

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)

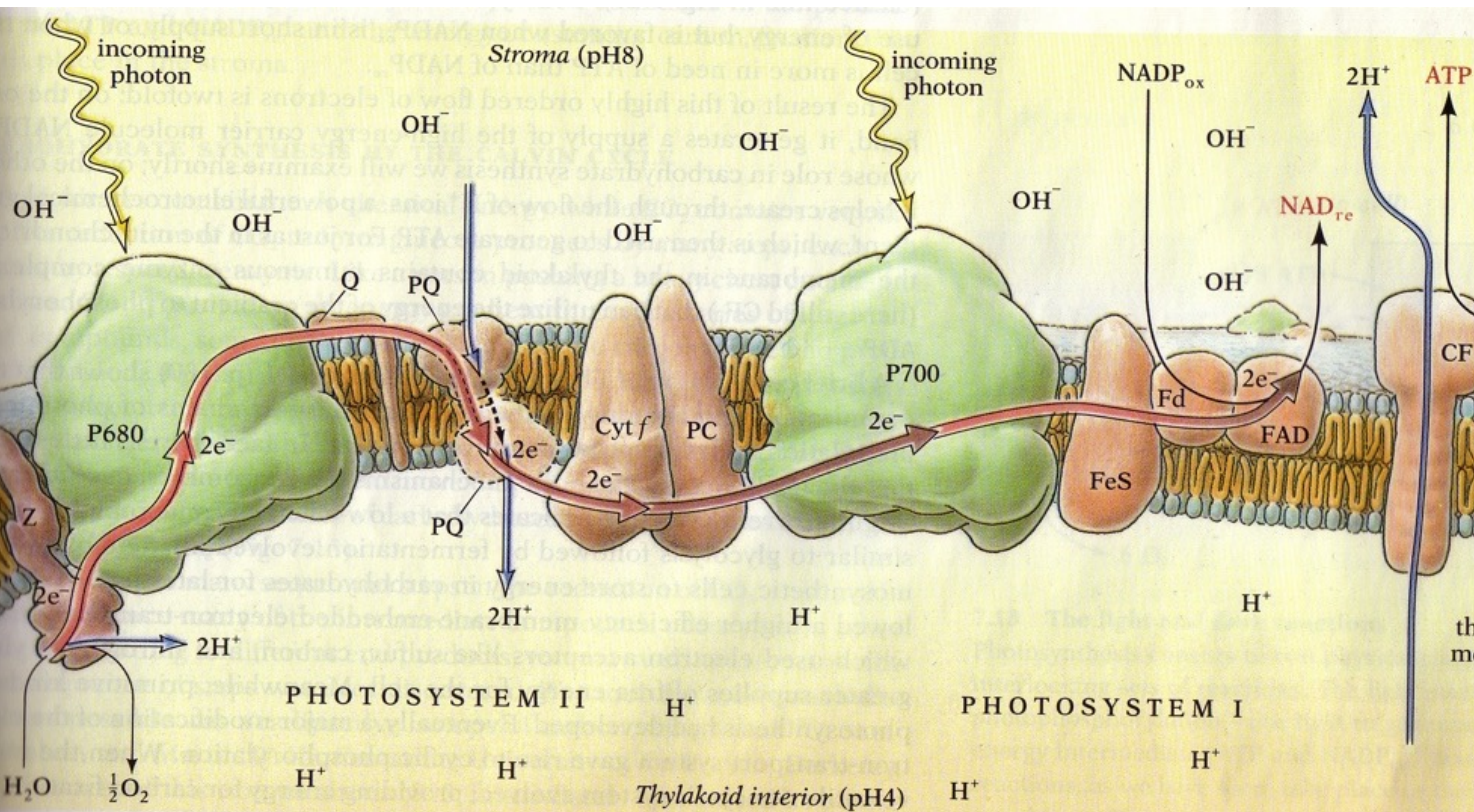
3. **Clicker** Attendance

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



Laptops closed (unless TopHat)





incoming photon

Stroma (pH8)

incoming photon

NADP_{ox}

2H⁺

ATP

OH⁻

OH⁻

OH⁻

OH⁻

NAD_{re}

Q

PQ

OH⁻

P700

P680

2e⁻

2e⁻

Cyt f

PC

2e⁻

Fd

2e⁻

FAD

FeS

Z

2e⁻

2H⁺

2H⁺

H⁺

H⁺

PHOTOSYSTEM II

H⁺

PHOTOSYSTEM I

H⁺

Thylakoid interior (pH4)

