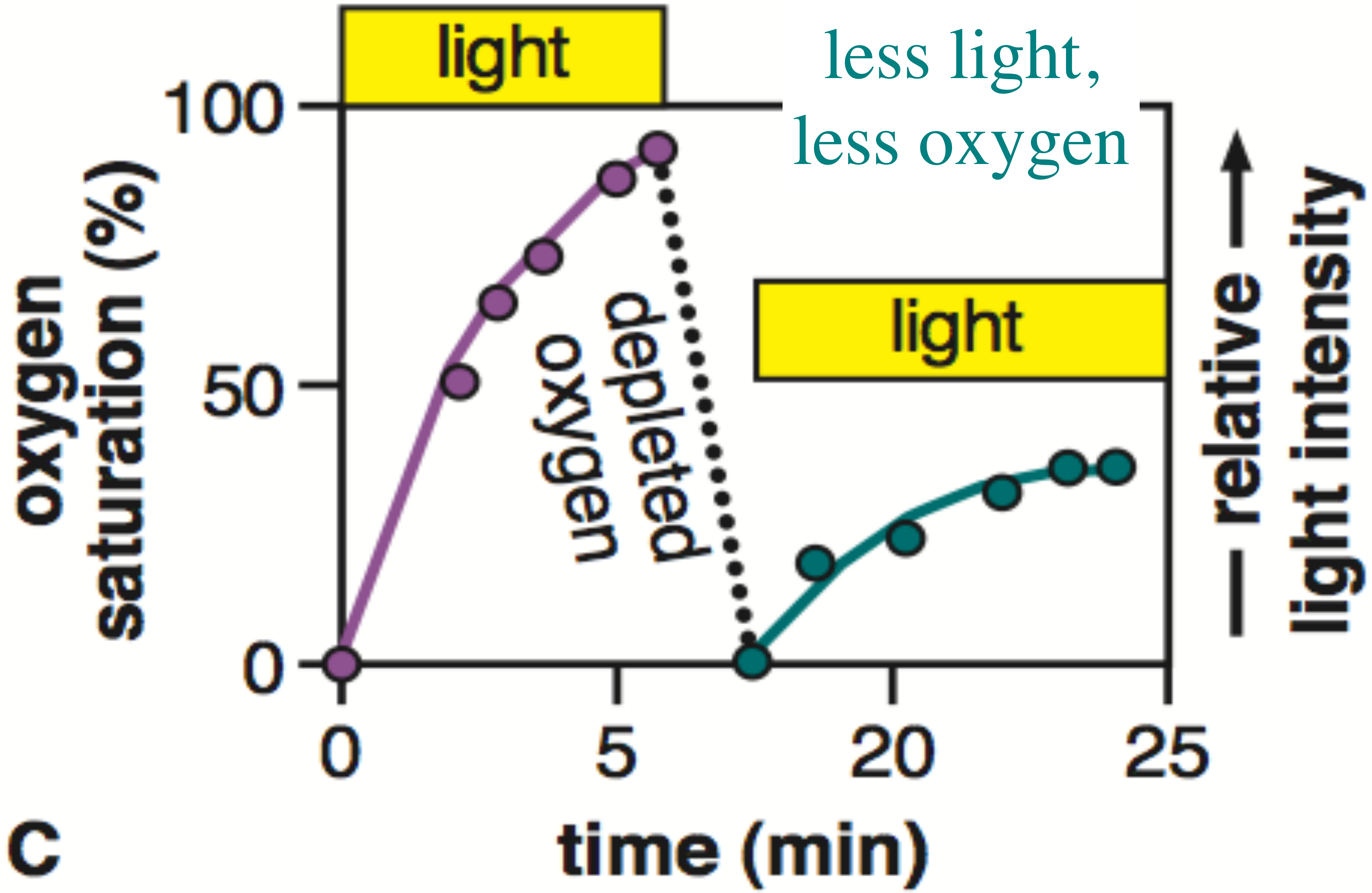


Fig. 11.2

A: from Priestly, 1774; B: from Engelmann, 1882; C: modified from Hill, 1937

Trifecta

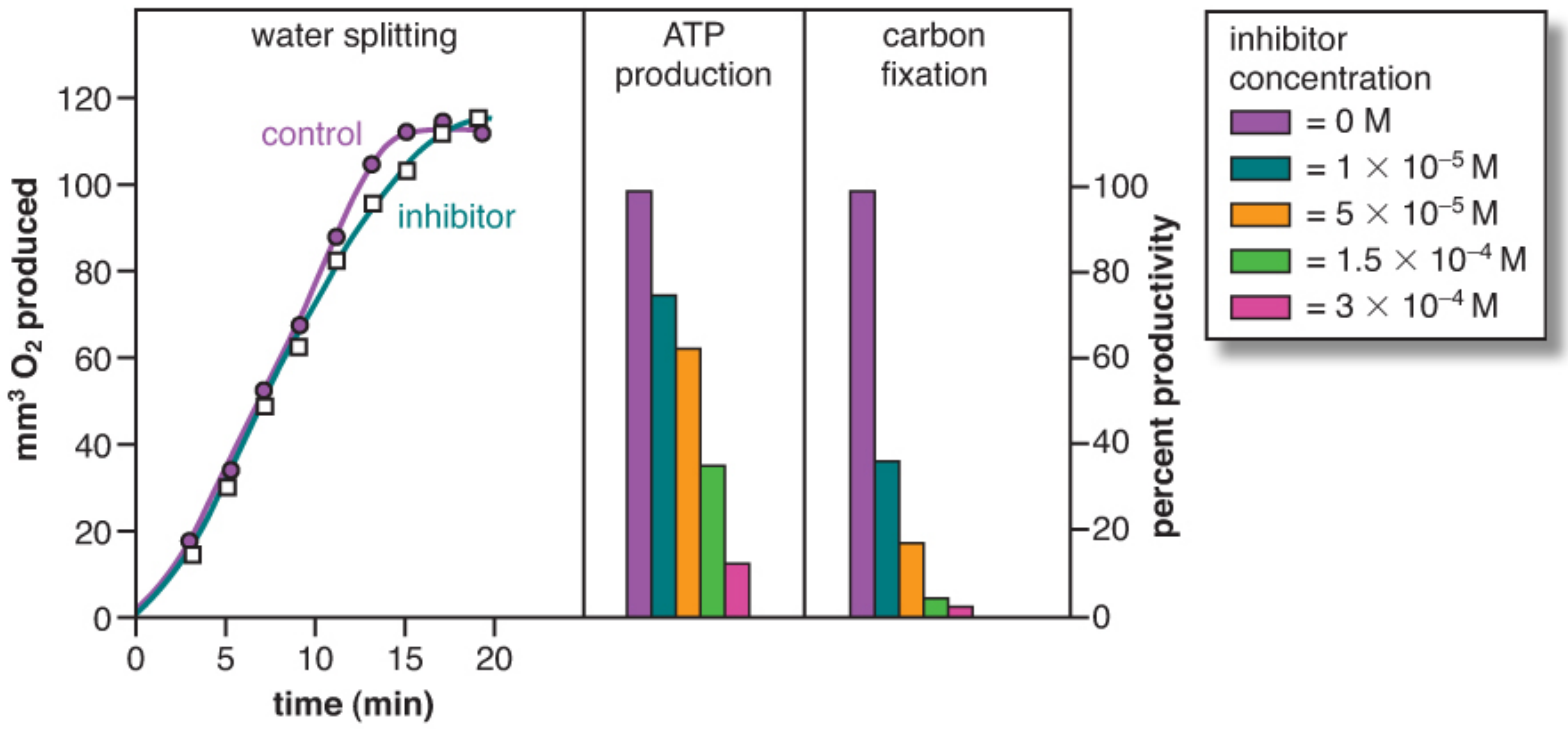


Figure 11.4 Photosynthesis is a summation of three parts. Using an enzyme inhibitor, botanists dissected photosynthesis by measuring the production of oxygen (+/- 10^{-5} M inhibitor), ATP, and carbon fixation (at the indicated inhibitor concentrations). Modified from Arnon et al., 1954; their figure 1. Reprinted by permission from Macmillan Publishers Ltd: Nature. Photosynthesis by Isolated Chloroplasts. Vol. 174(4426). copyright 1954.