H⁺

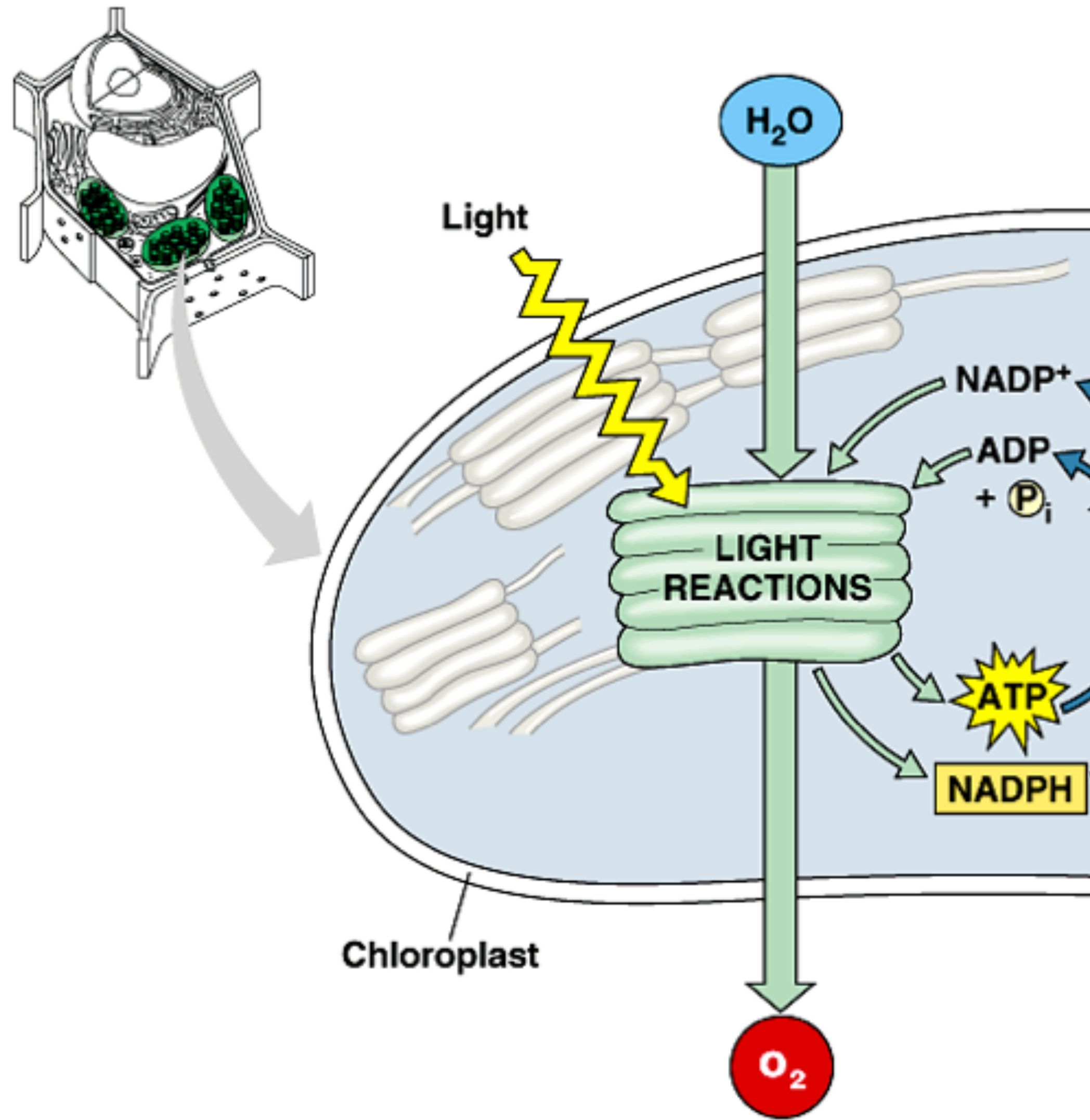
H₂O

1/2 O₂

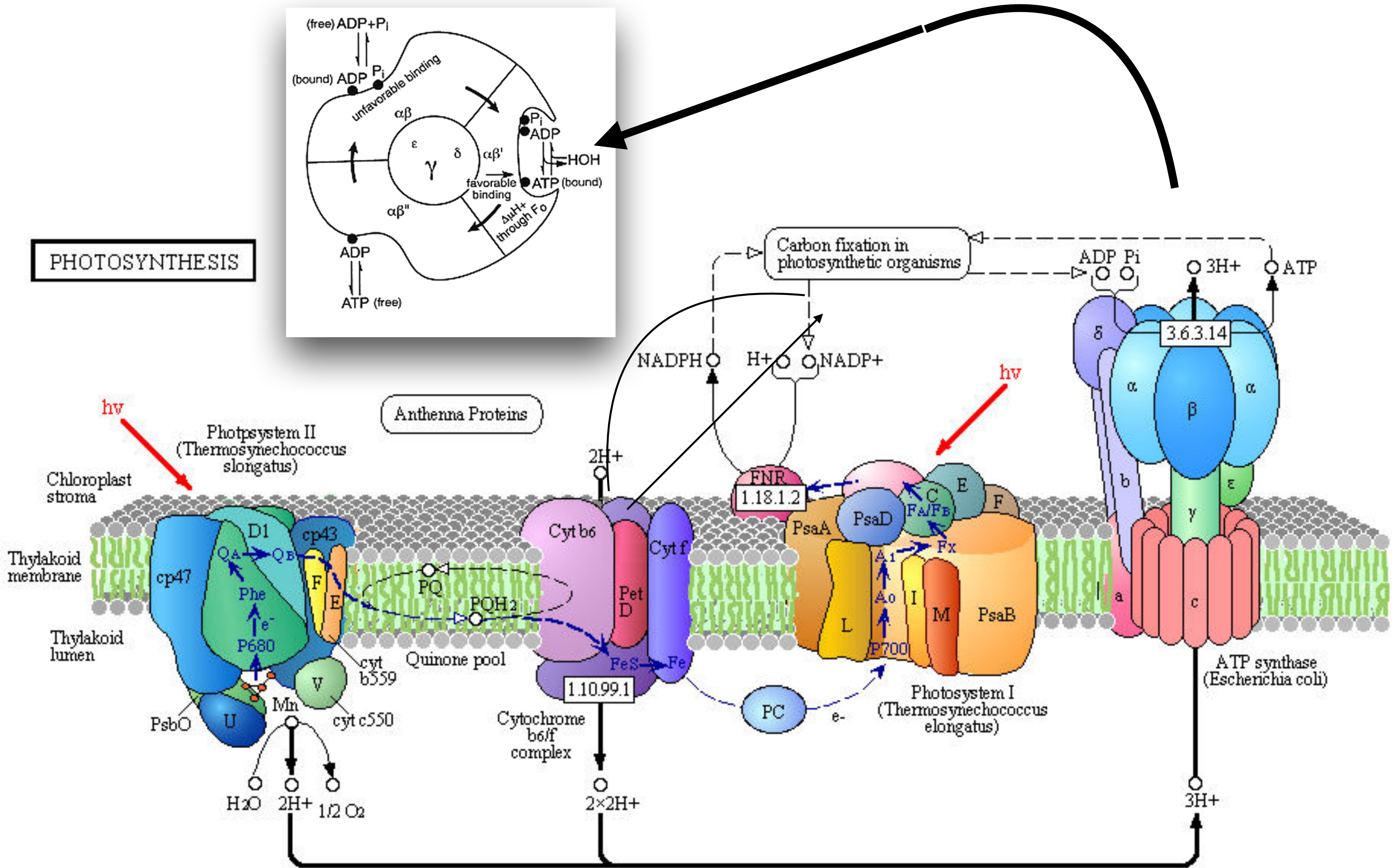
H⁺

H⁺

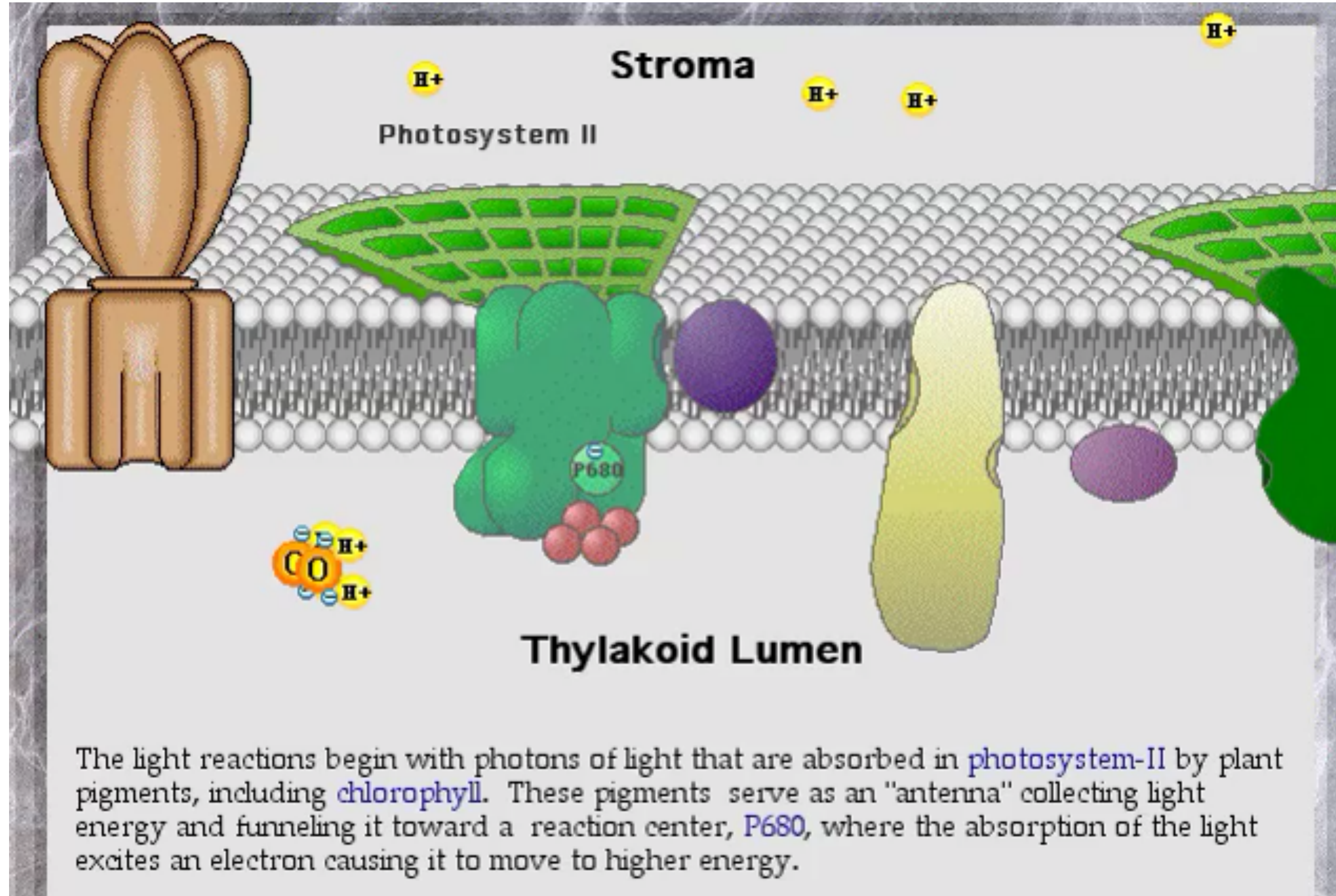
th
m



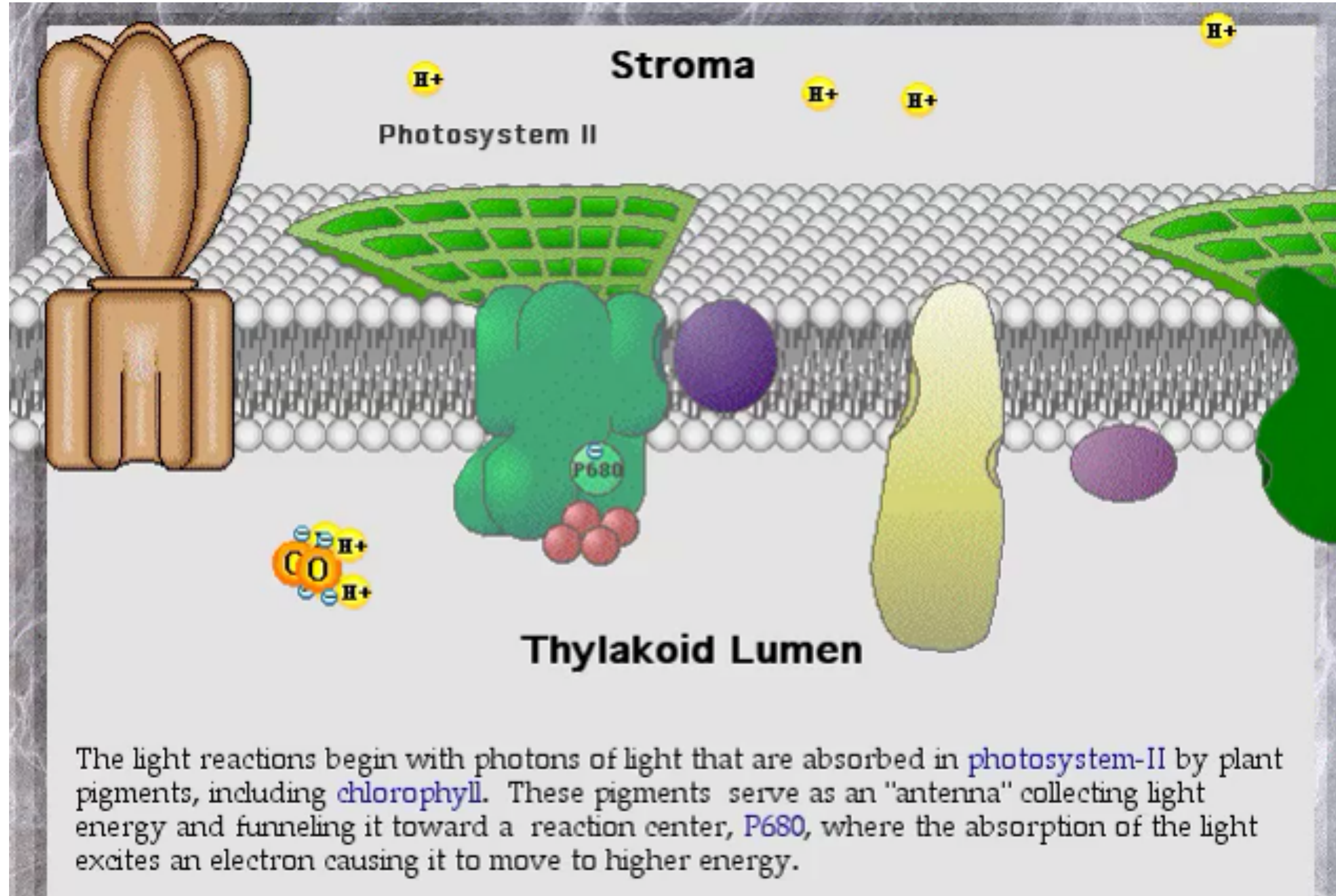
Images of "Xmas future"



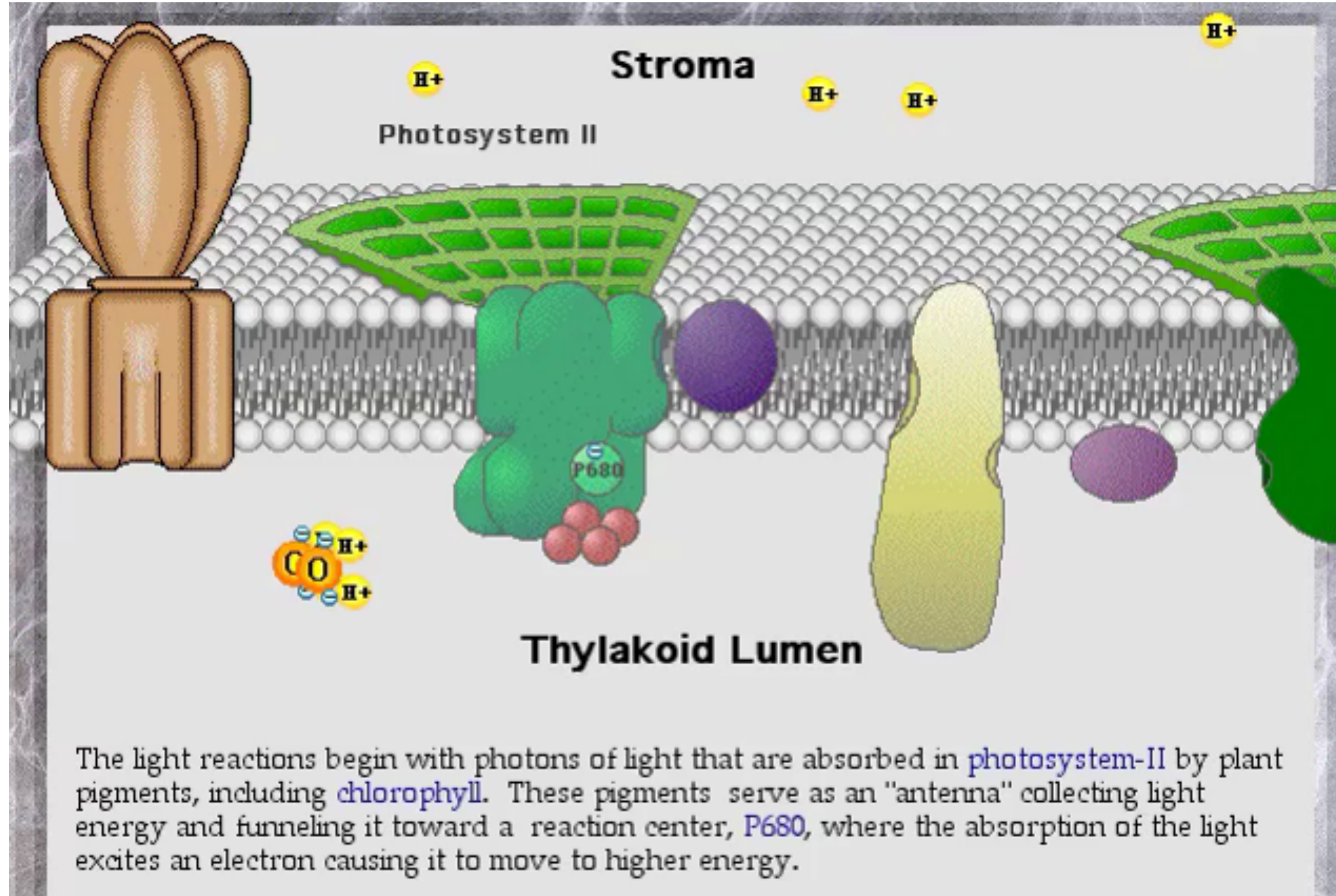
You get a chance to narrate (1.0)

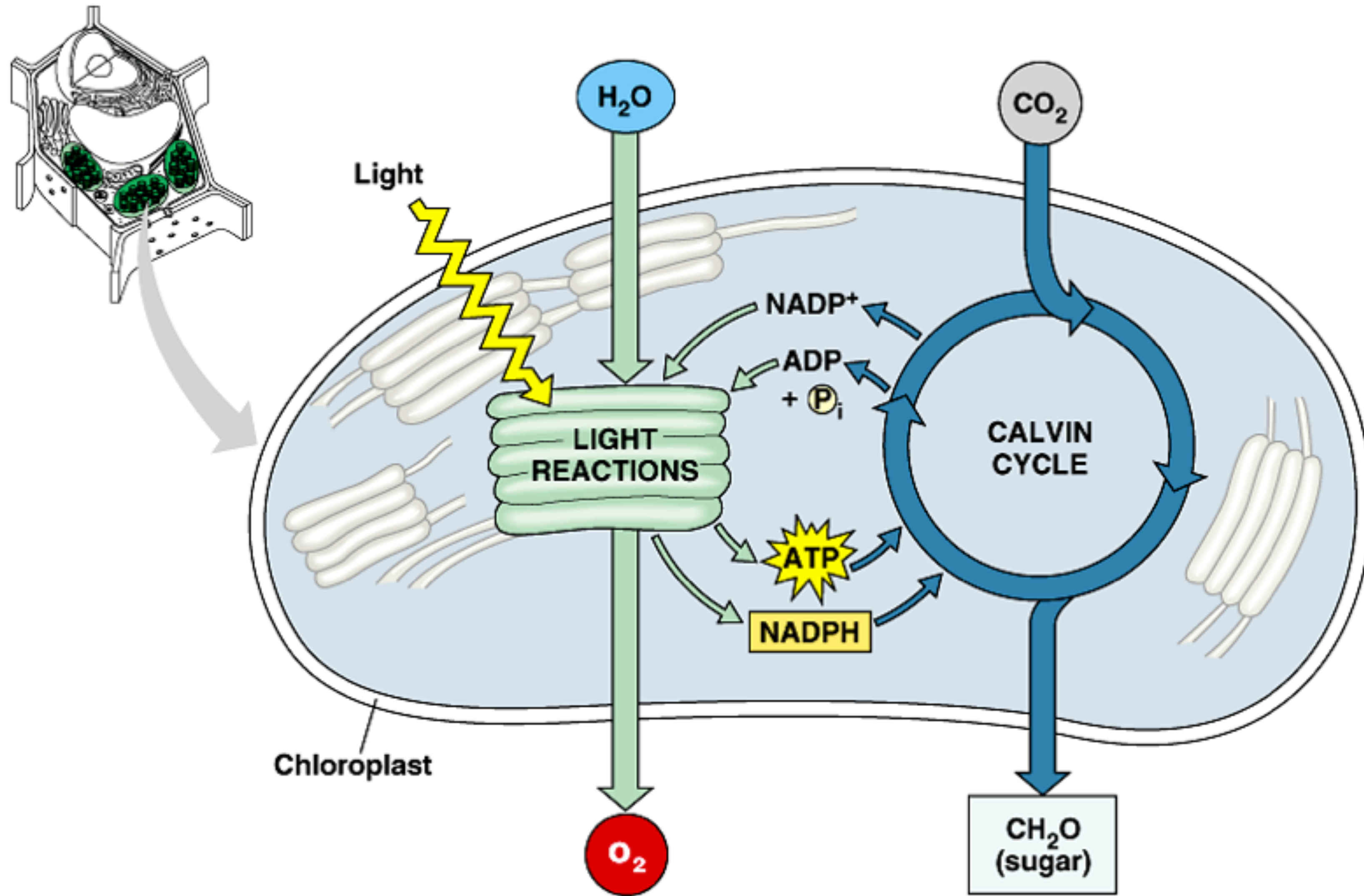


You get a chance to narrate (2.0)



You get a chance to narrate (3.0)





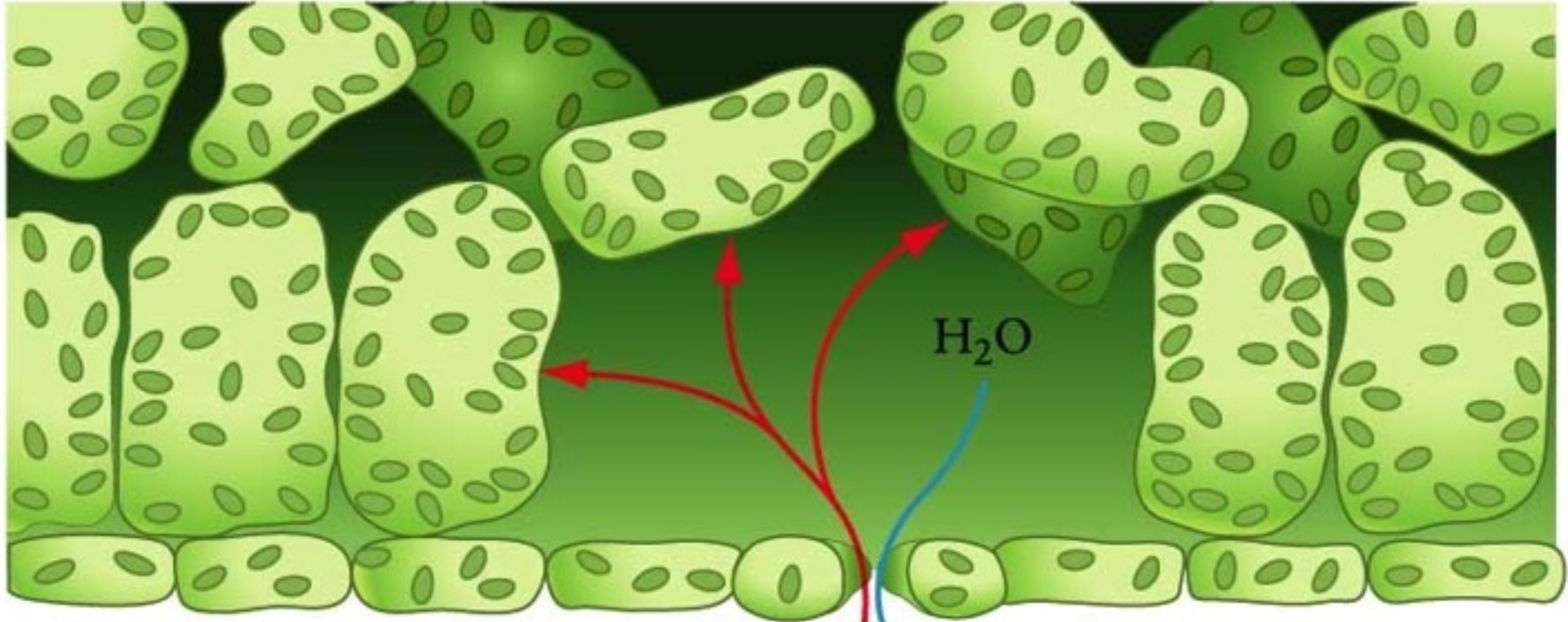
Where do plants get their 'food'...

C02

C02

C02

Thin Air...

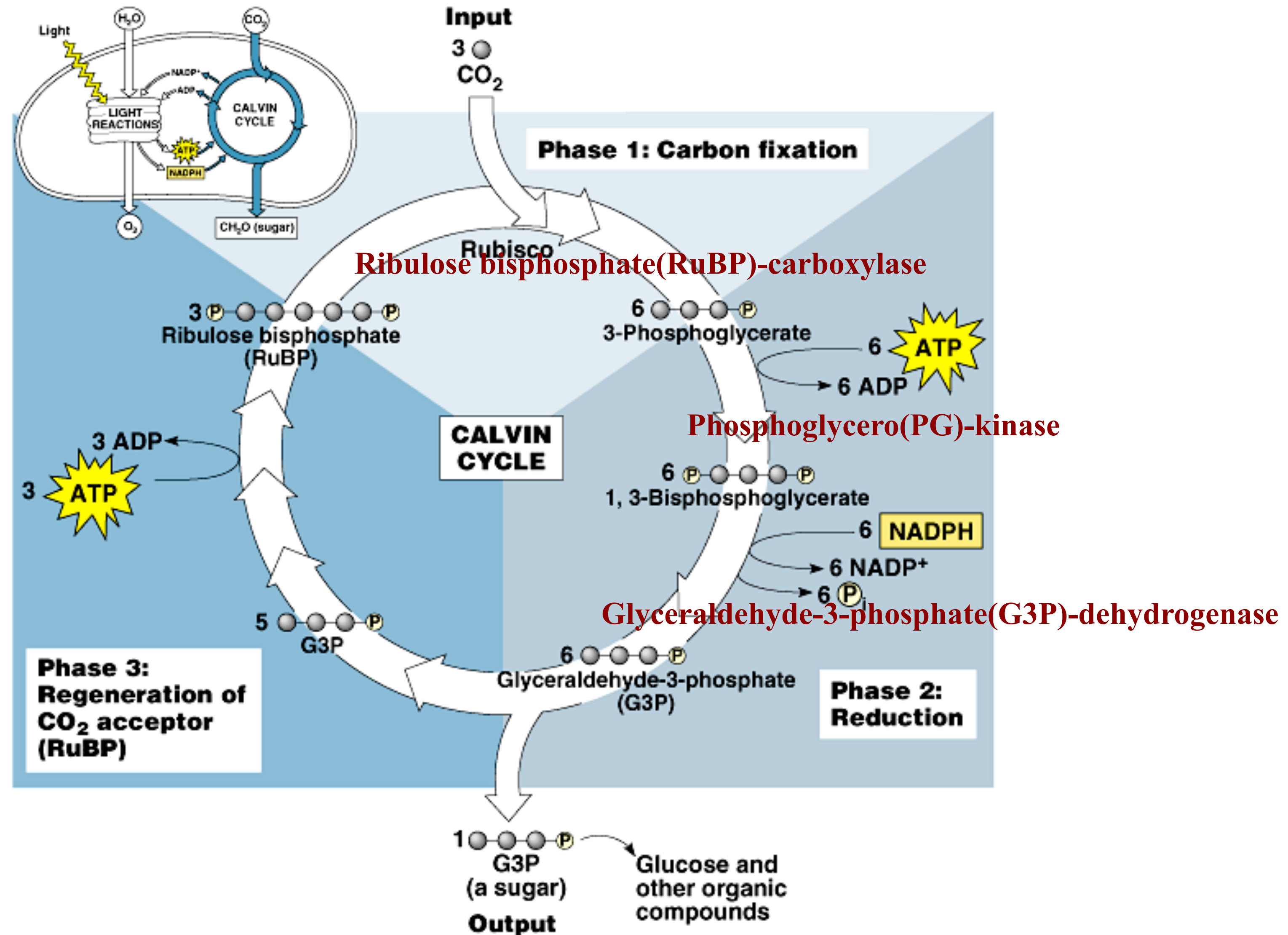


Leaf cross-section

CO_2

H_2O

Ok, but what do I need to know for the test?