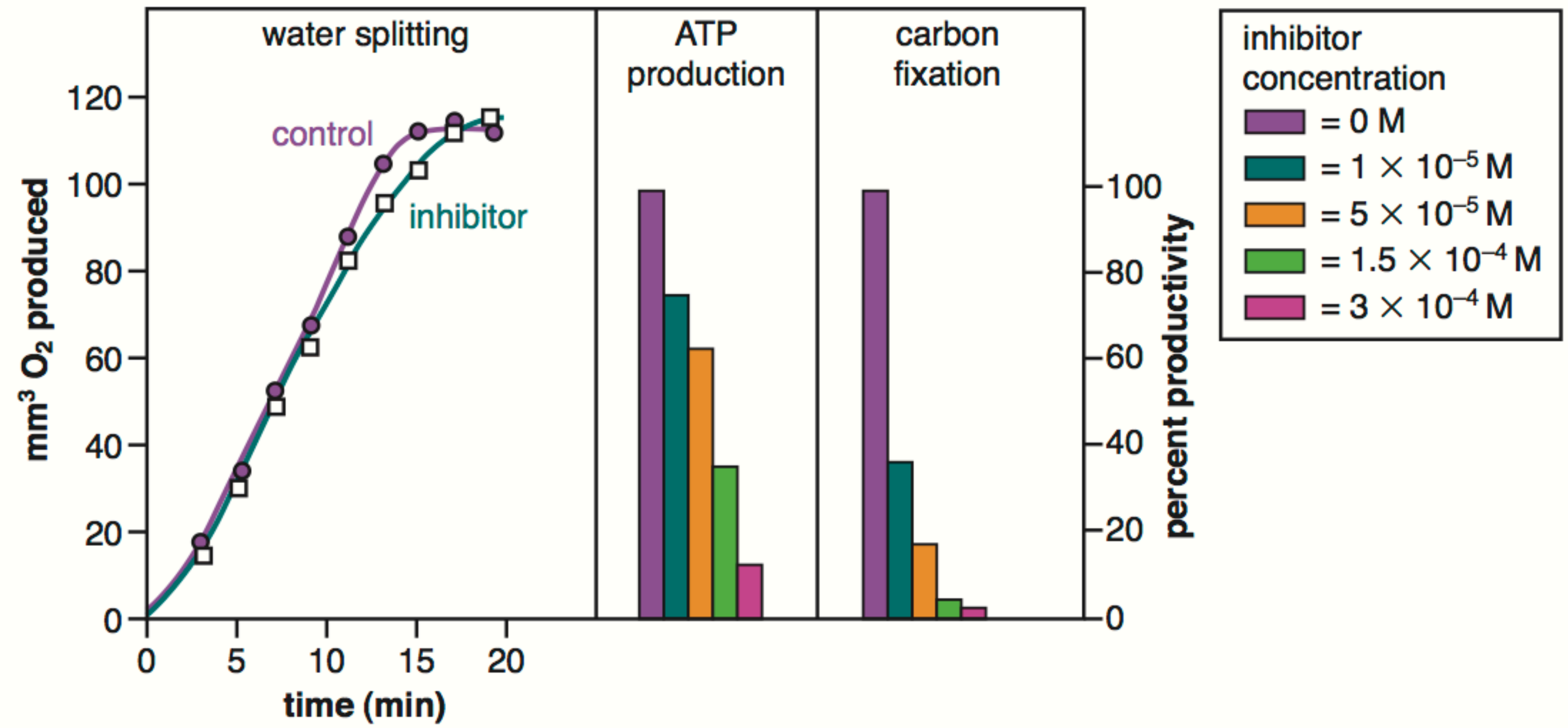


Fig. 11.4

modified from Arnon *et al.*, 1954

Photosynthesis Composed of Steps

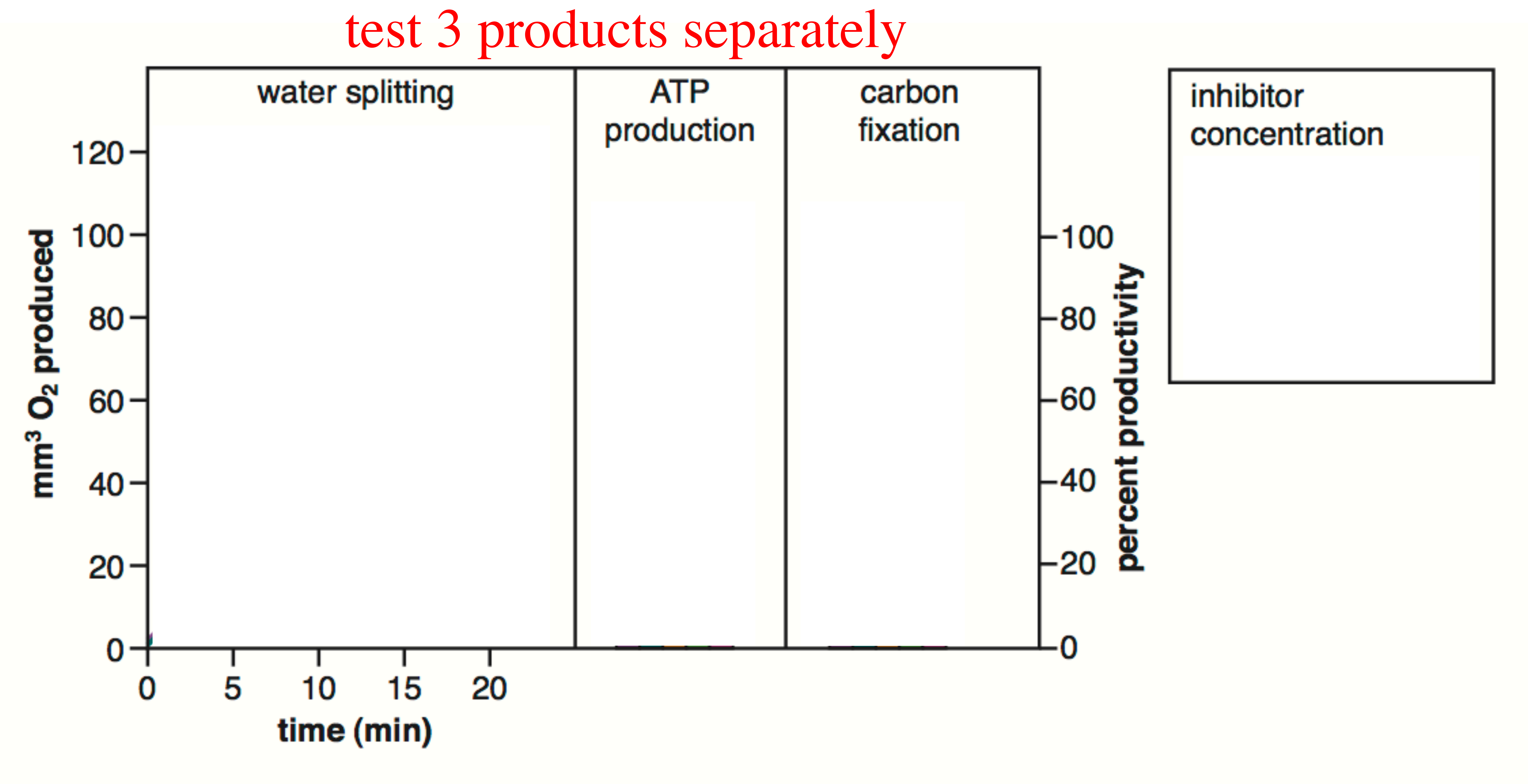


Fig. 11.4

modified from Arnon *et al.*, 1954

Photosynthesis Composed of Steps

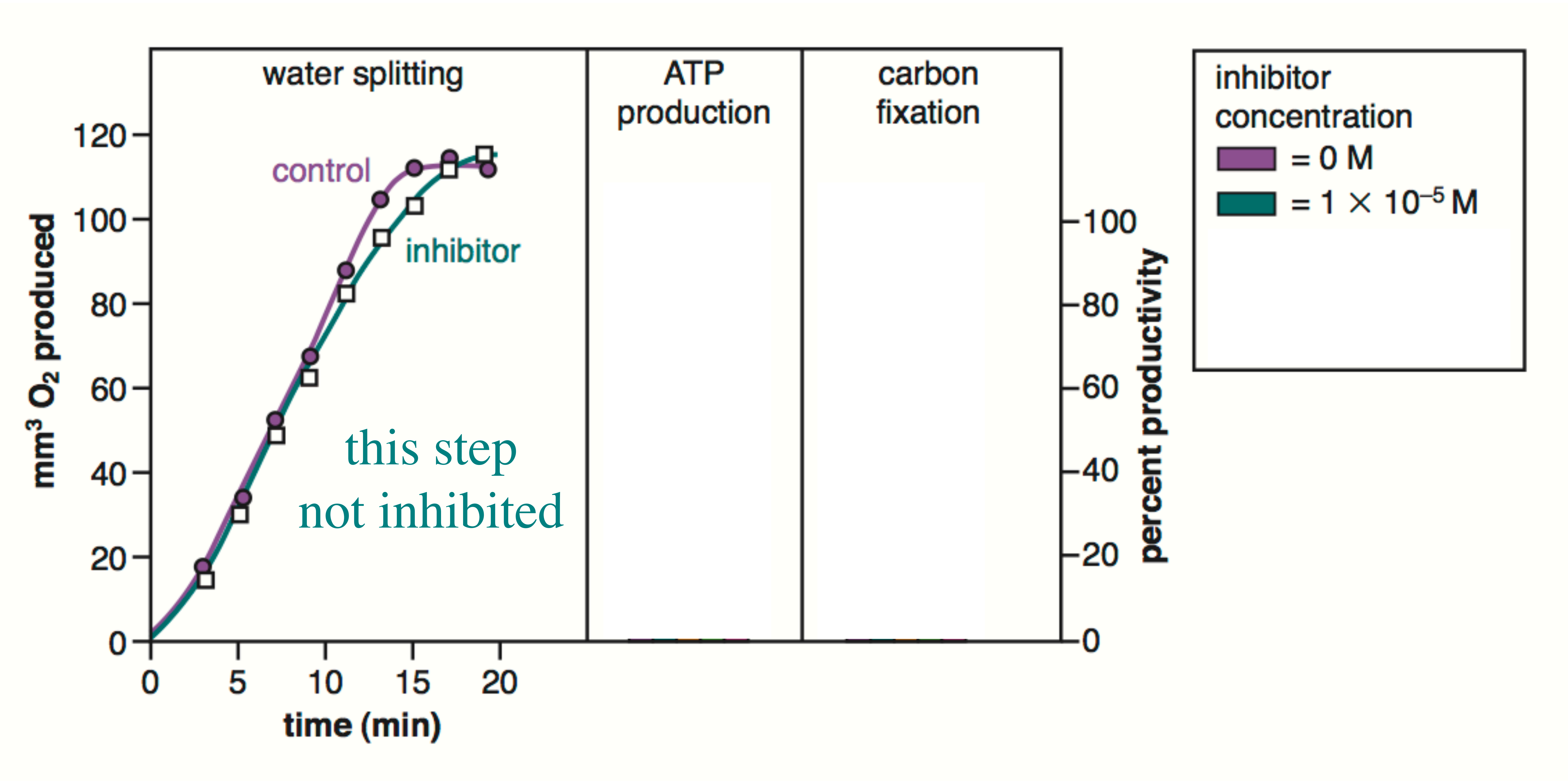


Fig. 11.4