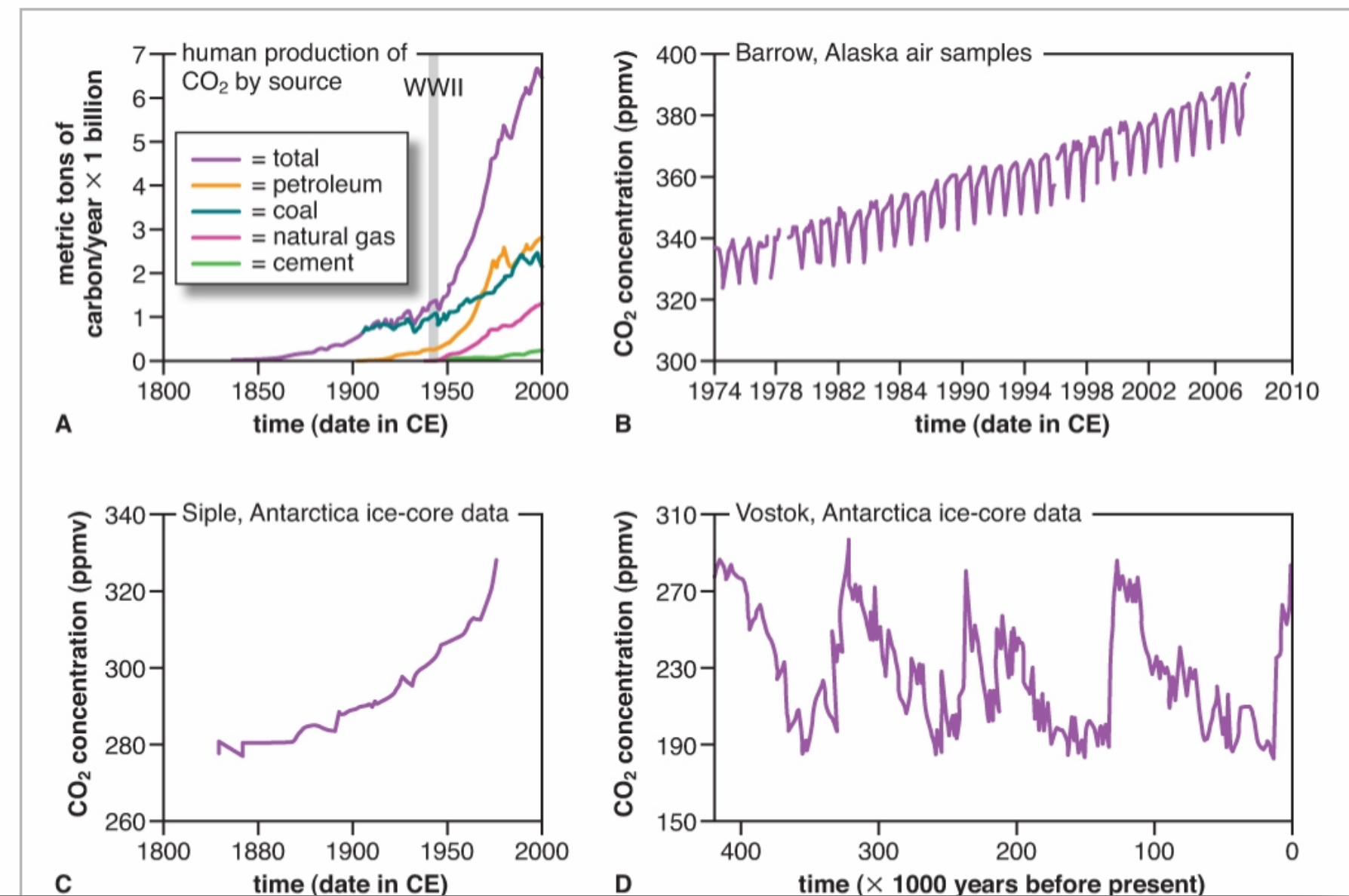
11.2 How does Brazil's rainforest affect Greenland's glaciers?

- Context: Plants produce O_2 and consume CO_2 to produce sugars as precursors to amino acids, carbohydrates, and lipids.
- 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 influences how it addresses physical and chemical challenges.
- Bottom line: Plants convert the energy stored in ATP and NADPH to reduce CO_2 and produce multicarbon molecules required for plant and animal life.

Biology Learning Objectives

- Explain the relationship between photosynthesis and global climate change.
- Discuss how carbon fixation is regulated by homeostasis of metabolic reactions.

Almost every week, you hear news about global climate change and **atmospheric CO_2 levels**. The amount of CO_2 released into the atmosphere as a direct consequence of human activity has increased dramatically over the last 150 years (Figure 11.11A). Consumption of petroleum, coal, and natural gas are the three leading sources of new CO_2 in the atmosphere. These three sources of CO_2 are called fossil fuels because like real fossils, these fuels were once organisms that died millions of years ago. Through pressure and chemical reactions, their bodies have produced a variety of hydrocarbons rich in covalent bonds. As human consumption of fossil fuels has increased, so has atmospheric concentration of CO_2 in parts per million (ppm; see Figure 11.11B and C). *{Connections: You learned how the concentration of gases is often measured in ppm in Bio-Math Exploration 10.1.}* The current level of atmospheric CO_2 has surpassed 403 ppm, which is nearly 50% higher than it was when America became a new country. Over the **last 400,000** years, the level of CO_2 has fluctuated between 290 and 190 ppm (Figure 11.11D). CO_2 levels had not exceeded 400 ppm since 15 million years



11.2 How does Brazil's rainforest affect Greenland's glaciers?

Biology Learning Objectives

- Explain the relationship between photosynthesis and global climate change.
- Discuss how carbon fixation is regulated by homeostasis of metabolic reactions.

“Training like an athlete”

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

Budgeting homework time (70 min): Chapter 11 section 11.2 is 3593 words in length with several data figures that require thinking and notetaking for the Trifecta. Reading at 200 words per minute would mean the section might take 18 minutes to read. 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. It could be shorter if you have been doing homework regularly, ie. training like an athlete, and getting much better at this now that it is week 5.

1. _____ **For Thursday's lecture, read Chapter 11: Photosynthesis, section 11.2 "How does Brazil's rainforest affect Greenland's glaciers?" (3593 words), and take handwritten notes in your lecture notebook.**
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 11.11 (just pick one graph), 11.12, 11.13, and 11.15 (Purpose, Methods, Findings).**

Shotgun Journal Club
East side versus West
(keep score)

Good answer = 1 point

Full *Trifecta* = 3 points

(purpose, methods and findings)

Trifecta

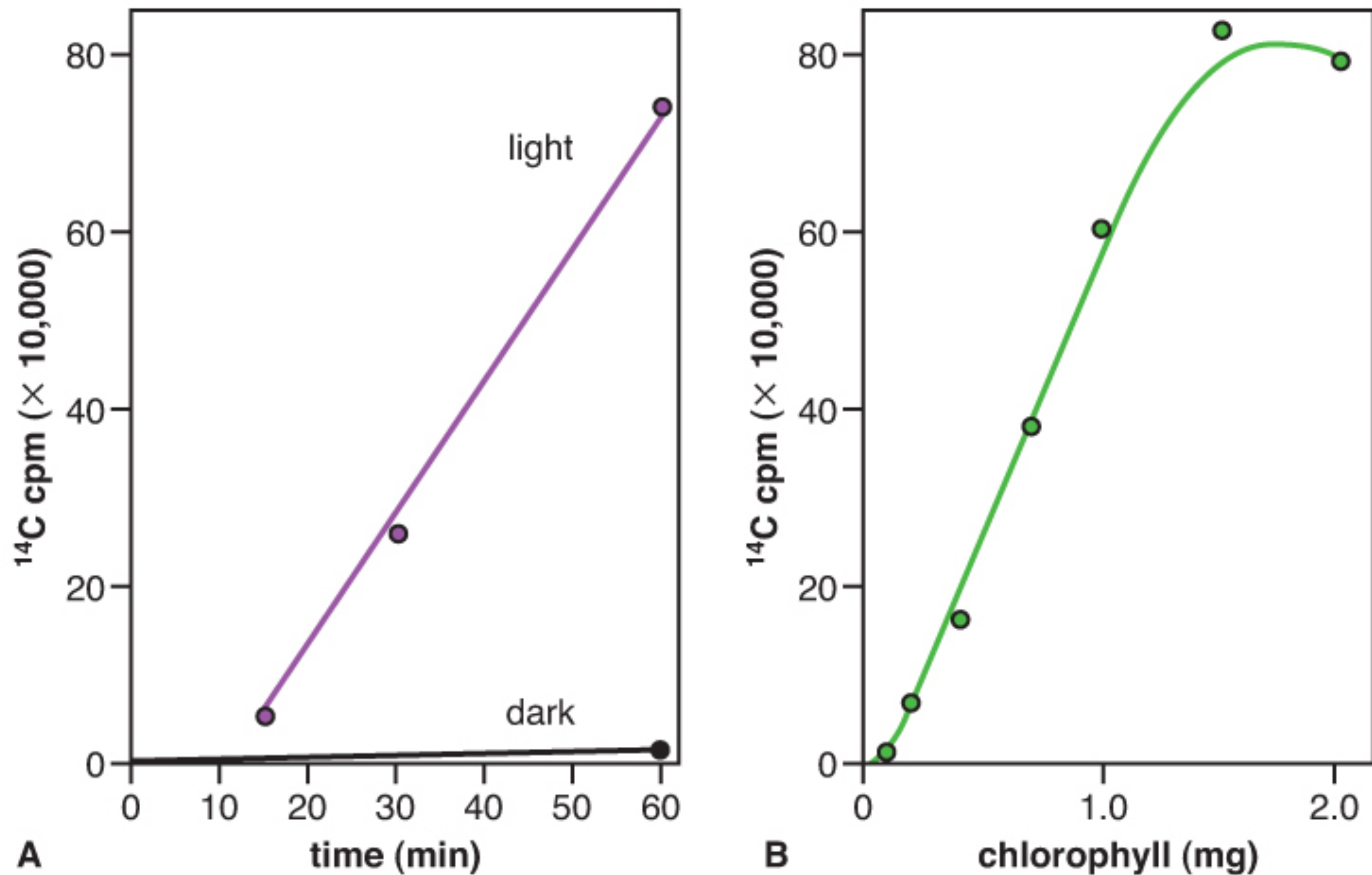


Figure 11.12 Carbon fixation capacity. **A**, When exposed to light for various periods of time, chloroplasts incorporated radioactive CO_2 inside the organelles. **B**, Investigators tested different

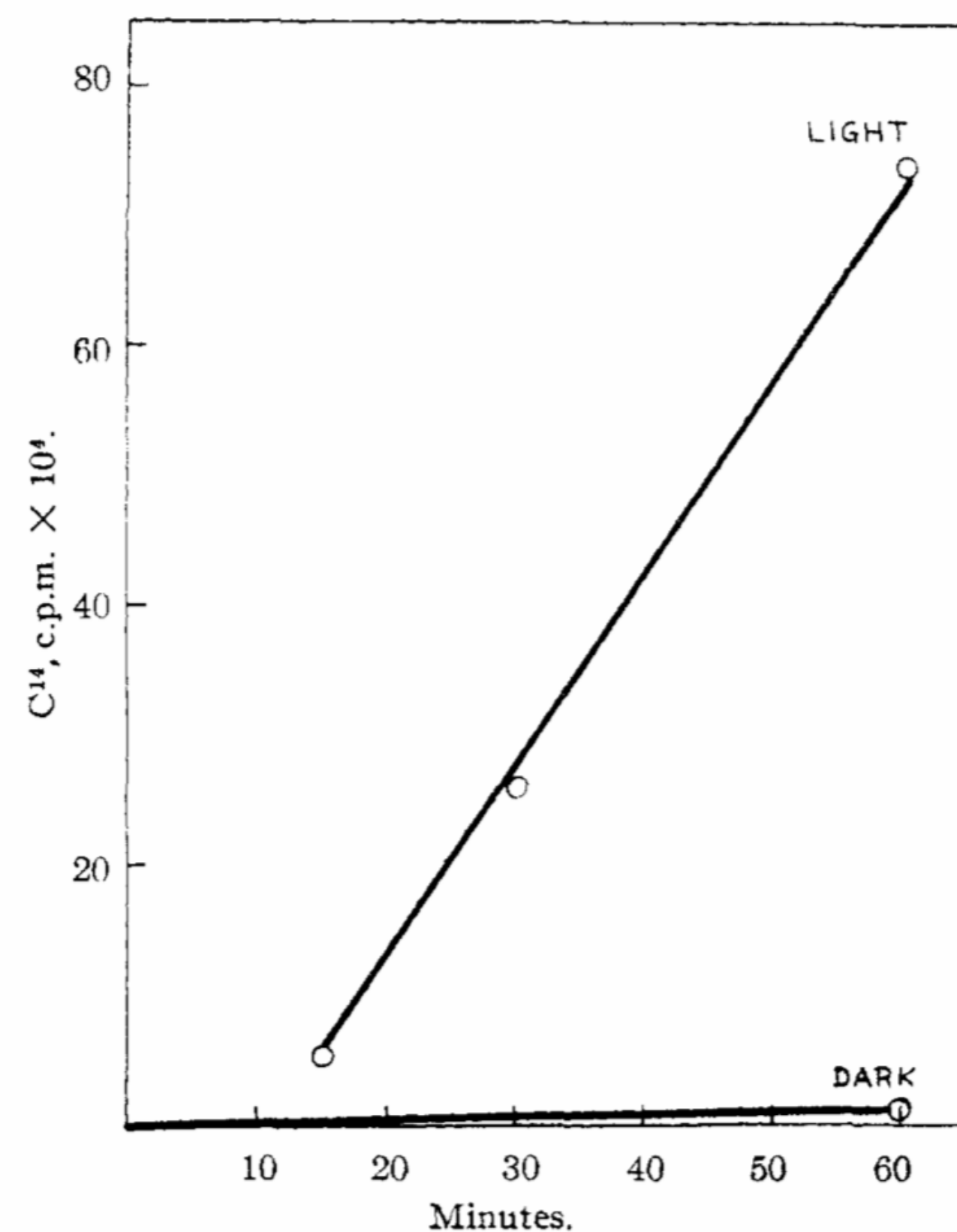


Fig. 1.—Time course of CO₂ fixation by isolated spinach chloroplasts in light and dark. Reaction mixture is described in text. The lag in CO₂ fixation during the first few minutes of illumination is attributed to a time lag in equilibration after the release of C¹⁴O₂ gas from the sidearm (see Methods).

Results

CO₂ Fixation and Oxygen Evolution.—The fixation of CO₂ by isolated spinach chloroplasts is illustrated in Fig. 1. It is evident that the reaction was strictly light-dependent and proceeded at an almost constant rate for an hour. As shown in Fig. 2, the rate of the reaction was directly proportional to the amount of whole chloroplast material added, up to 1.5 mg. of chlorophyll, where the

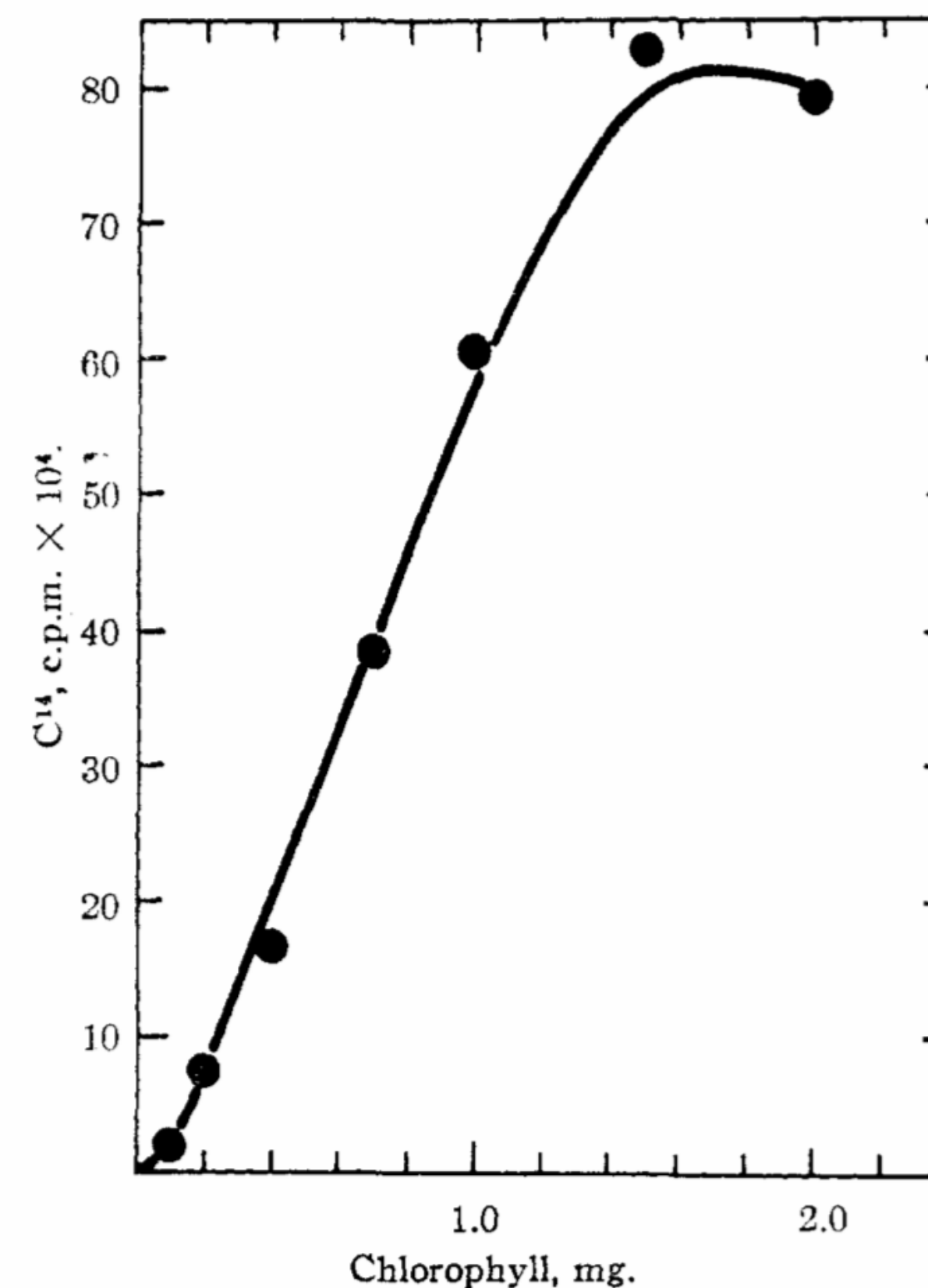
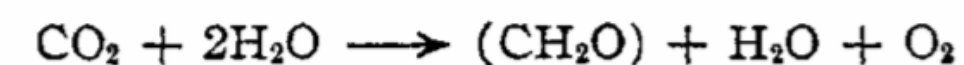


Fig. 2.—Dependence of CO₂ fixation upon amount of chloroplast suspension added. Reaction mixture is described in text.

with the well-known photosynthetic quotient of intact cells, and suggests that the over-all reaction of photosynthesis by isolated chloroplasts may tentatively be represented by the general photosynthetic equation³



Products of CO₂ Fixation.—Both soluble and insoluble products resulted from the fixation of radiocarbon by chloroplasts. The distribution of C¹⁴ between soluble and insoluble compounds after various periods of illumination is shown in Table

Trifecta

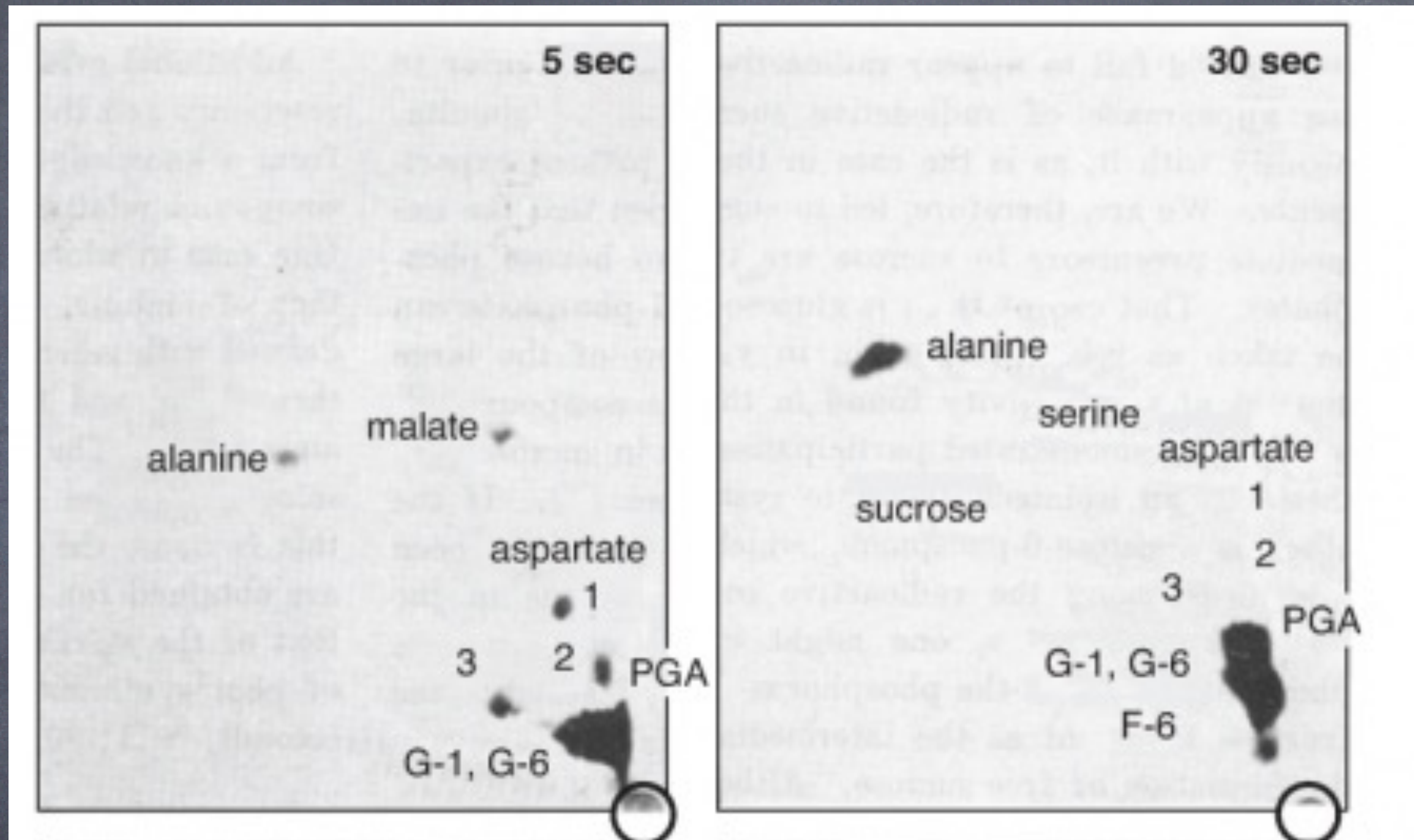


Figure 11.13 Incorporation of radioactive carbon into organic molecules. Algae cells *Chorella pyrenoidosa* cells produce increasingly more complex organic molecules with longer exposure times to light and CO₂. Black circles in the bottom right corner indicate the location of the spotted materials placed on the TLC surface. Dashed

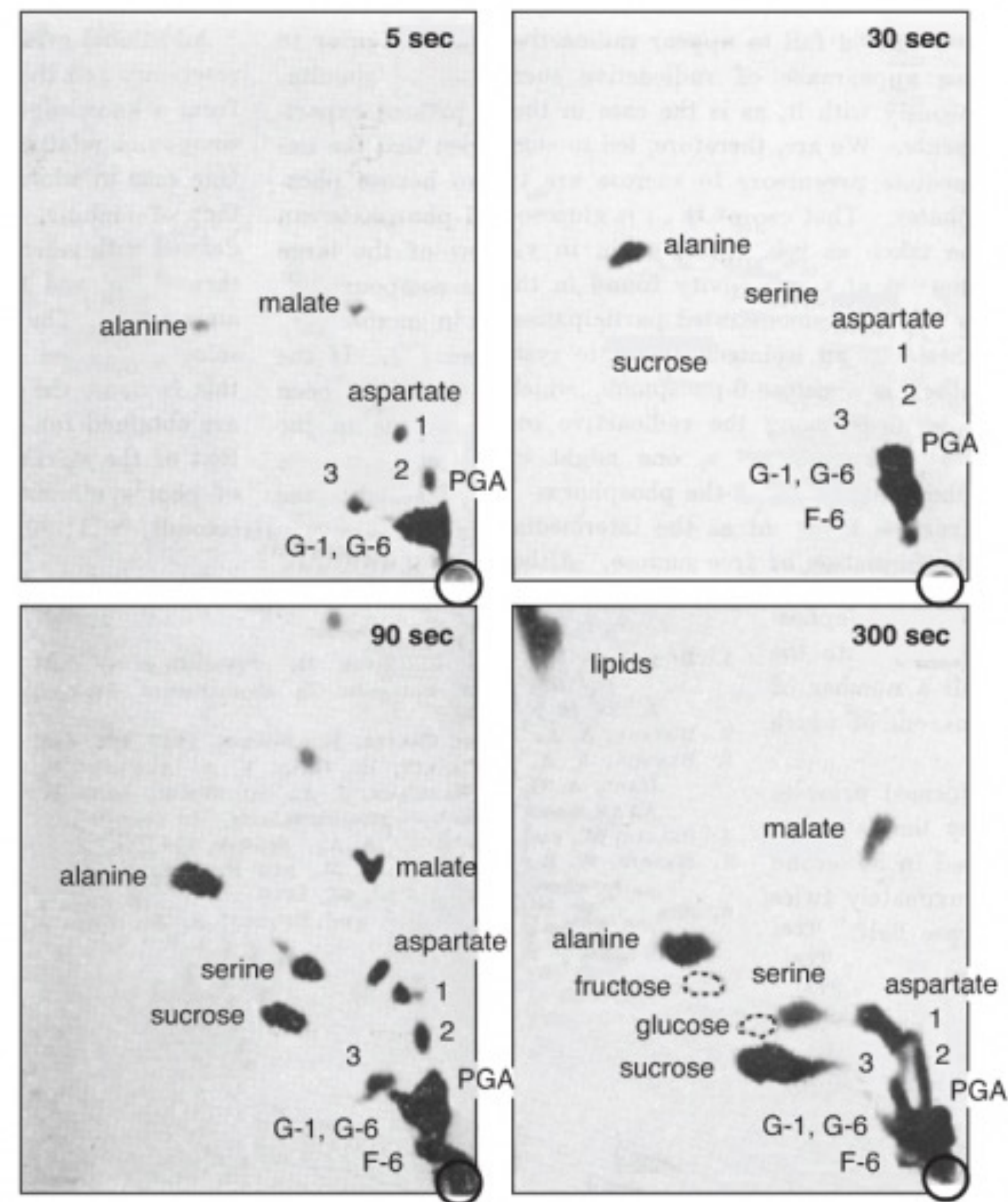
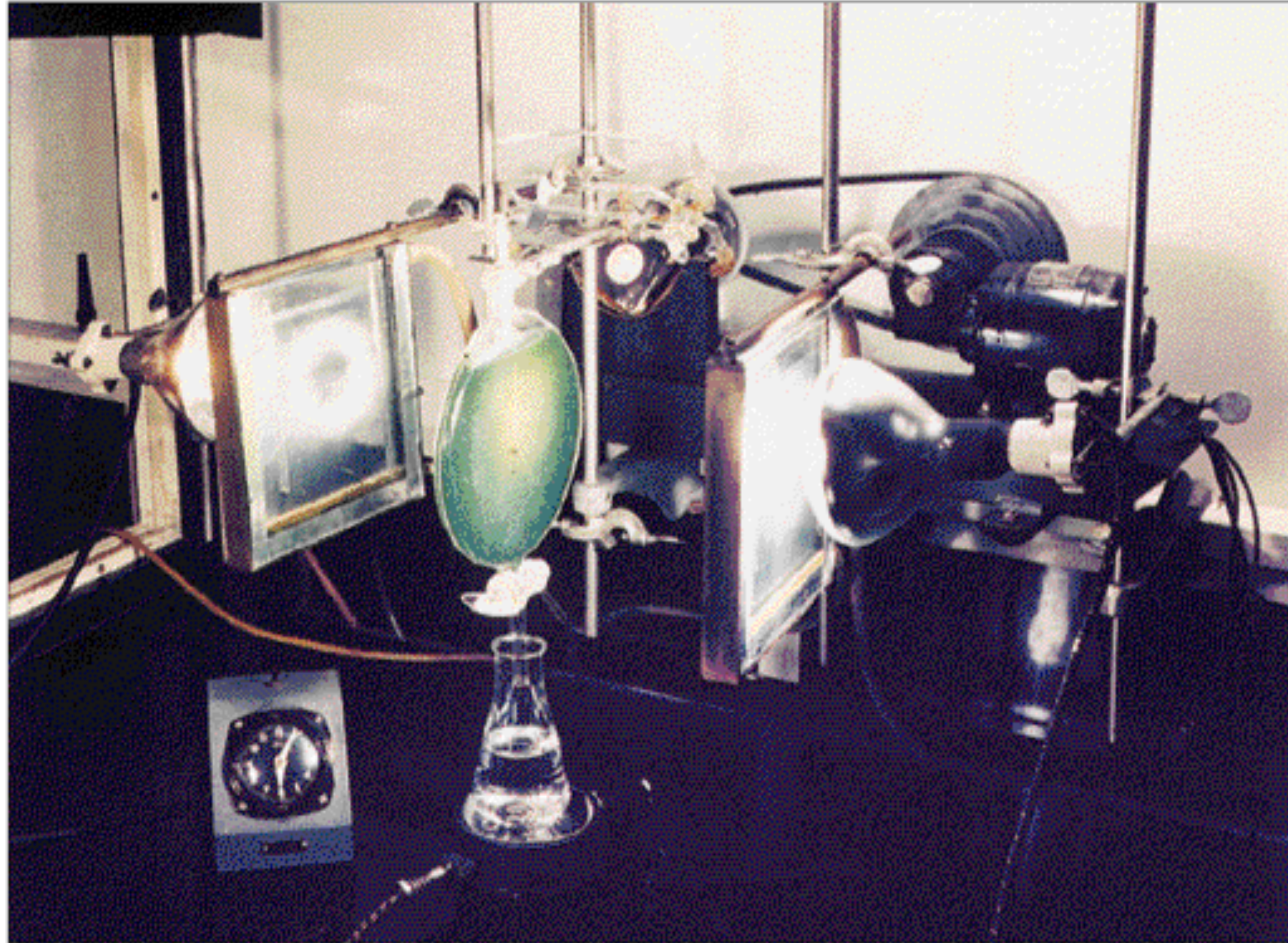
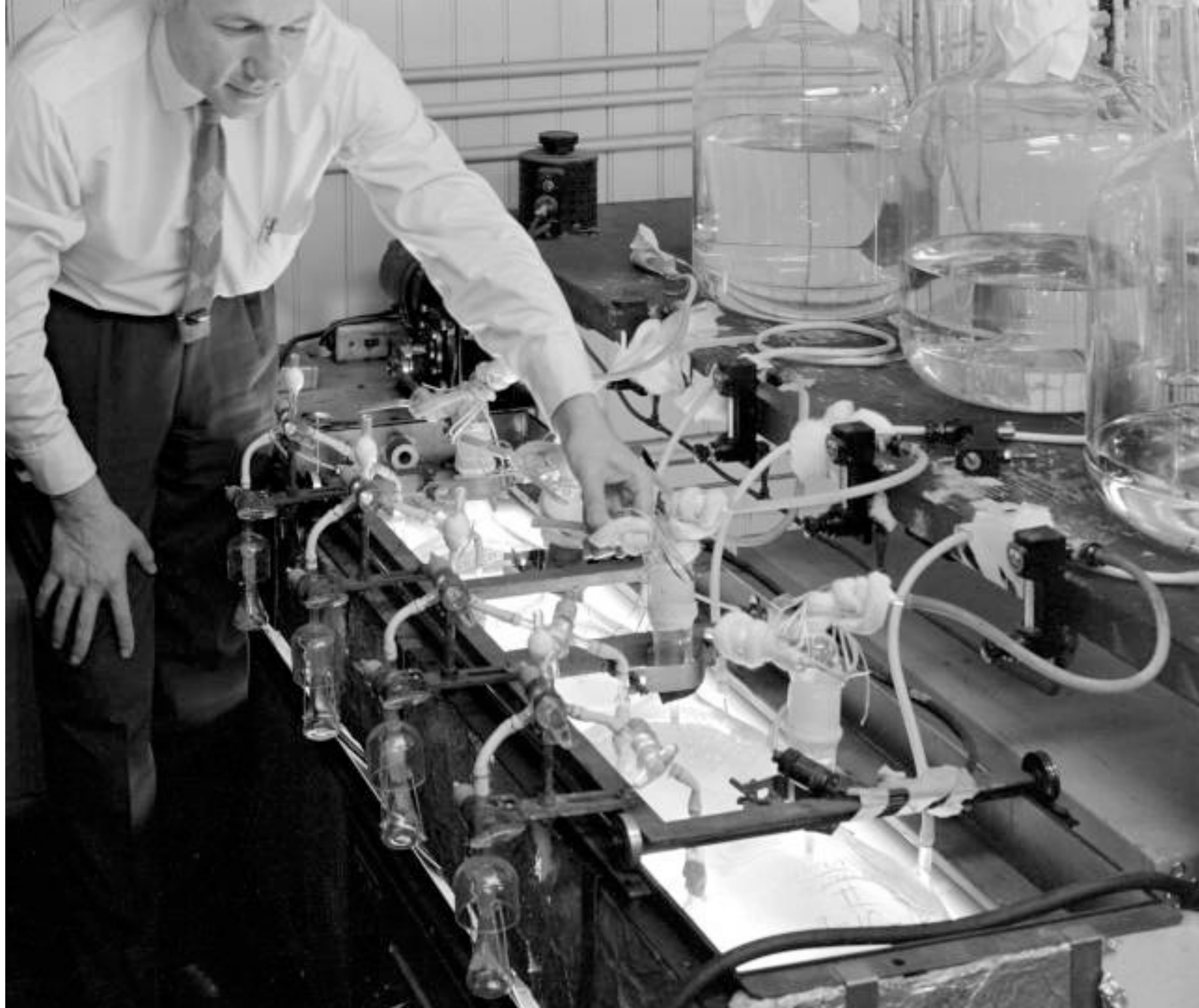