modified from Arnon *et al.*, 1954

Photosynthesis Composed of Steps

ATP production
partially inhibited

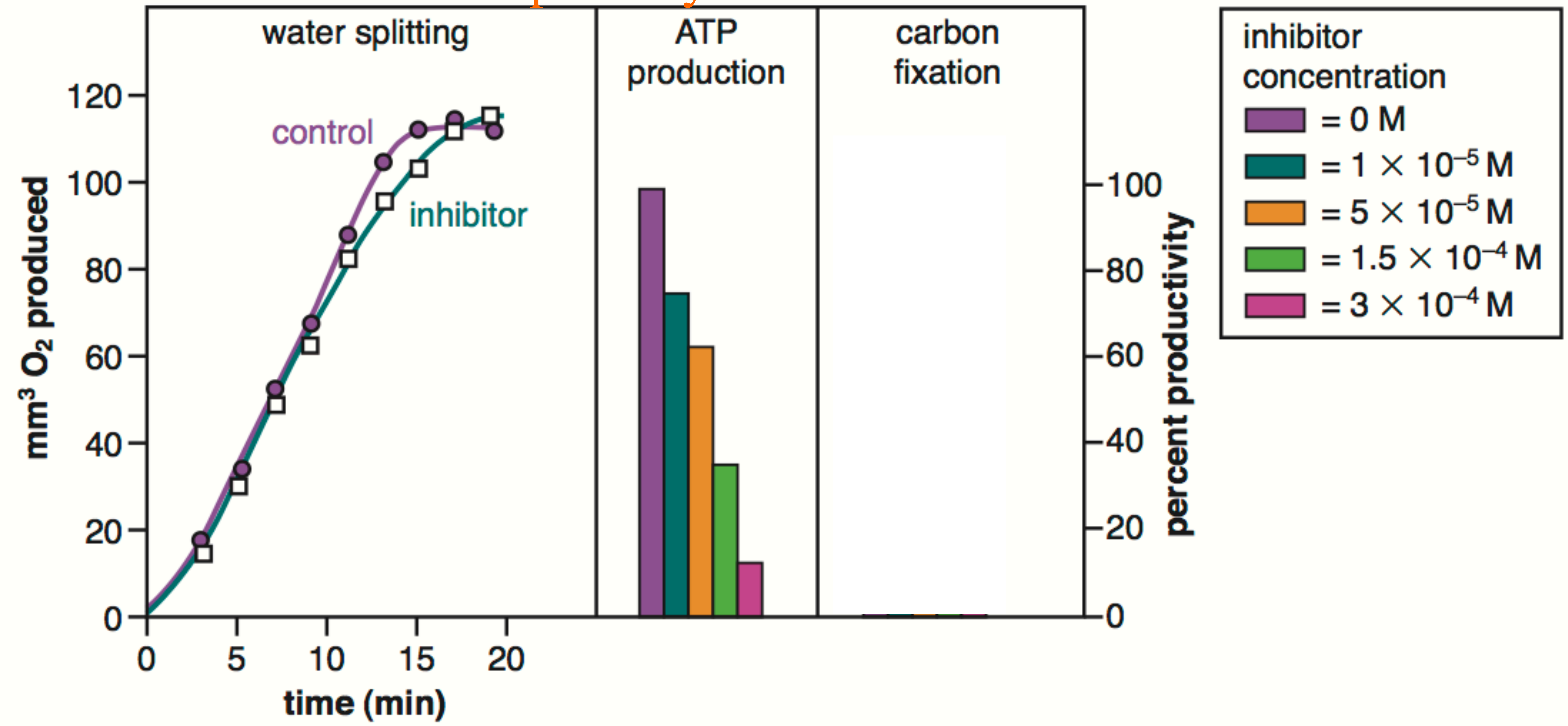


Fig. 11.4

modified from Arnon *et al.*, 1954

Photosynthesis Composed of Steps

CO_2 fixation
inhibited faster

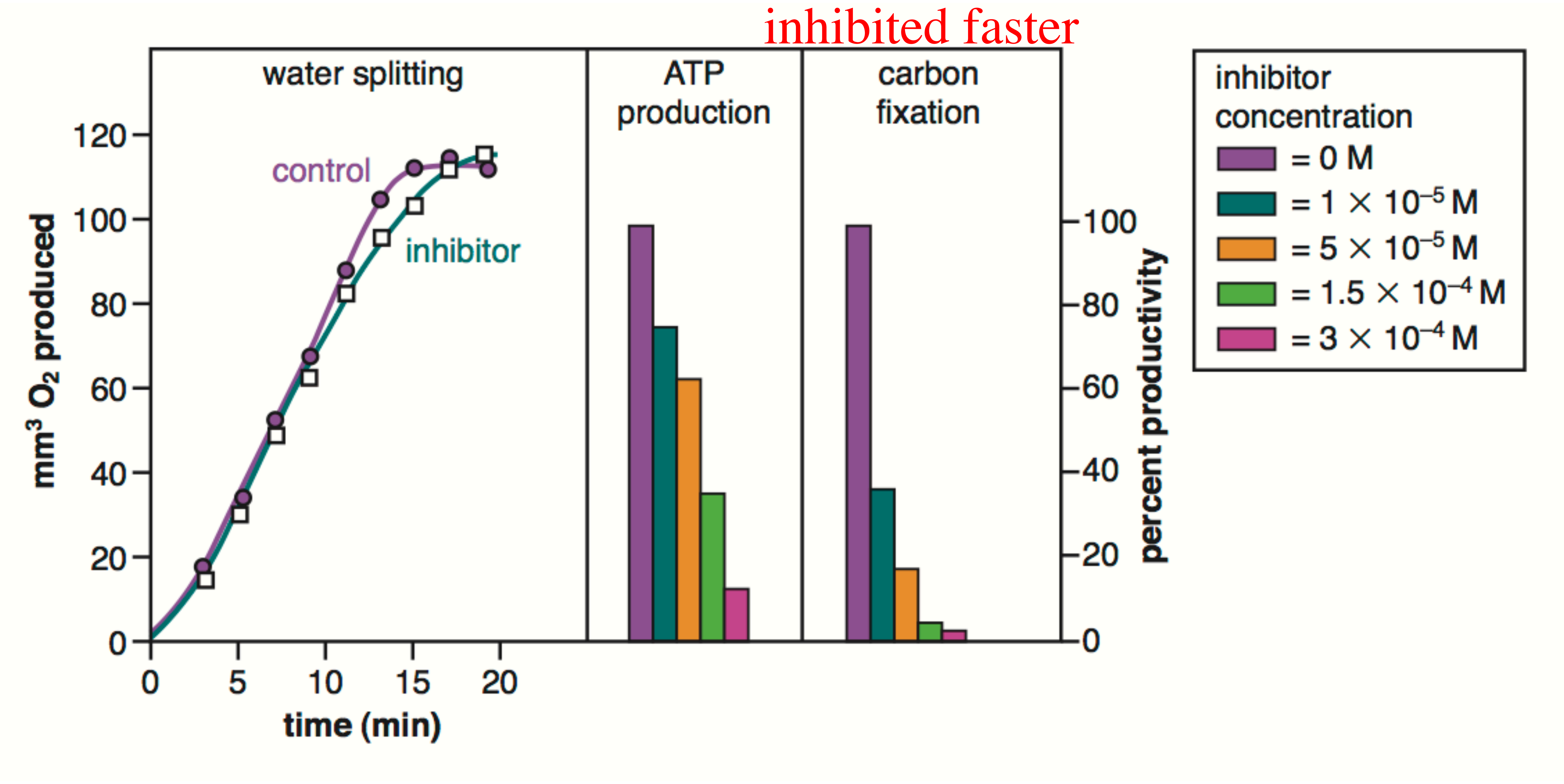