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1. How do they visualize the molecules of interest?
2. How do they separate them in an orderly fashion?

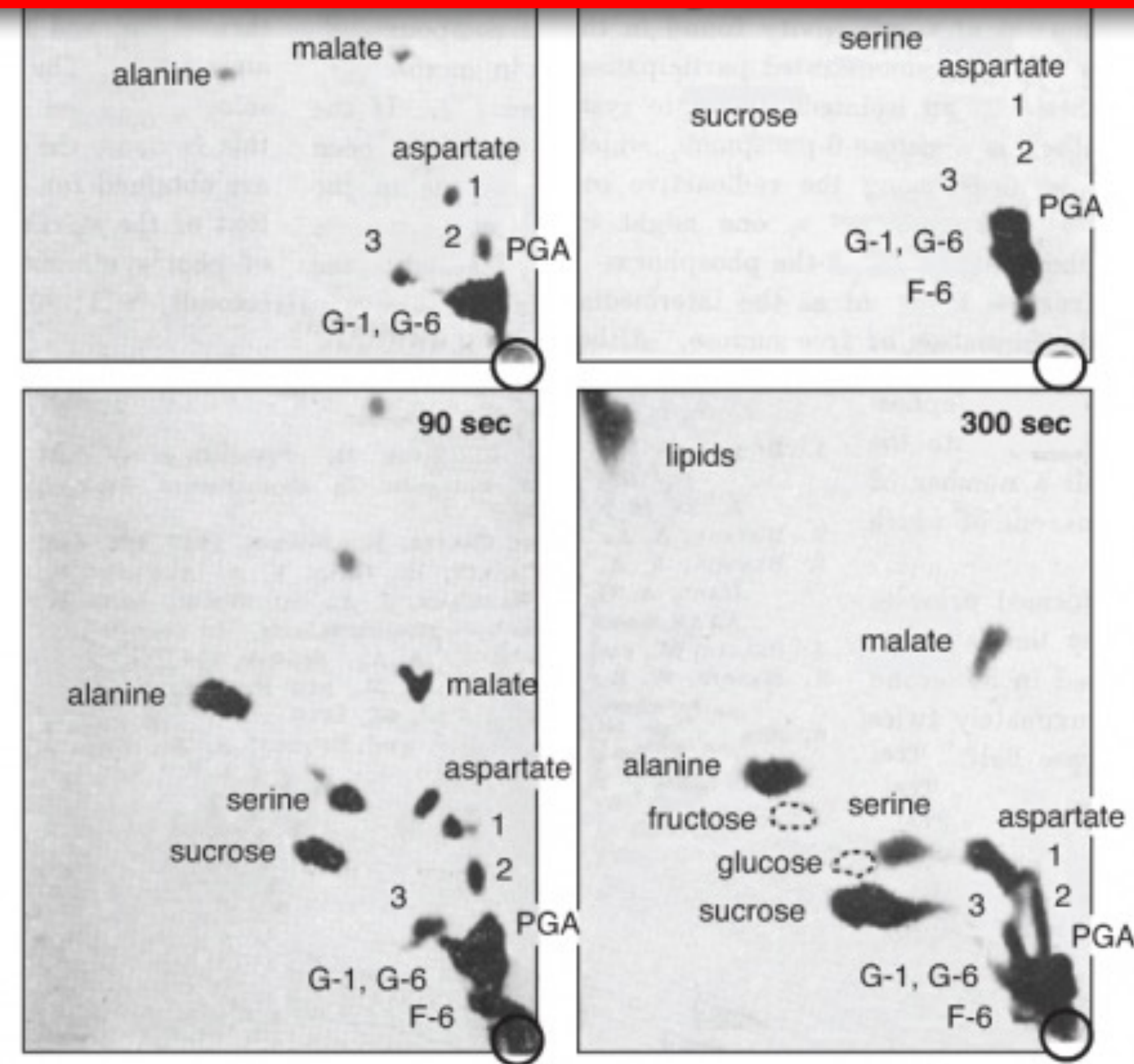


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Who else separated by TLC?

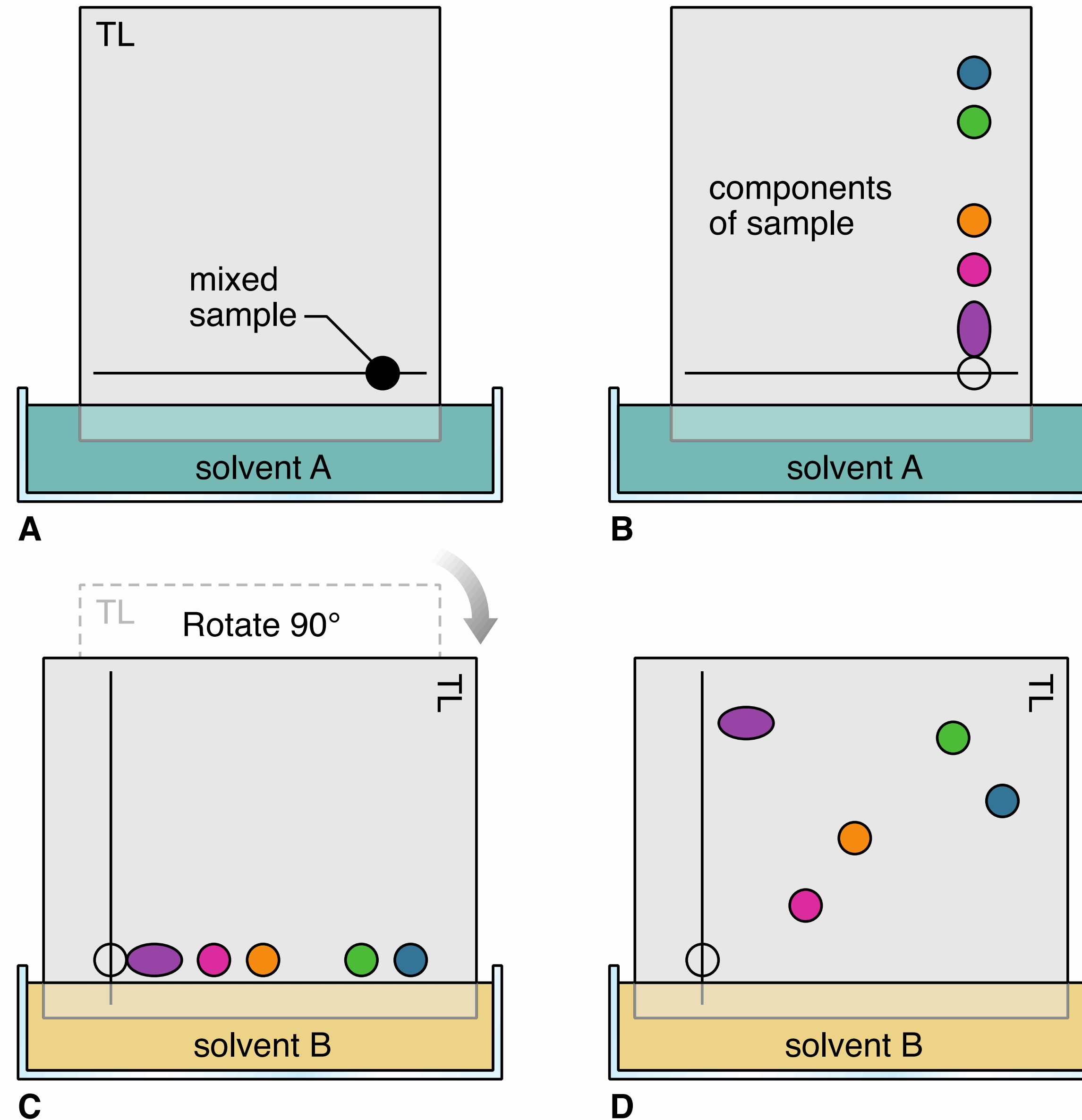
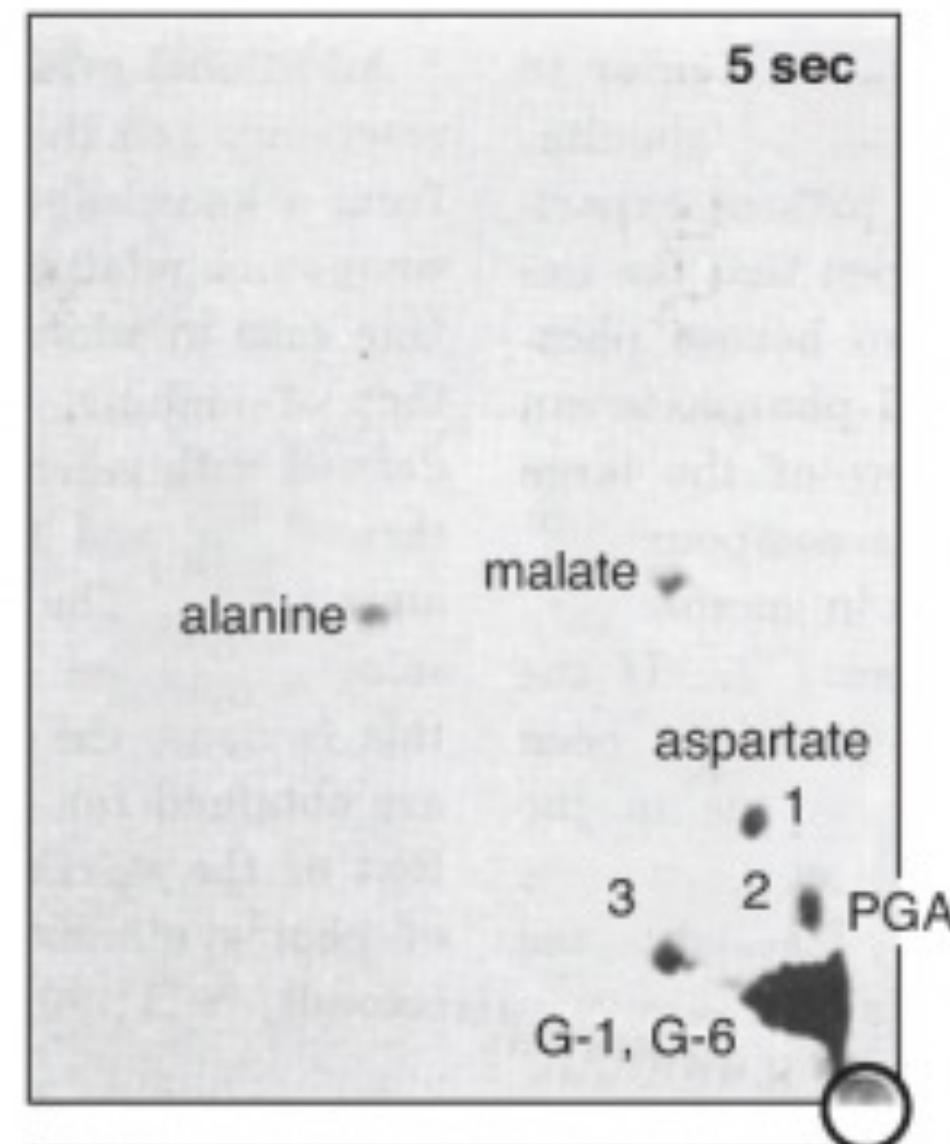


Fig. 1.19

1. First **stable** product of Calvin Cycle

***C-C-C-P**

3-Phosphoglycerate (3-PGA)



Initial Sugar Production by Plants

5 sec of fixation

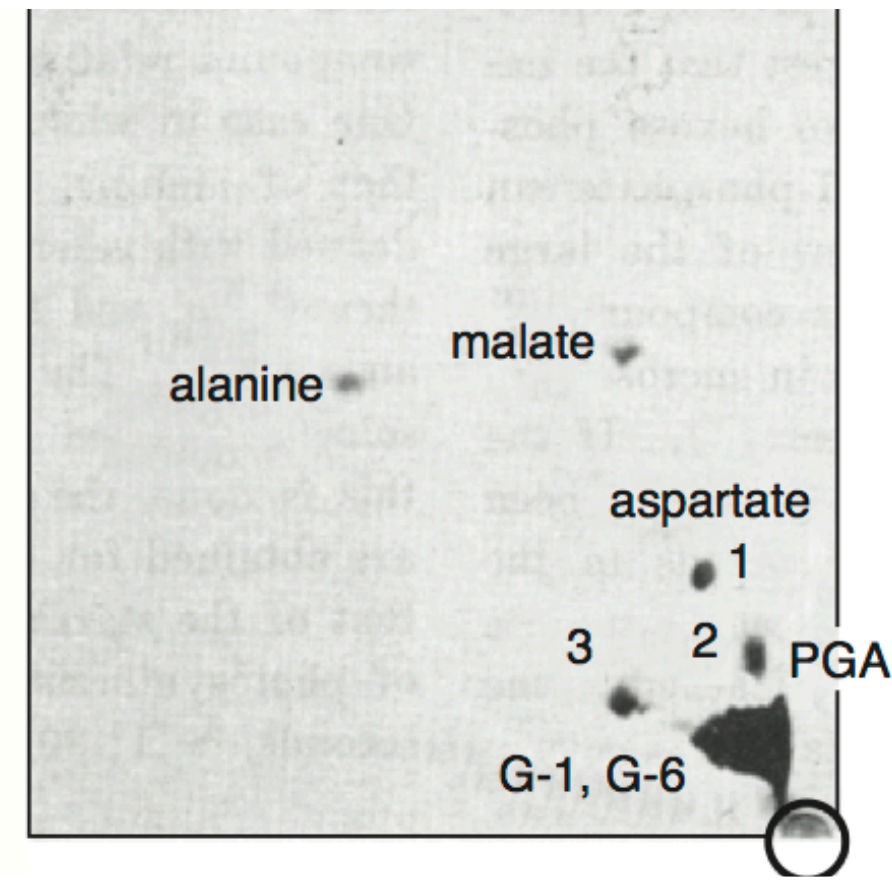


Fig. 11.13

Initial Sugar Production by Plants

5 sec of fixation

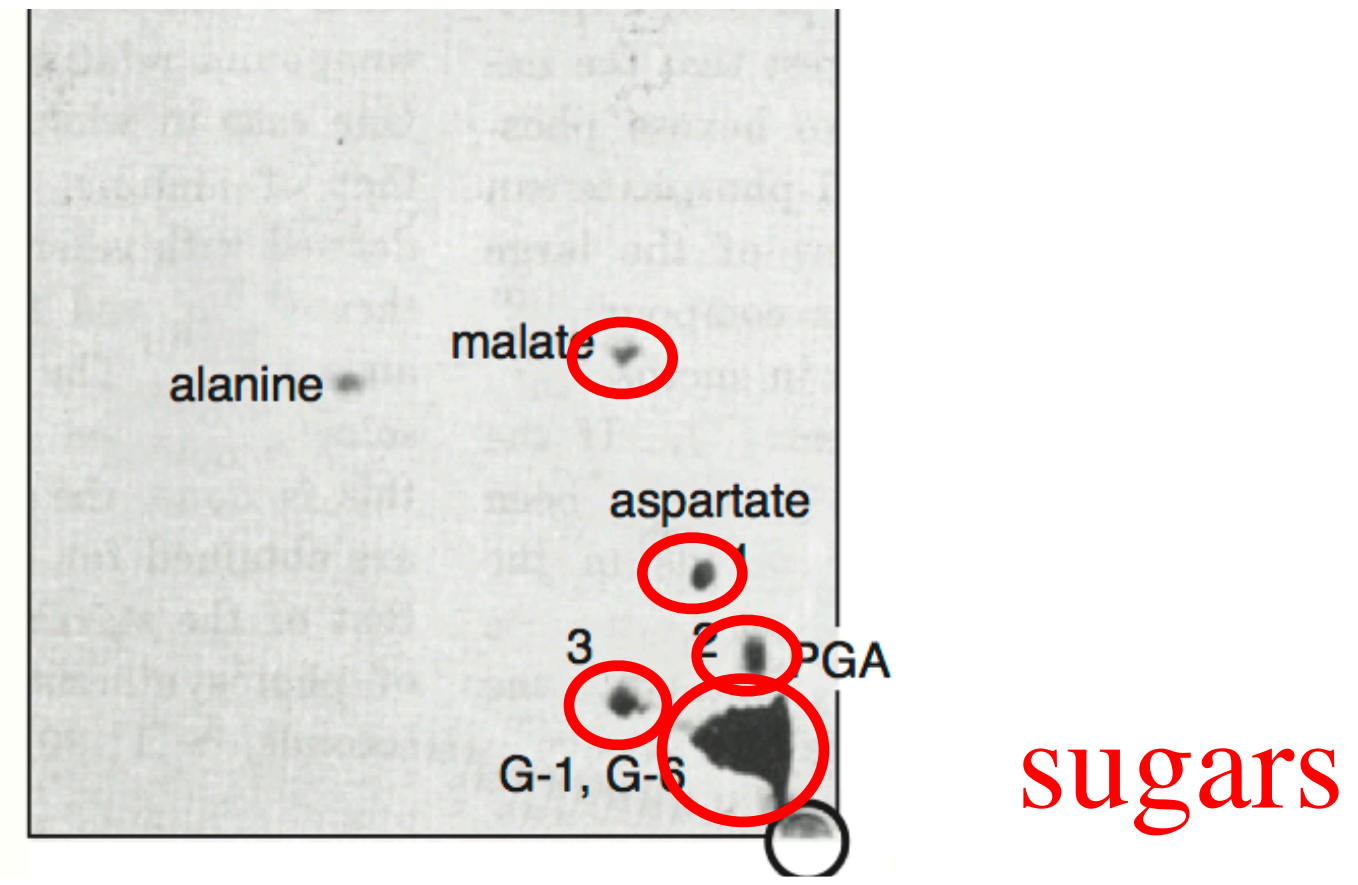


Fig. 11.13

Amino Acids from Plants

5 sec of fixation

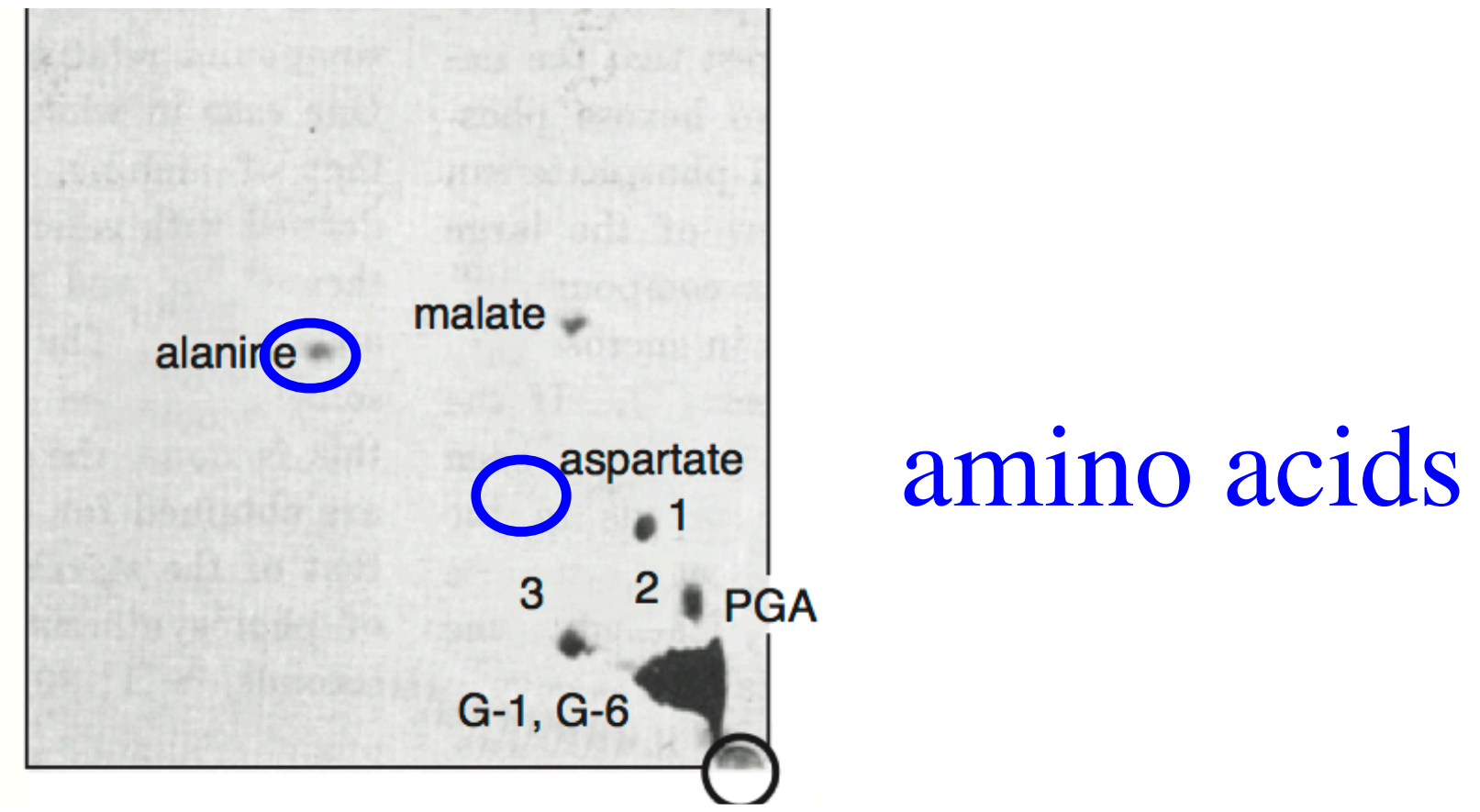


Fig. 11.13

Incorporation of Carbon

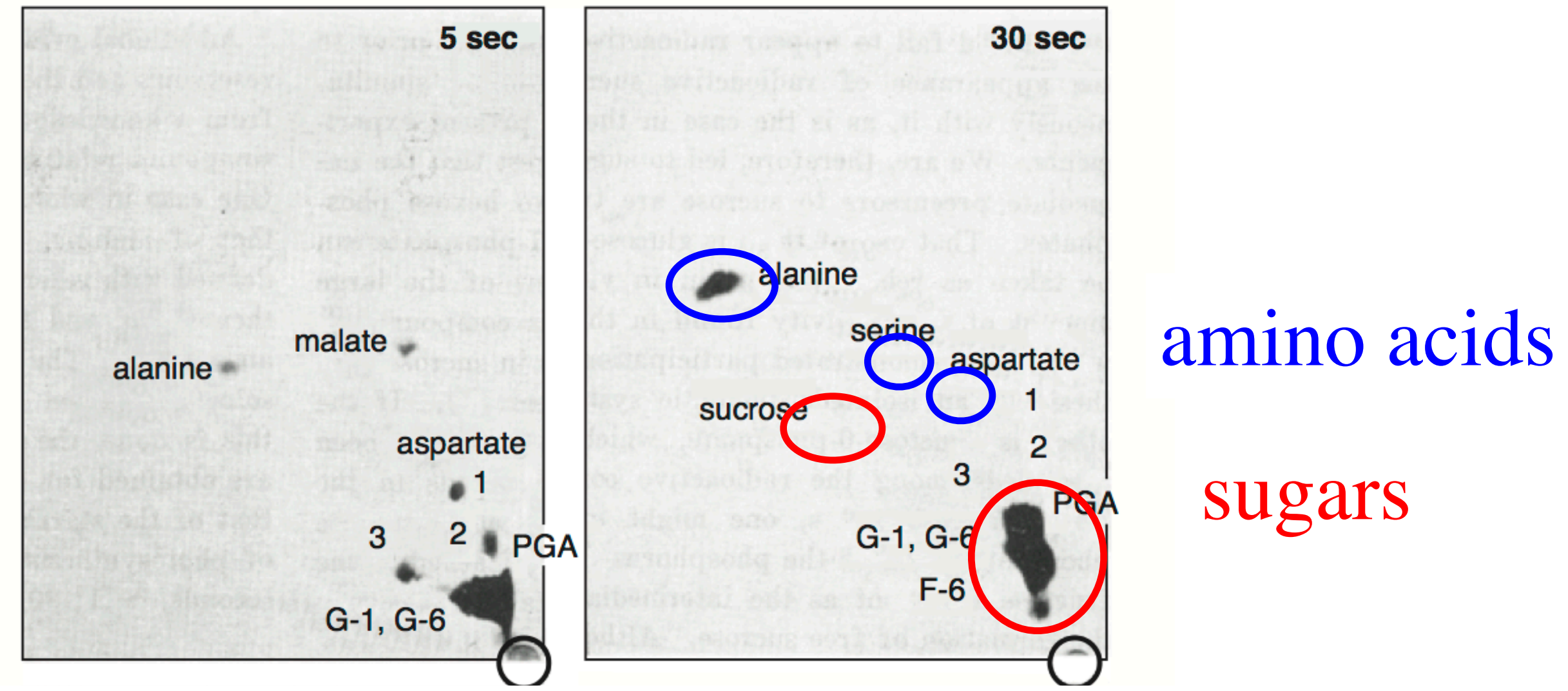


Fig. 11.13

Incorporation of Carbon

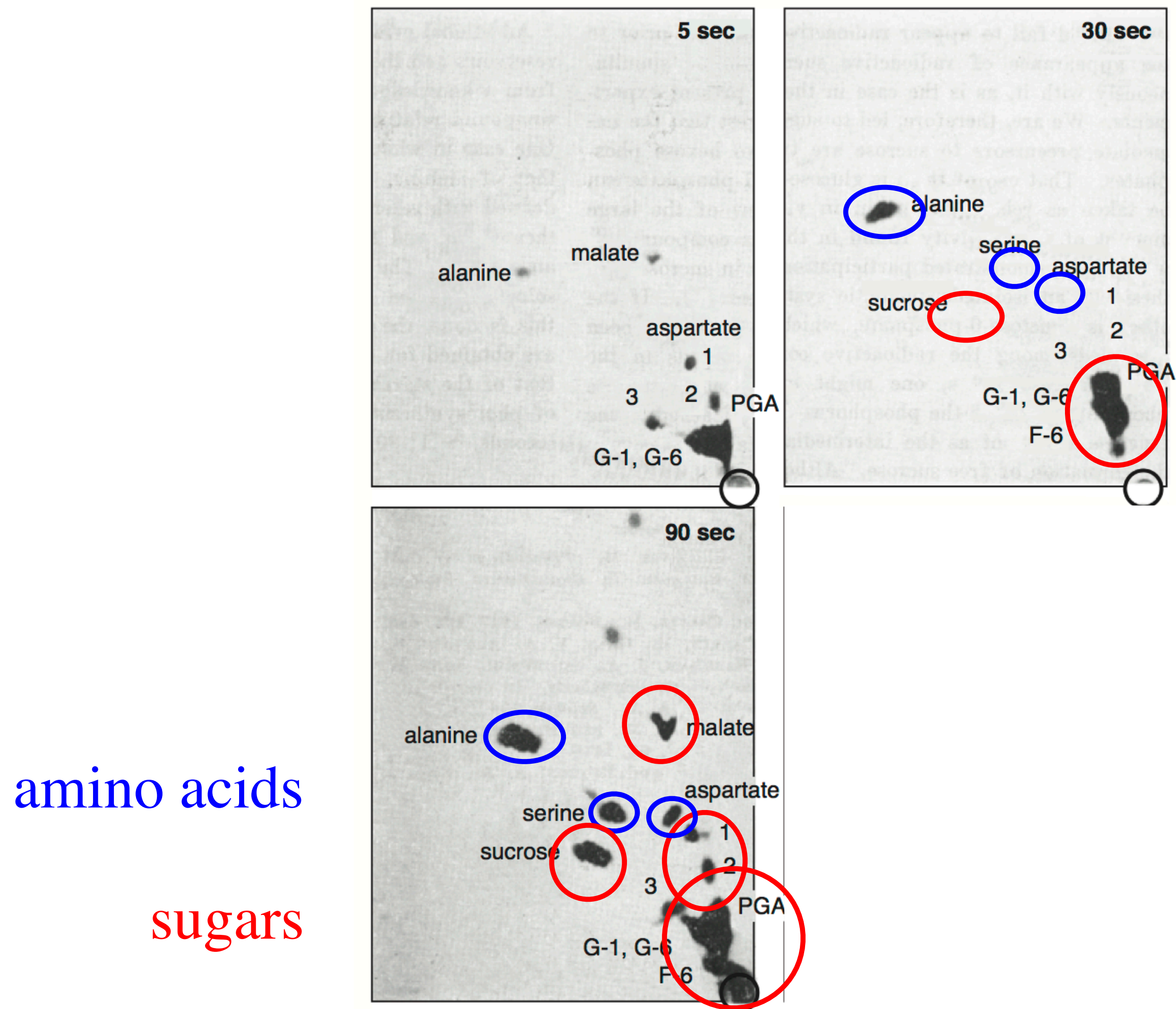


Fig. 11.13

Incorporation of Carbon

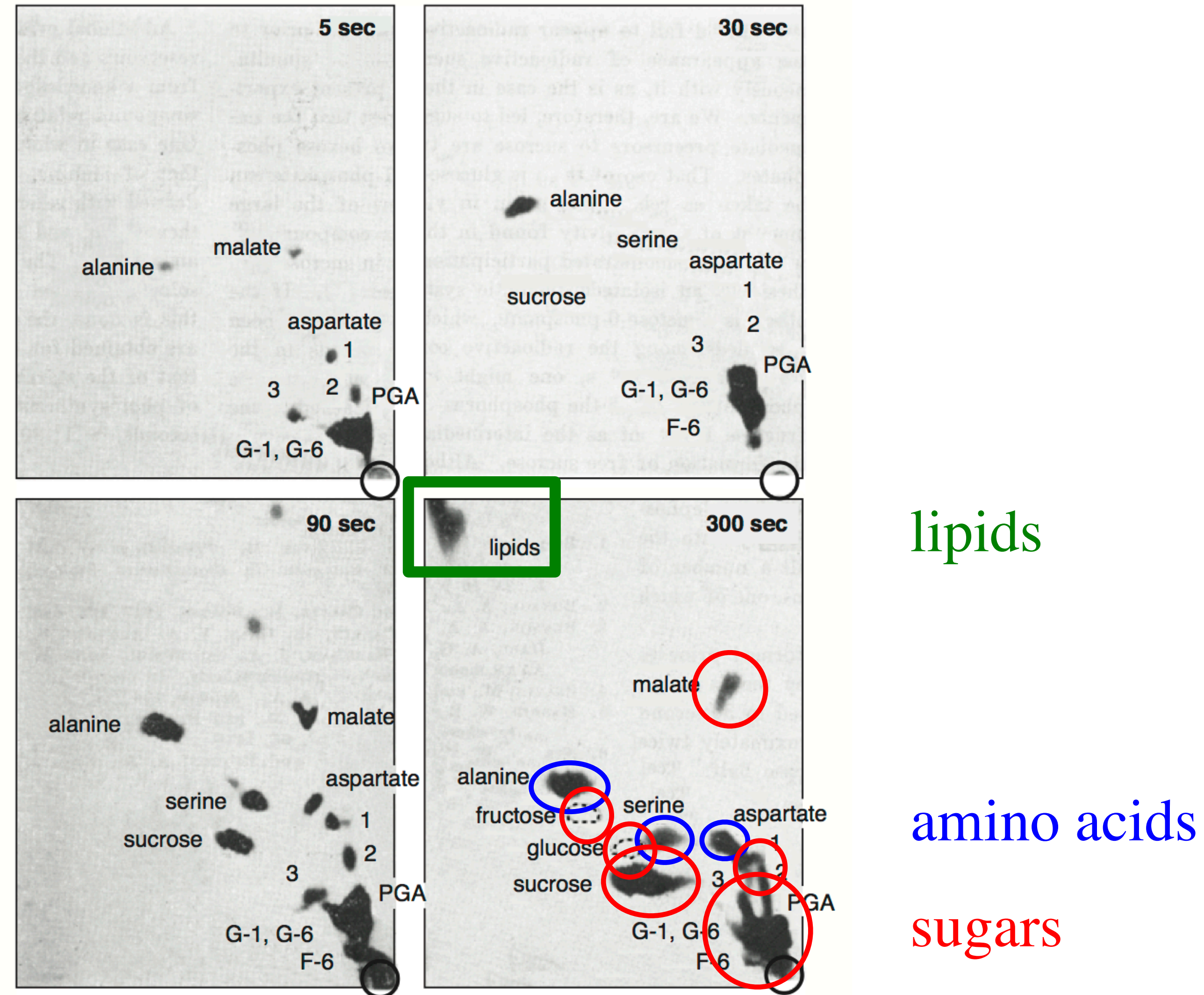


Fig. 11.13

Why this order of production?

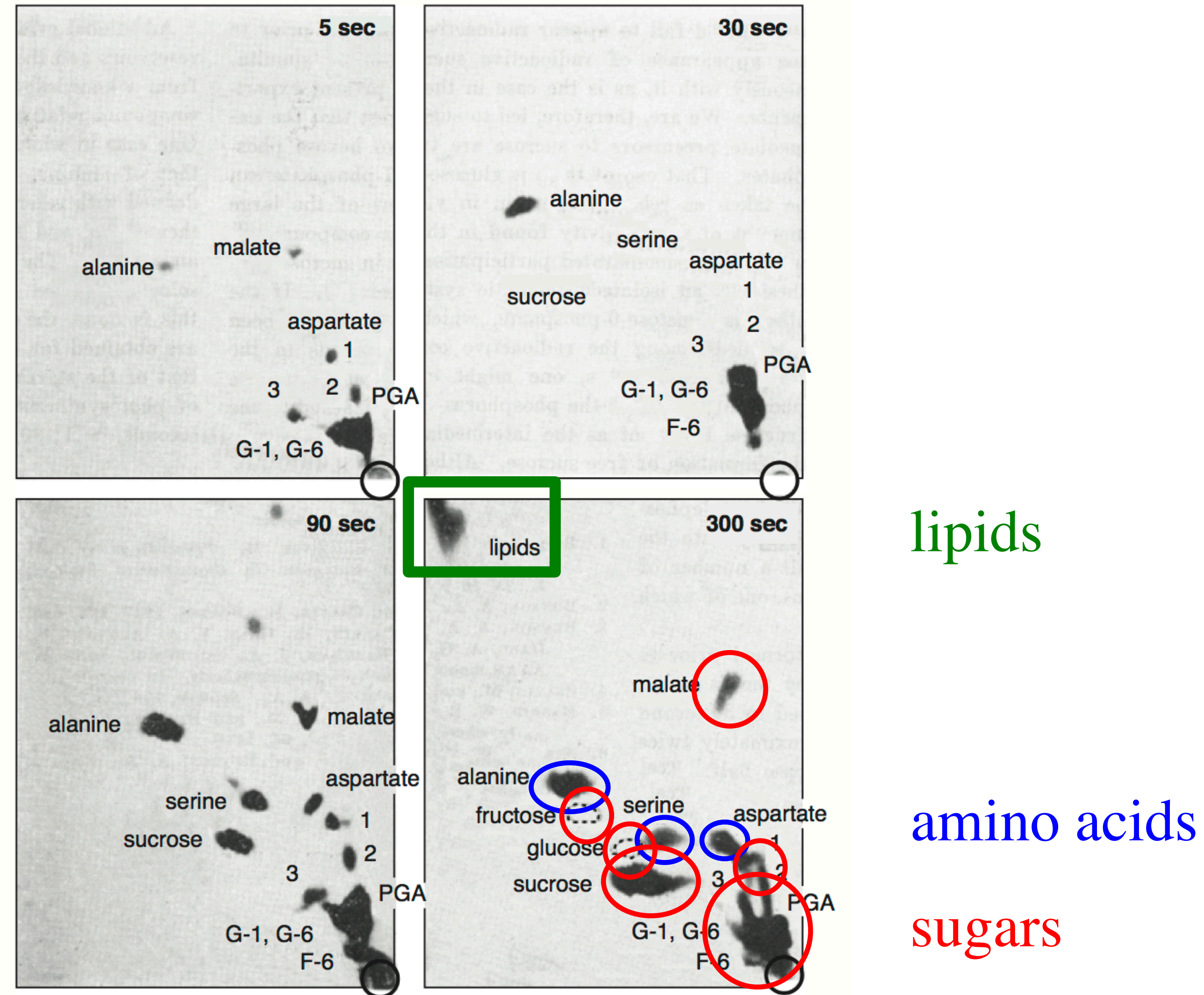