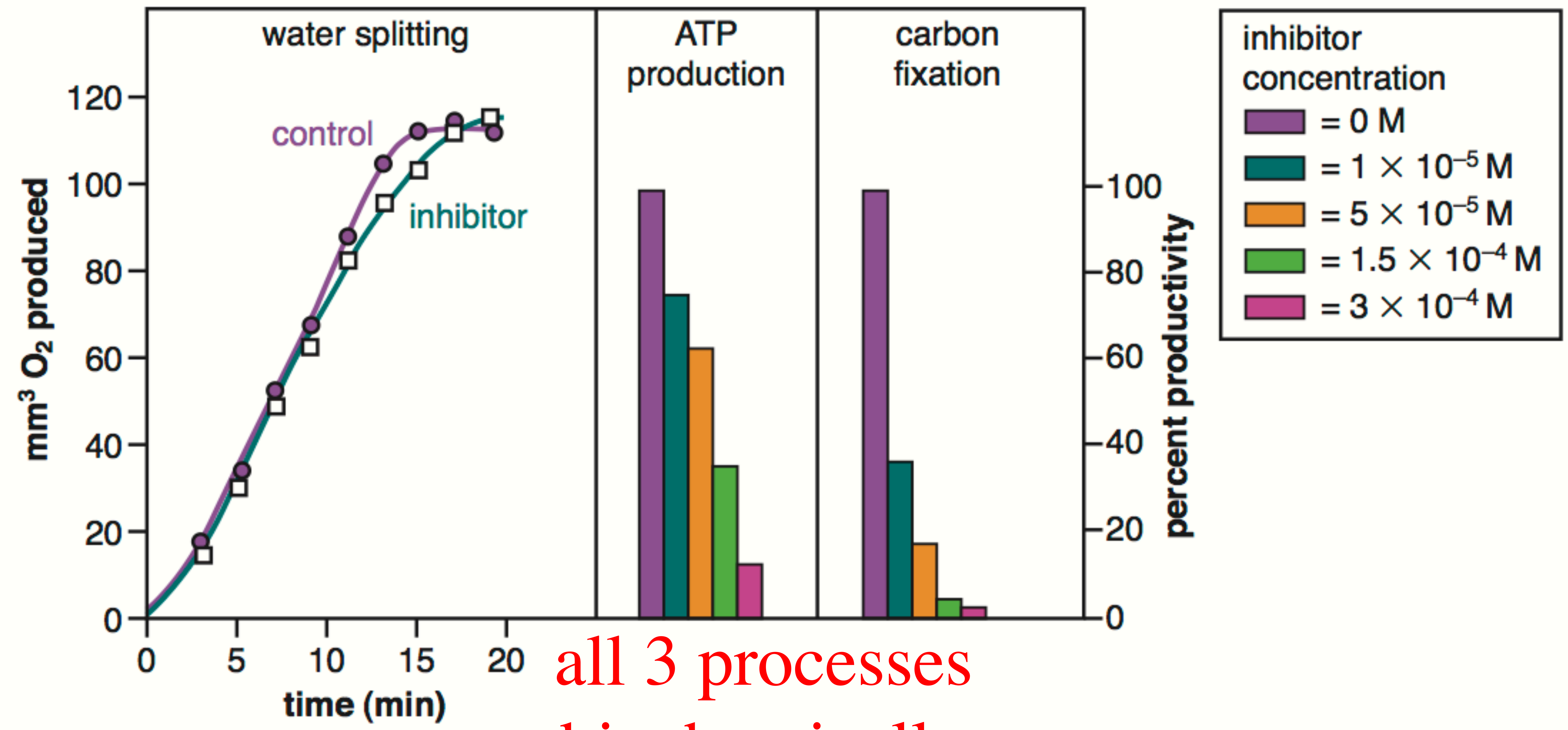


Fig. 11.4

modified from Arnon *et al.*, 1954

Photosynthesis Composed of Steps



all 3 processes biochemically separate

Fig. 11.4

modified from Arnon *et al.*, 1954

Trifecta

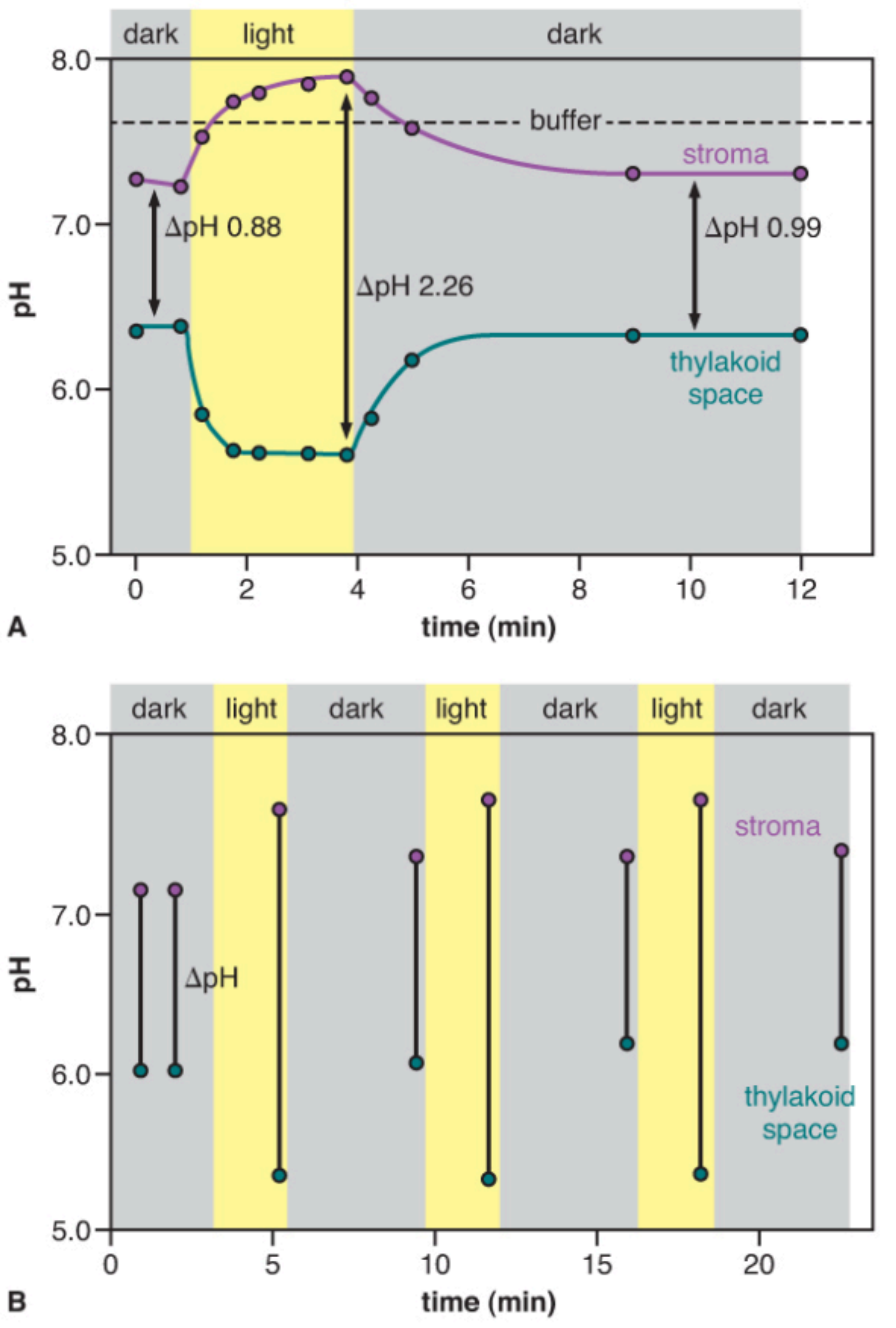
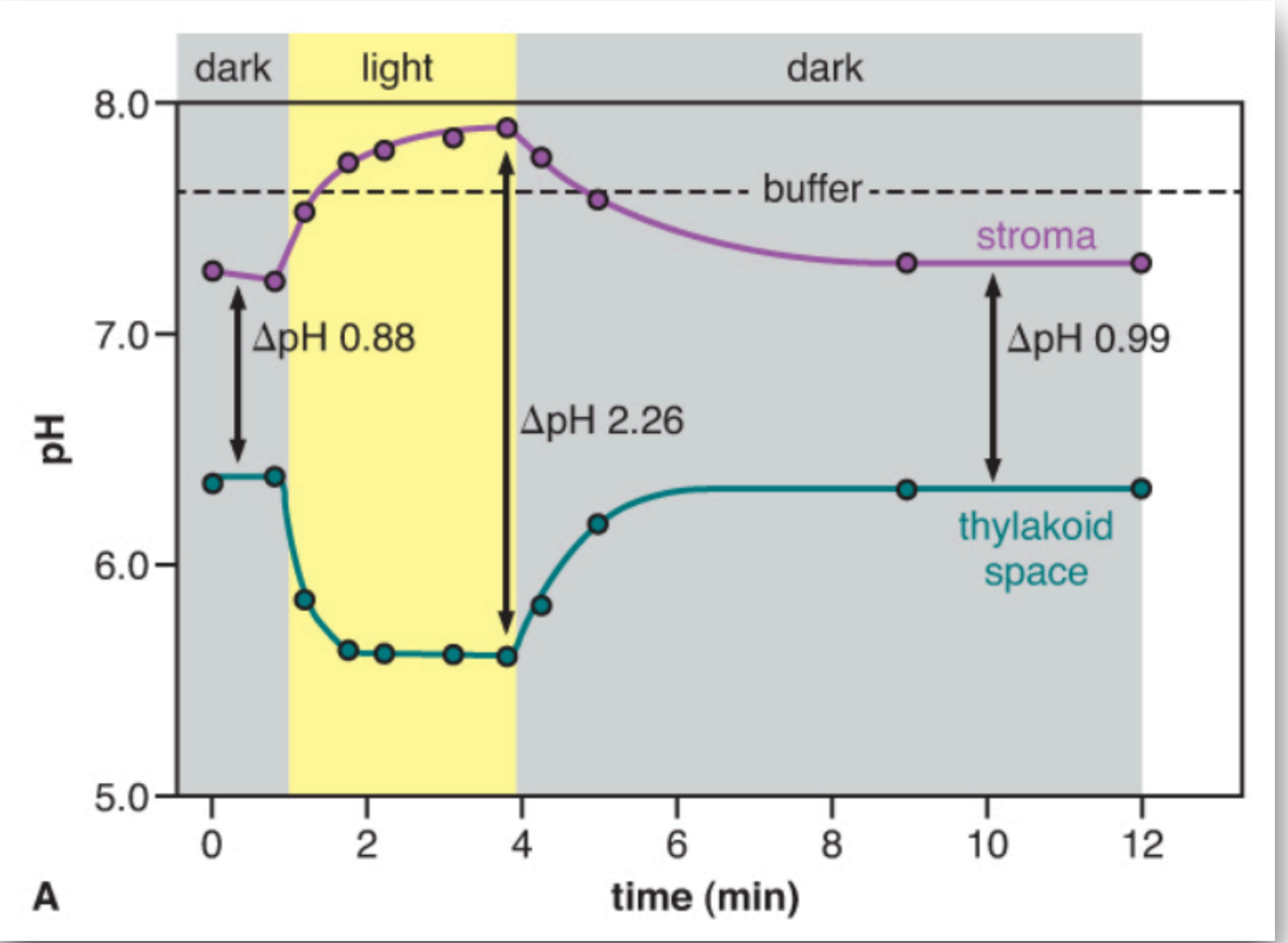