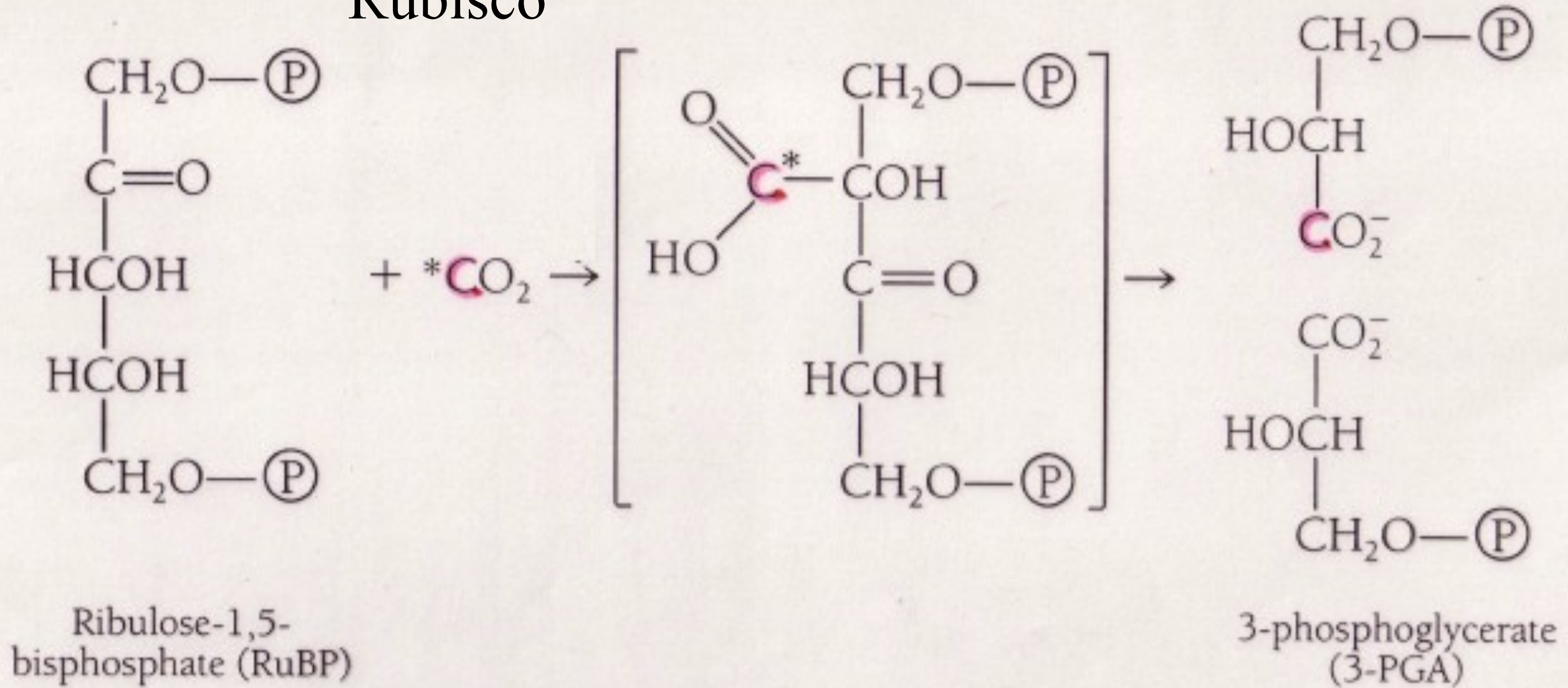


Fig. 11.13

Rubisco



1. Fixation

Trifecta

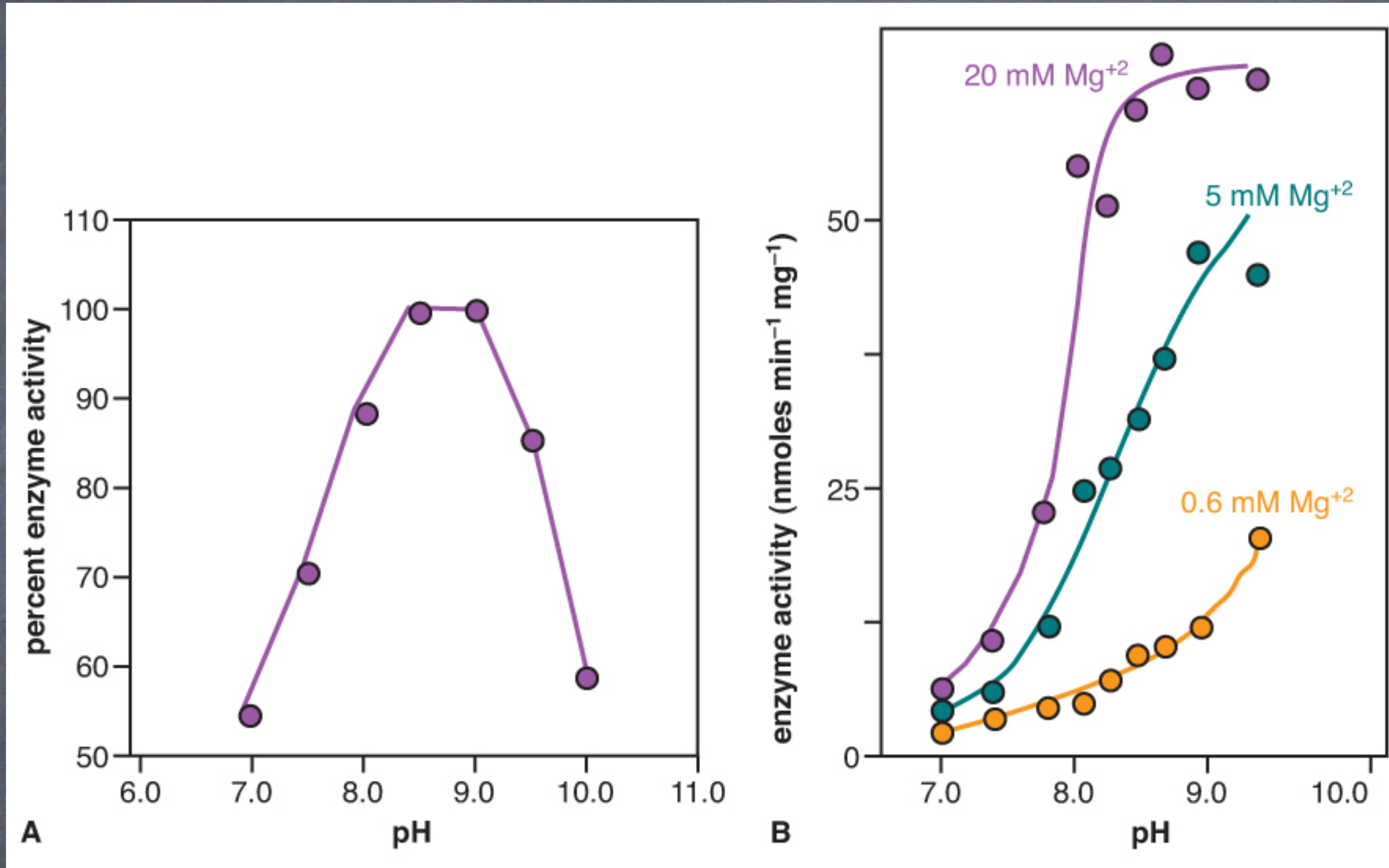


Figure 11.15 Physiological regulation of rubisco. **A**, Rubisco activity is sensitive to pH. **B**, Rubisco activity is sensitive to Mg²⁺ concentration and pH. Panel A modified from Chakrabarti et al., 2003, figure 2. Panel B modified from Lorimer et al., 1976, their figure 5. Reprinted (adapted) with permission from Lorimer, George H., Murray R. Badger and T. John Andrews. 1976. The Activation of Ribulose- 1,5-bisphosphate Carboxylase by Carbon Dioxide and Magnesium Ions. *Equilibria, Kinetics, a*