Figure 11.5 Comparison of pH in stroma and thylakoid space. **A,** Botanists measured the pH of a single chloroplast exposed to dark or light, as indicated. **B,** Repeated exposures of a chloroplast to light and dark cycles within minutes of each other. Panel A modified from Heldt *et al.*, 1973; their figure 4. Panel B modified from Heldt *et al.*, 1973; their figure 5. Heldt, Hans W., Karl Werdan, *et al.*

Trifecta



dark
light
dark
8.0
7.0
6.0
5.0
pH
buffer
stroma
ΔpH 0.88
ΔpH 2.26
ΔpH 0.99
thylakoid space
0
2
4
6
8
10
12
time (min)
A

pH Differential in Chloroplast

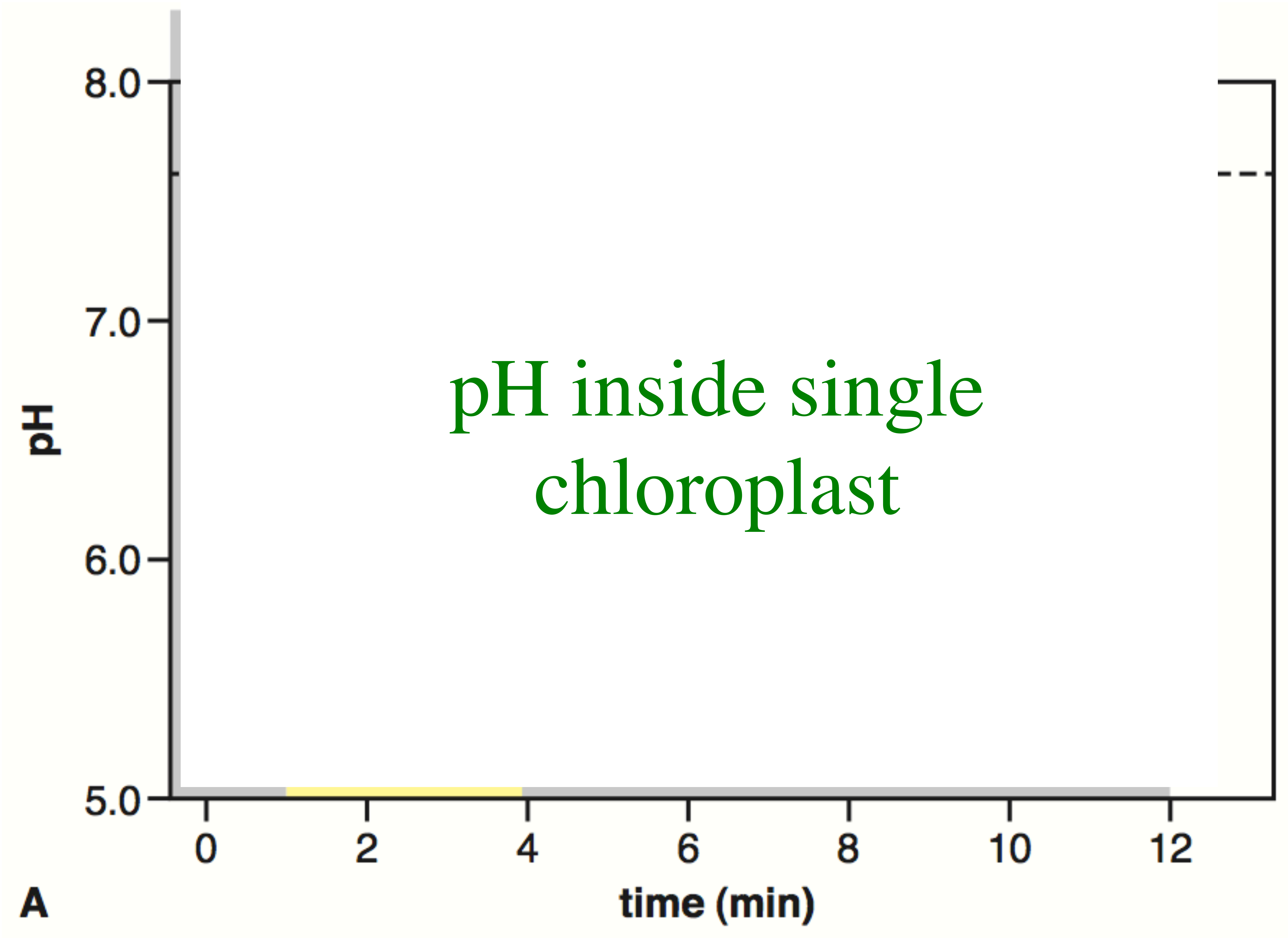


Fig. 11.5

modified from Heldt *et al.*, 1973

pH Differential in Chloroplast

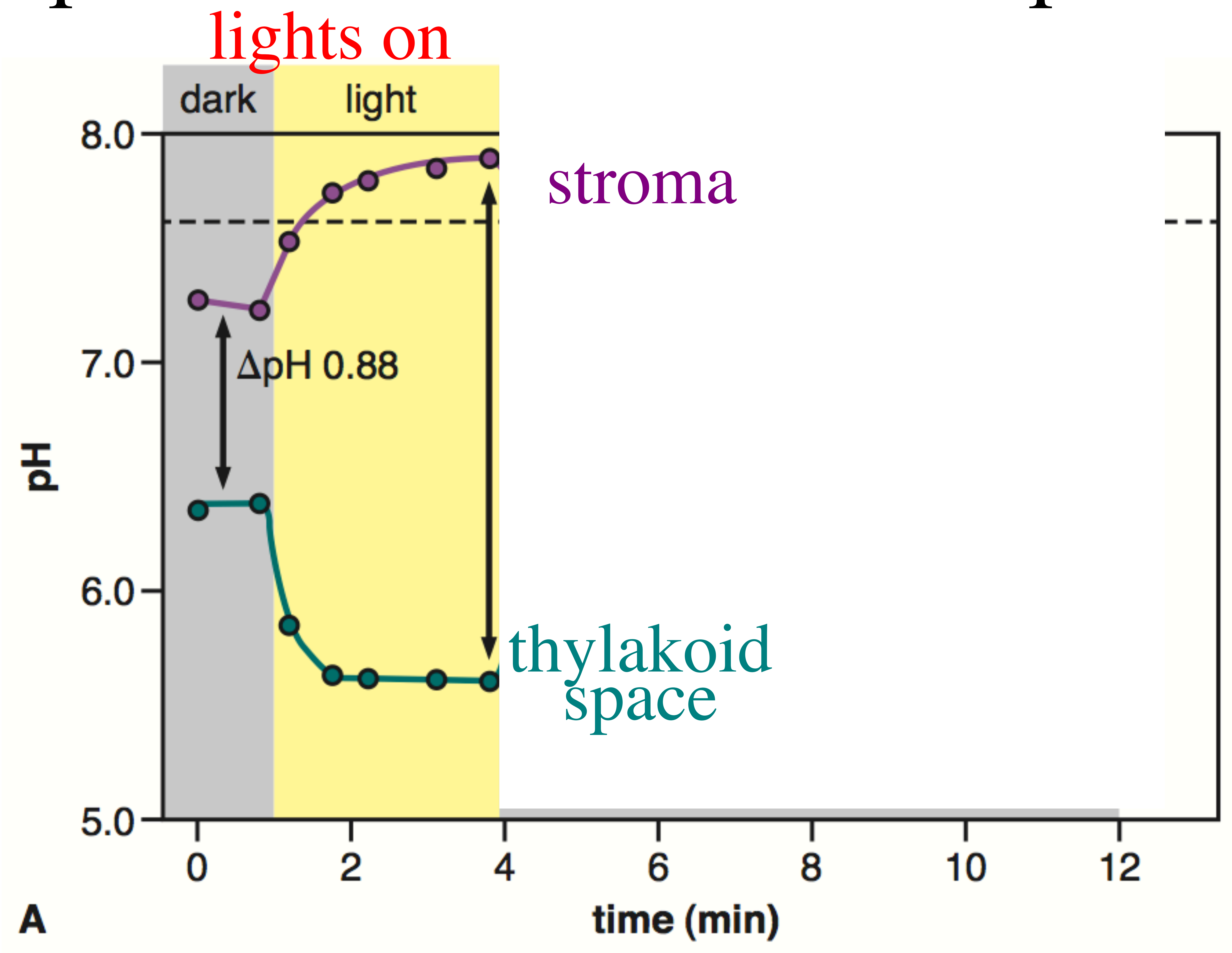


Fig. 11.5

modified from Heldt *et al.*, 1973

pH Differential in Chloroplast

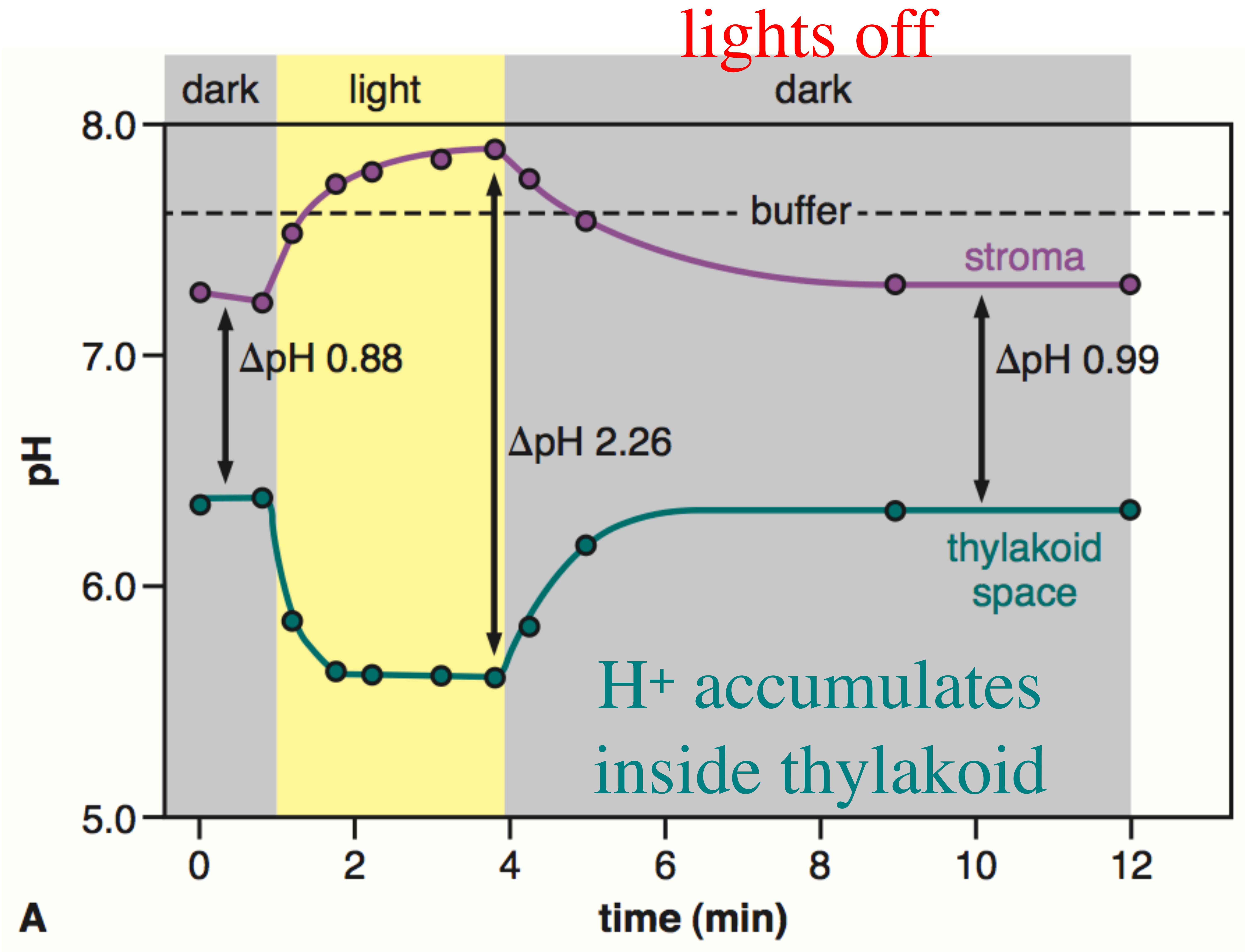


Fig. 11.5

modified from Heldt *et al.*, 1973

pH Differential in Chloroplast

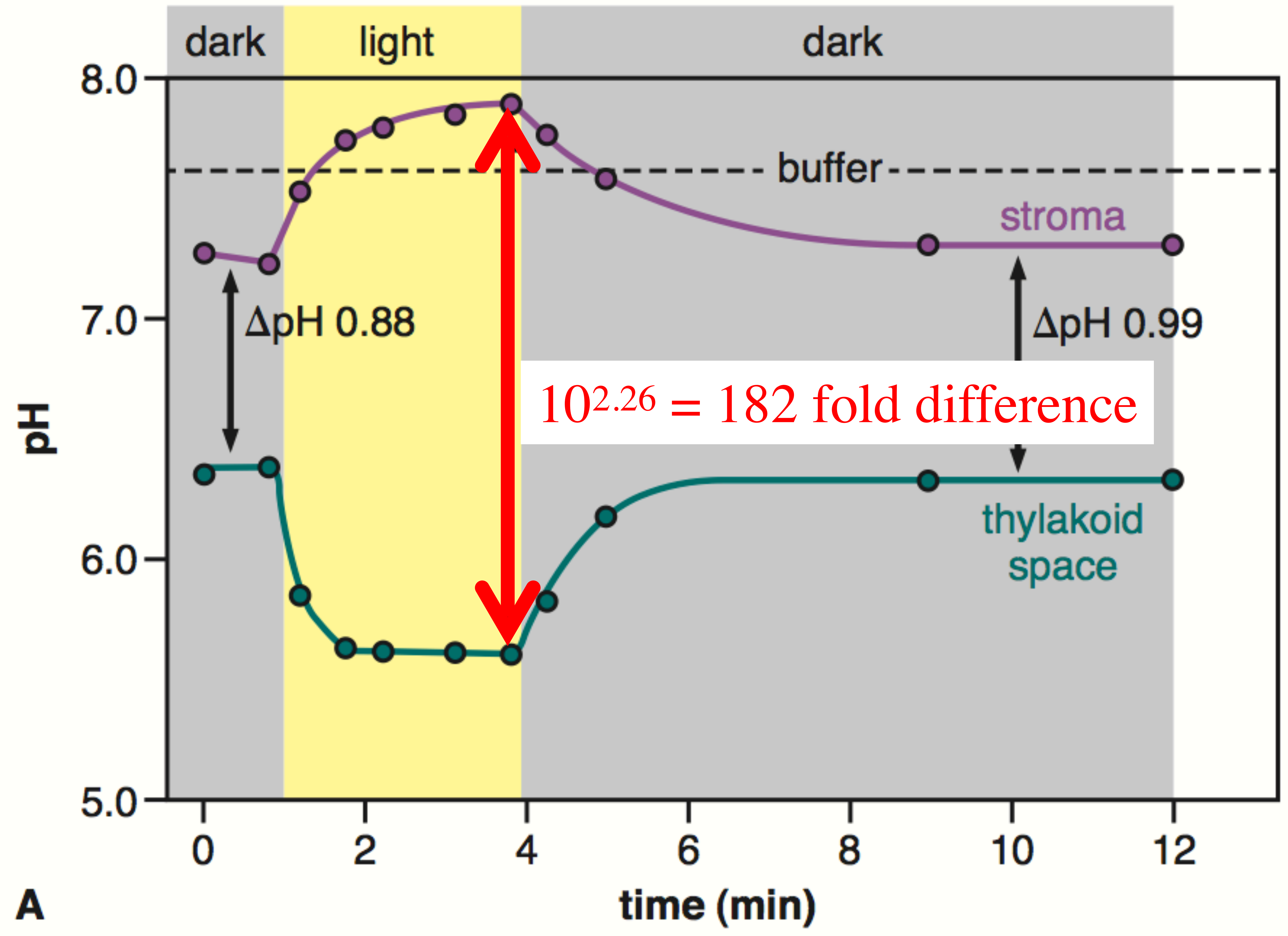
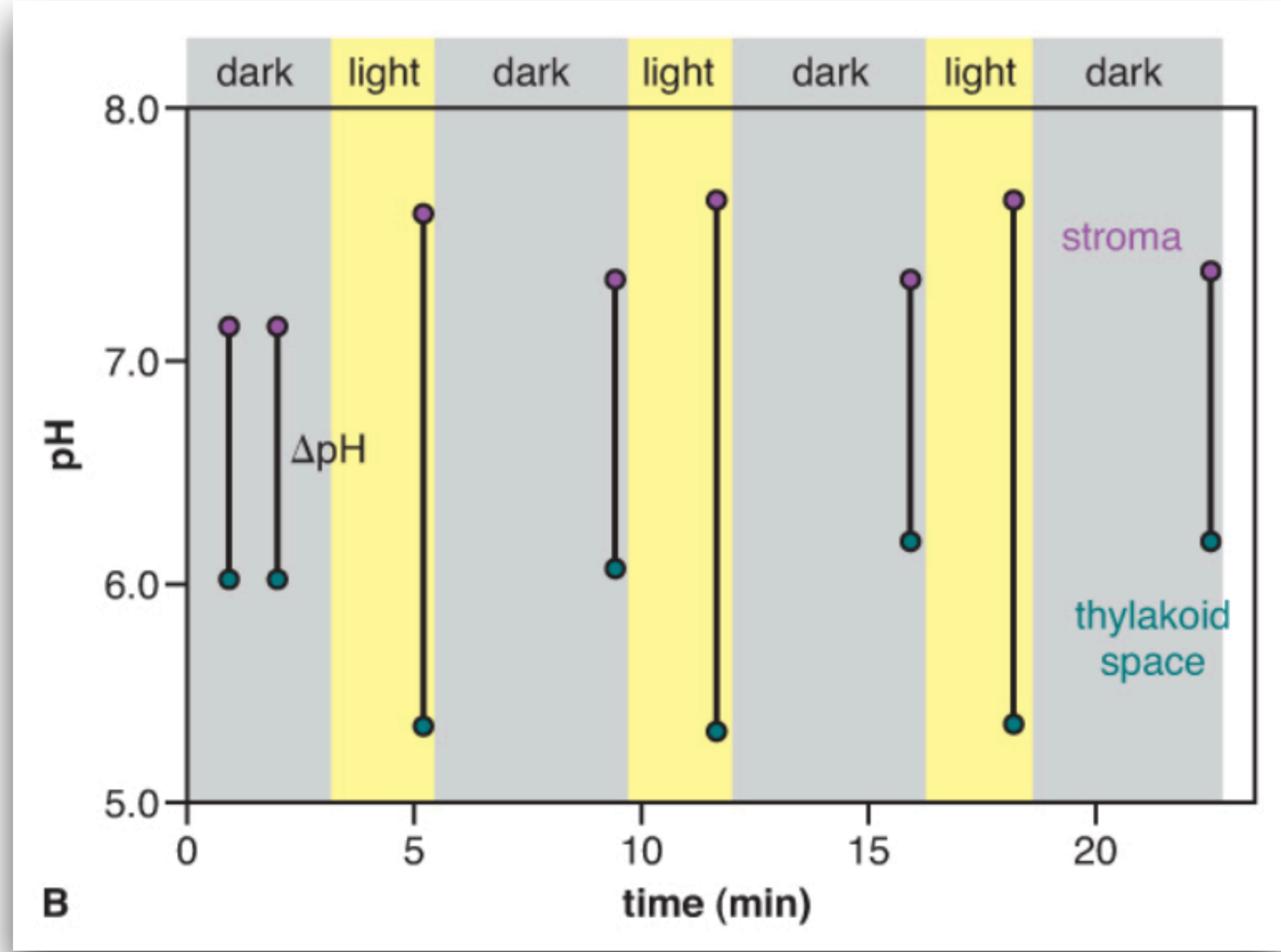


Fig. 11.5

modified from Heldt *et al.*, 1973

Trifecta


dark
light
dark
light
dark
light
dark
8.0
7.0
6.0
5.0
pH
ΔpH
stroma
thylakoid space
0
5
10
15
20
B
time (min)

Can Chloroplast Recharge & Repeat?

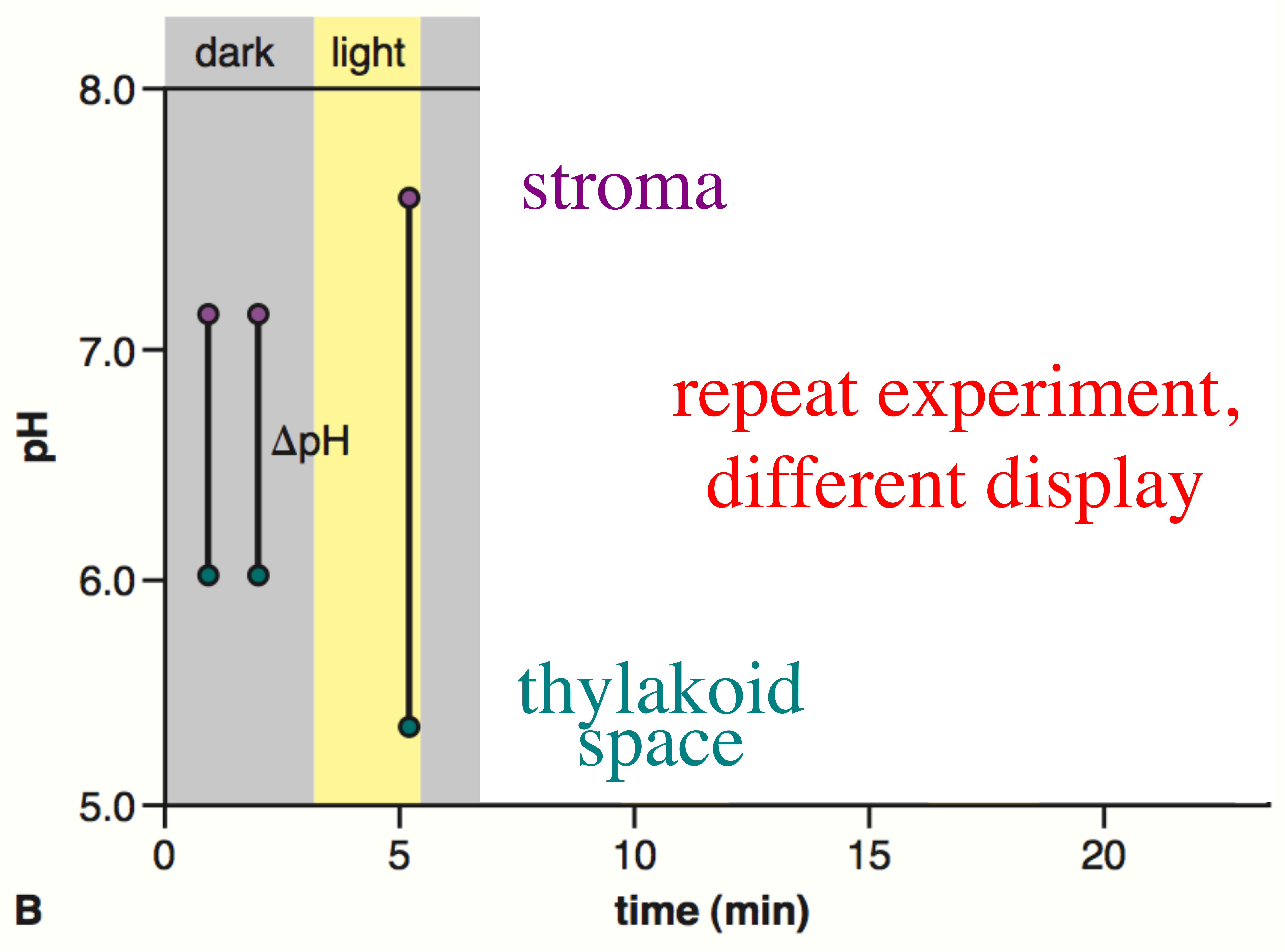


Fig. 11.5

modified from Heldt *et al.*, 1973

Can Chloroplast Recharge & Repeat?

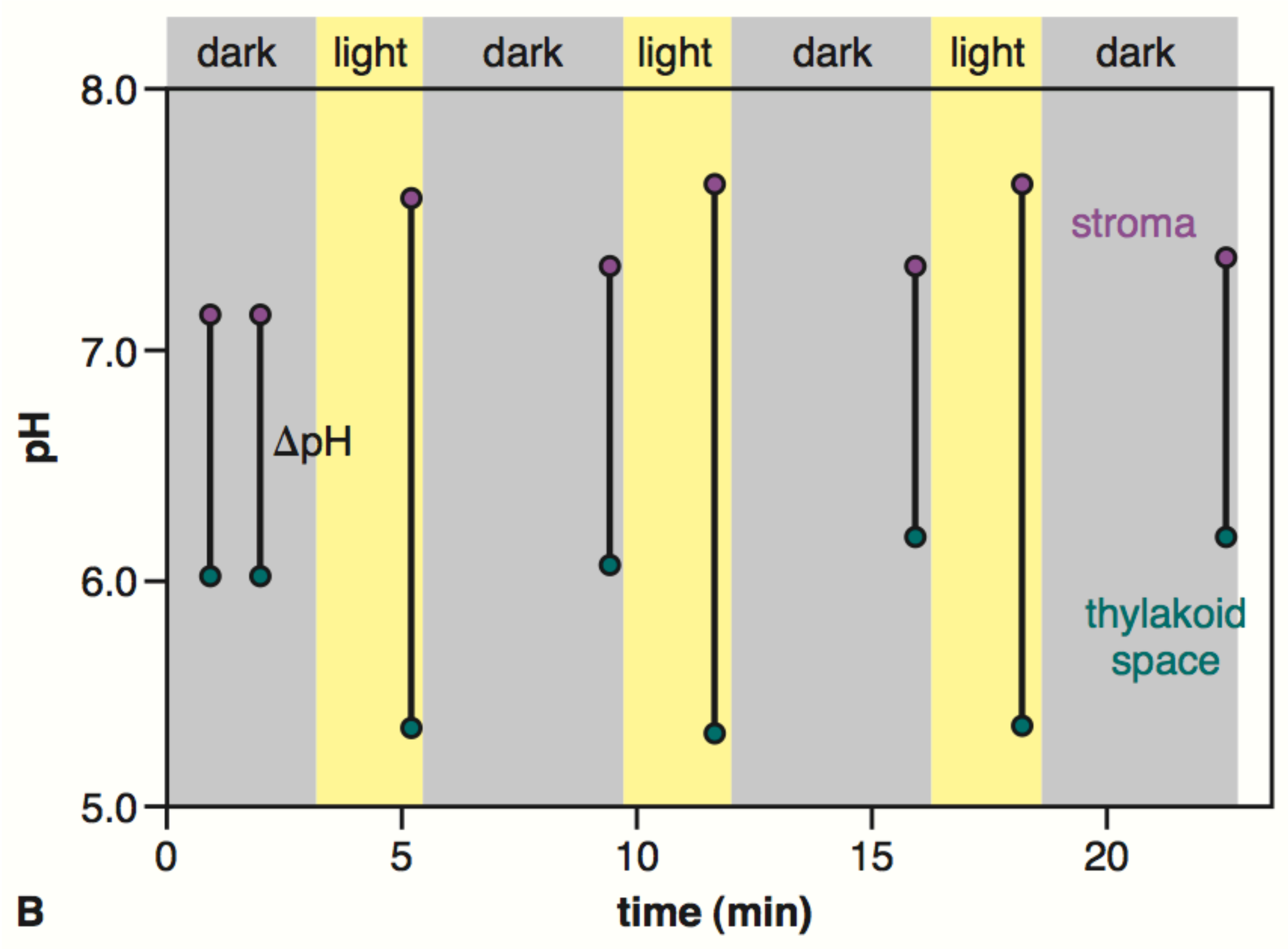


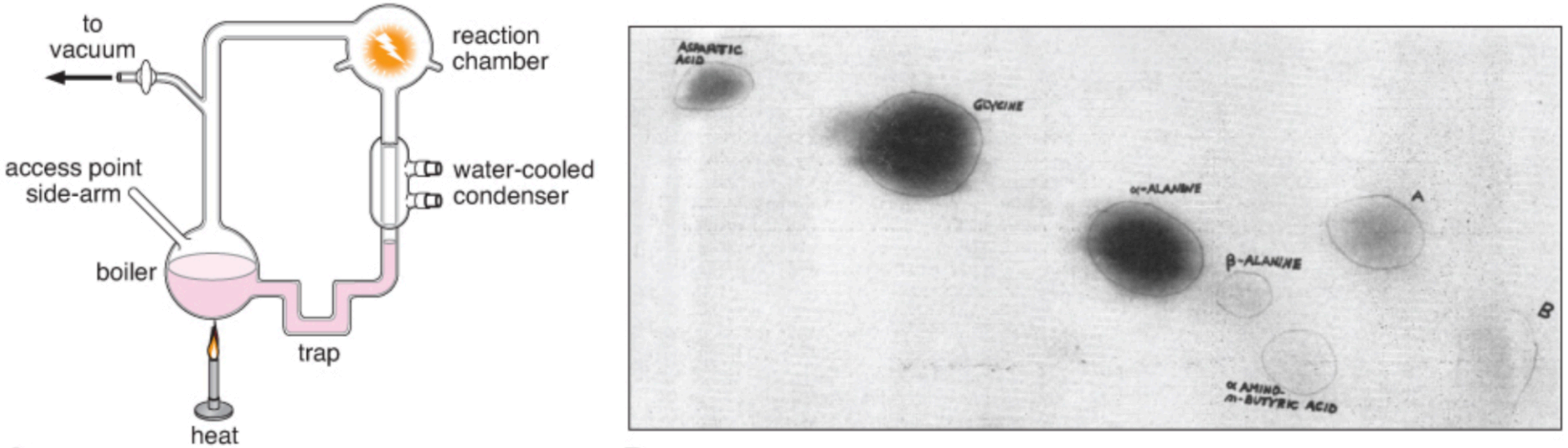
Fig. 11.5

modified from Heldt *et al.*, 1973

Possible exam question format

<u>Predict</u> how many photons of red light are minimally required to create one glucose molecule in photosynthesis (or two glyceraldehyde-3-phosphate molecules) and explain your reasoning. (i) **Illustrate** the non-cyclic electron transport version of light reactions and the Calvin cycle. (ii) **Explain** in full sentences your prediction and your rationale for it. Explain in detail the sequence of events that occur in the process of photosynthesis and your step-by-step rationale/logic in your calculations [Assume: the Calvin cycle must occur in full cycles, you must only use linear electron transport, 3 H+ travel through ATP Synthase for it to generate one ATP].

Possible exam question format



A B

6) What was the outcome of this experiment on the origin of life? Structure your answer into: Purpose, Methods, Findings.

Possible exam question format

5) Explain the Purpose, Methods and Findings of Stanley Miller's famous experiment. (50 word limit)

Possible exam question format

What is a multiple True/False/Why question?
(Multiple-choice with partial credit)

Example:
A. What are the official sport team colors of Michigan State University?
1. Maize
2. Blue
3. Green
4. Yellow
5. White

6. **Why?:** Historically, why were those colors chosen?

For full credit you must respond with:
The answer #3 is True
The answer #5 is True
The answer to #6 you accurately explain why those are the colors

How should I study ?

Dr Lynn Margulis

- Who is she, what’s the purpose of her research, and relevance?
- Draw a figure from her work and Trifecta it.
- Explain two learning goals associated with her work. What are you supposed to learn as a result?

Yet remember: Can bring 3x5 inch card with handwritten notes on both sides.