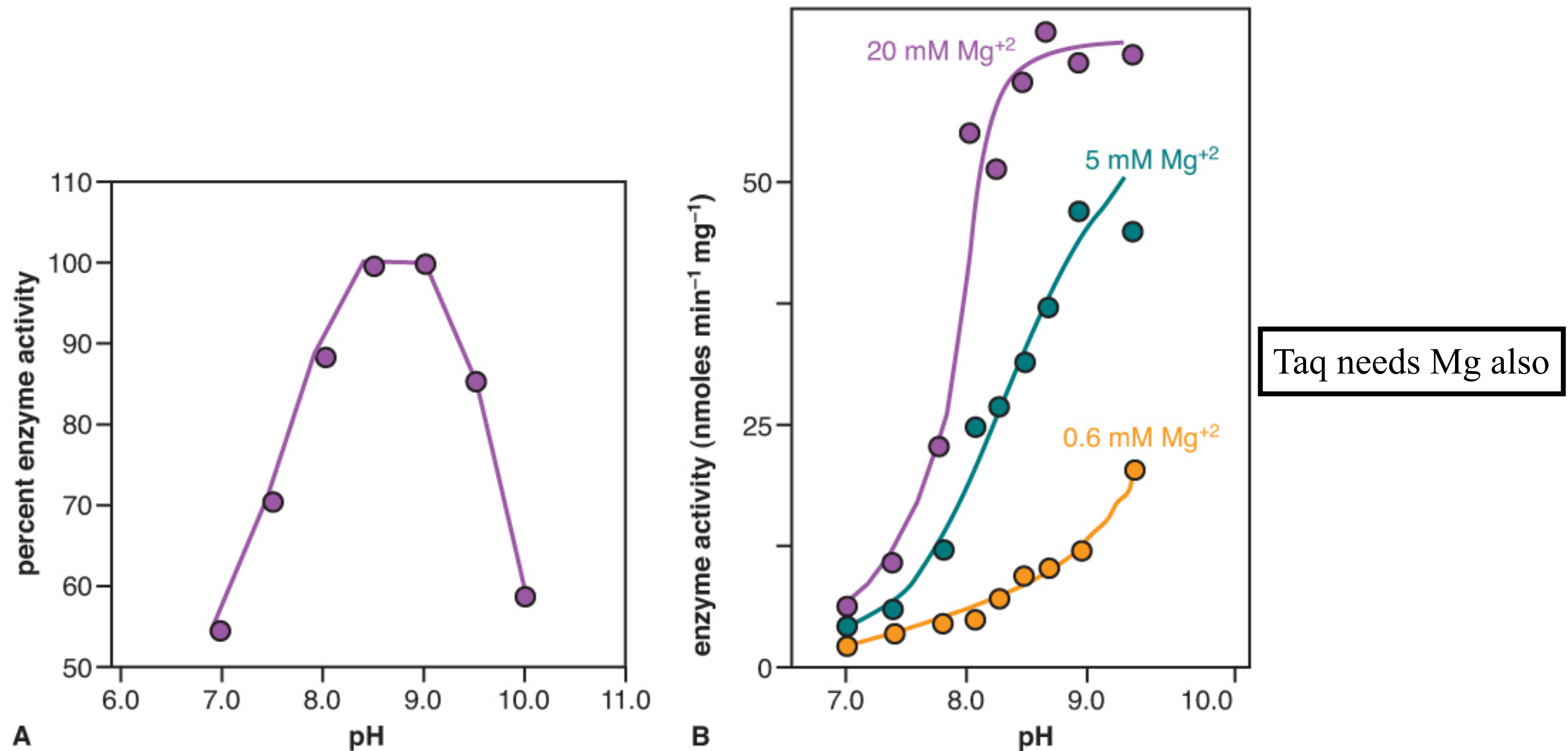
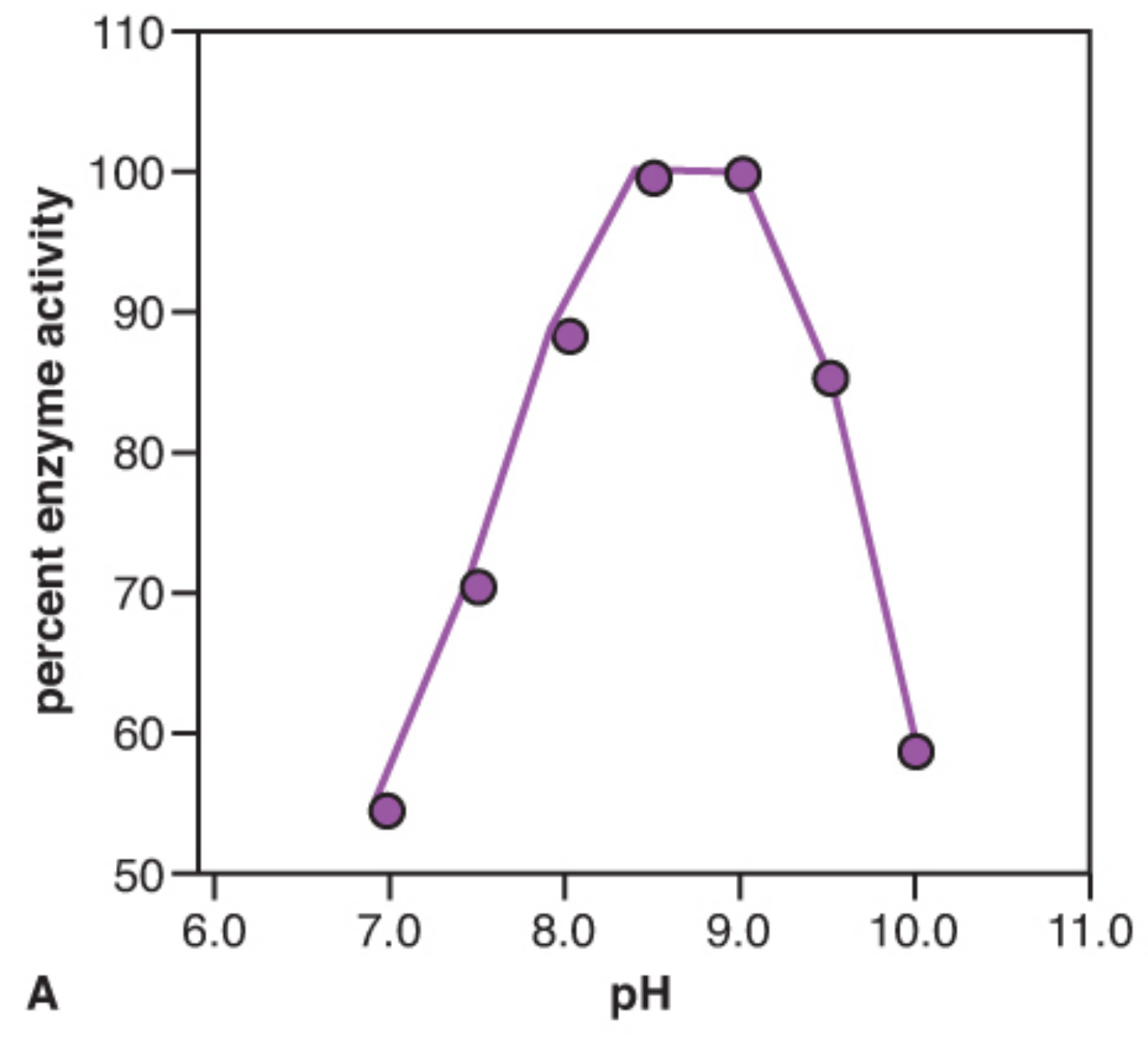


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A

activity plateau between pH 8.0 and 9.0, while soluble enzyme showed activity plateau between the pH range of 8.0 and 9.0. The decrease in activity to either side of plateau for soluble enzyme was sharper than that observed for immobilized enzyme. The immobilized enzyme pH–activity profile showed a shift to the right as compared to the soluble enzyme (Fig. 2).

Temperature–Activity Relationship

The residual activity as a function of time was determined at different temperatures. Figure 3 presents temperature–activity profile of soluble and immobilized Rubisco. To determine the effect of temperature on the rate of deactivation of the enzyme at 20°C and at 55°C, the lowest and highest temperatures at which Rubisco activity has been determined in the present investigation, the residual activity (percent) at these temperatures was determined and the natural log of the ratio of residual activity at specified temperature to that of the initial activity (taken as 100%) was plotted against incubation time. The resulting plots are presented in Fig. 4. As evident from Fig. 4, rates of deactivation at 20°C among enzymes (soluble or immobilized) were

Table II. Leached protein amounts with respect to number of use cycle for Rubisco immobilized on nylon matrix and on protein A agarose.^a

No. of residence time	Rubisco immobilized on nylon matrix	Rubisco immobilized on protein A agarose
1	0	0
2	0	0
3	0	0
4	8 ± 2	0
5	10 ± 2	0
6	30 ± 2	5 ± 2

^aThe total initial protein load was taken as 100 percent and leached protein amounts determined using method of Bradford have been expressed as percent.



Figure 1. SDS-PAGE analysis of purified spinach Rubisco. Spinach Rubisco was purified from freshly prepared leaf extract. Lysate (15 µg) and purified protein (5 µg) were loaded on a 12% SDS-PAGE and stained with Coomassie blue.

extremely low, differences in the rates of deactivation (slope of the graph) were also very low, and slopes were almost identical. However, the rate of deactivation at 55°C is significantly different for soluble and immobilized enzymes.

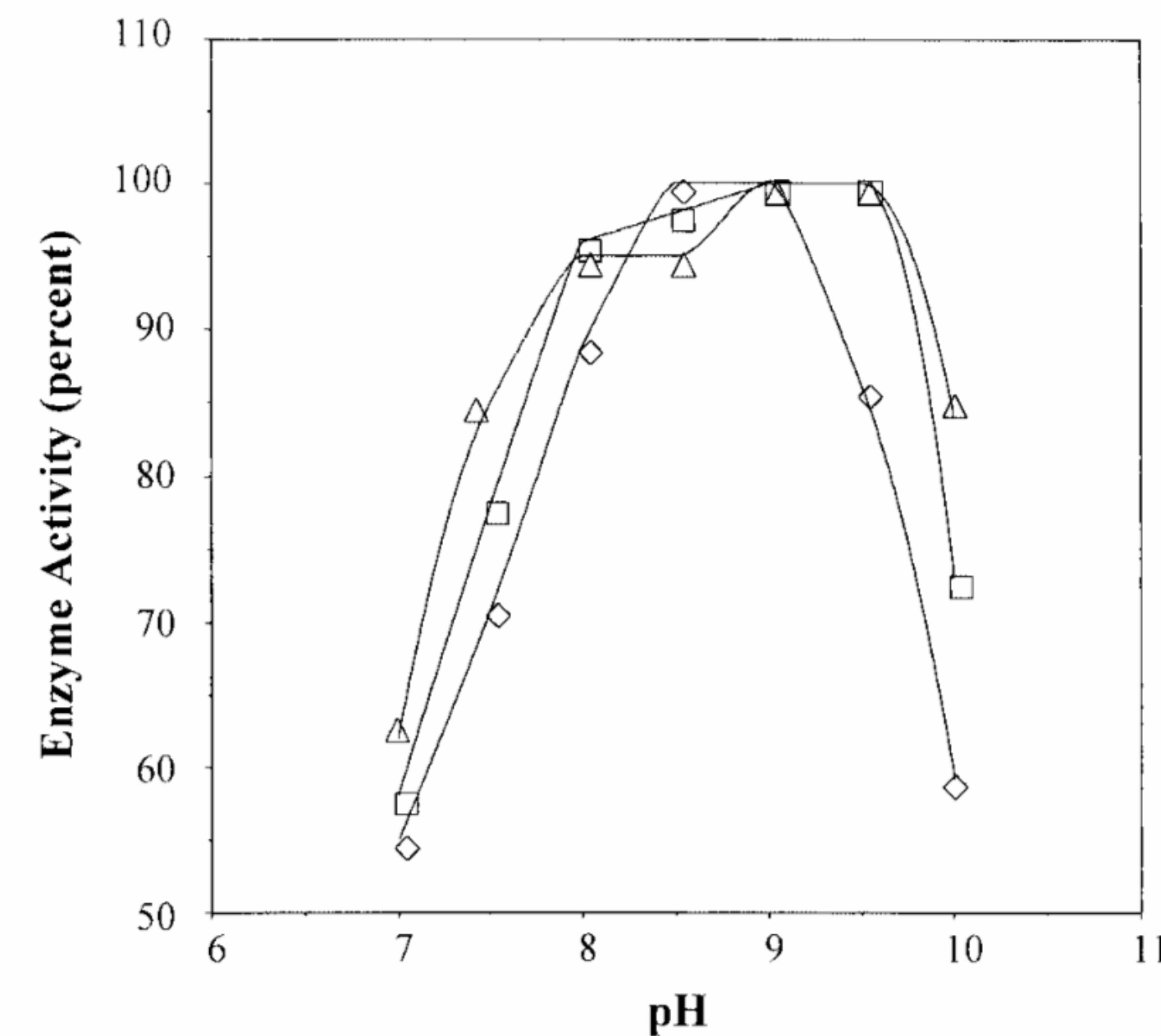
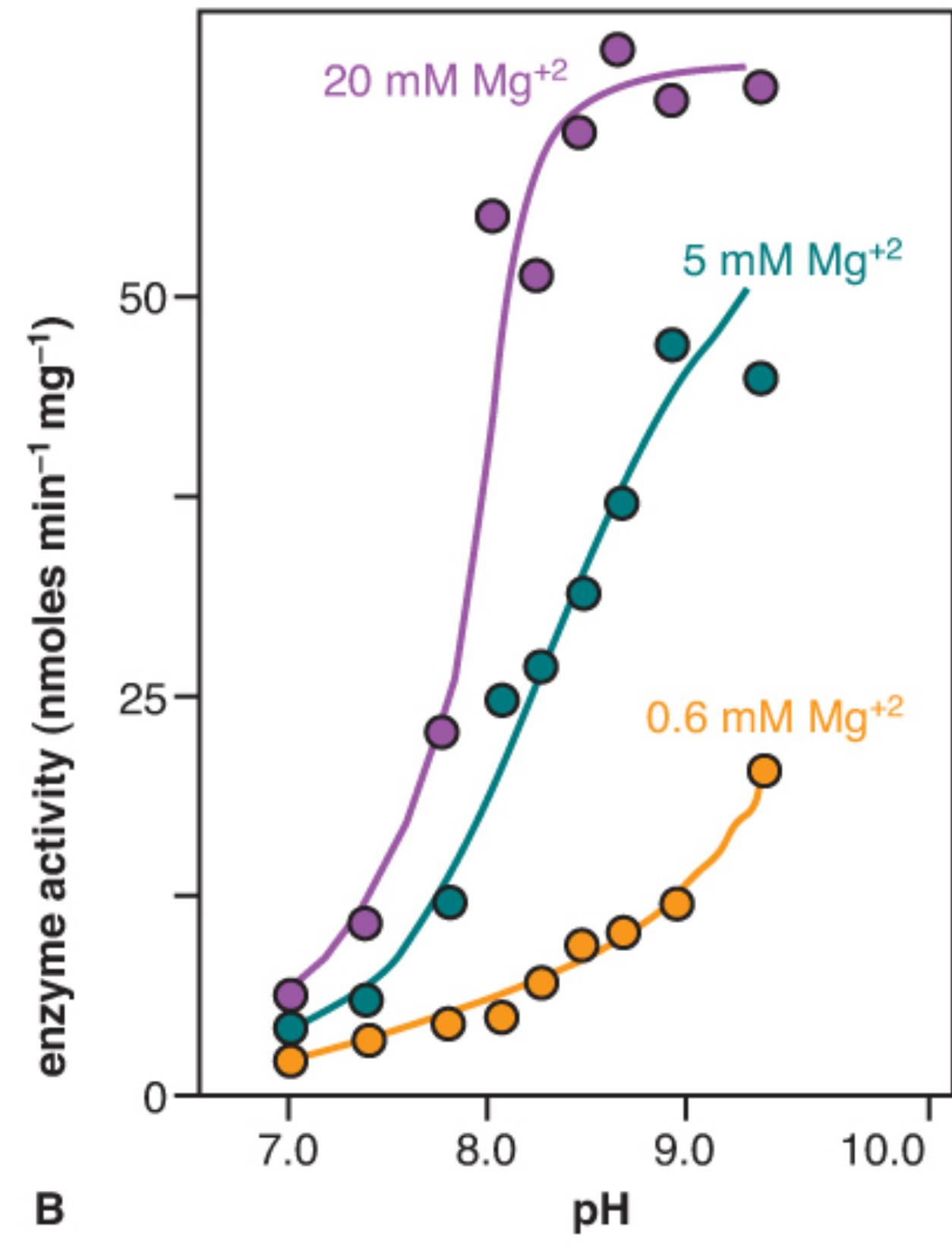


Figure 2. pH–activity profile of the soluble and immobilized Rubisco. The enzymes were subjected to a buffer of pH 7.0–10.0 for determination of activity. Soluble enzyme (◇), Rubisco immobilized using DCC coupling on nylon (□), and Rubisco immobilized using DMP coupling (△).



Trifecta

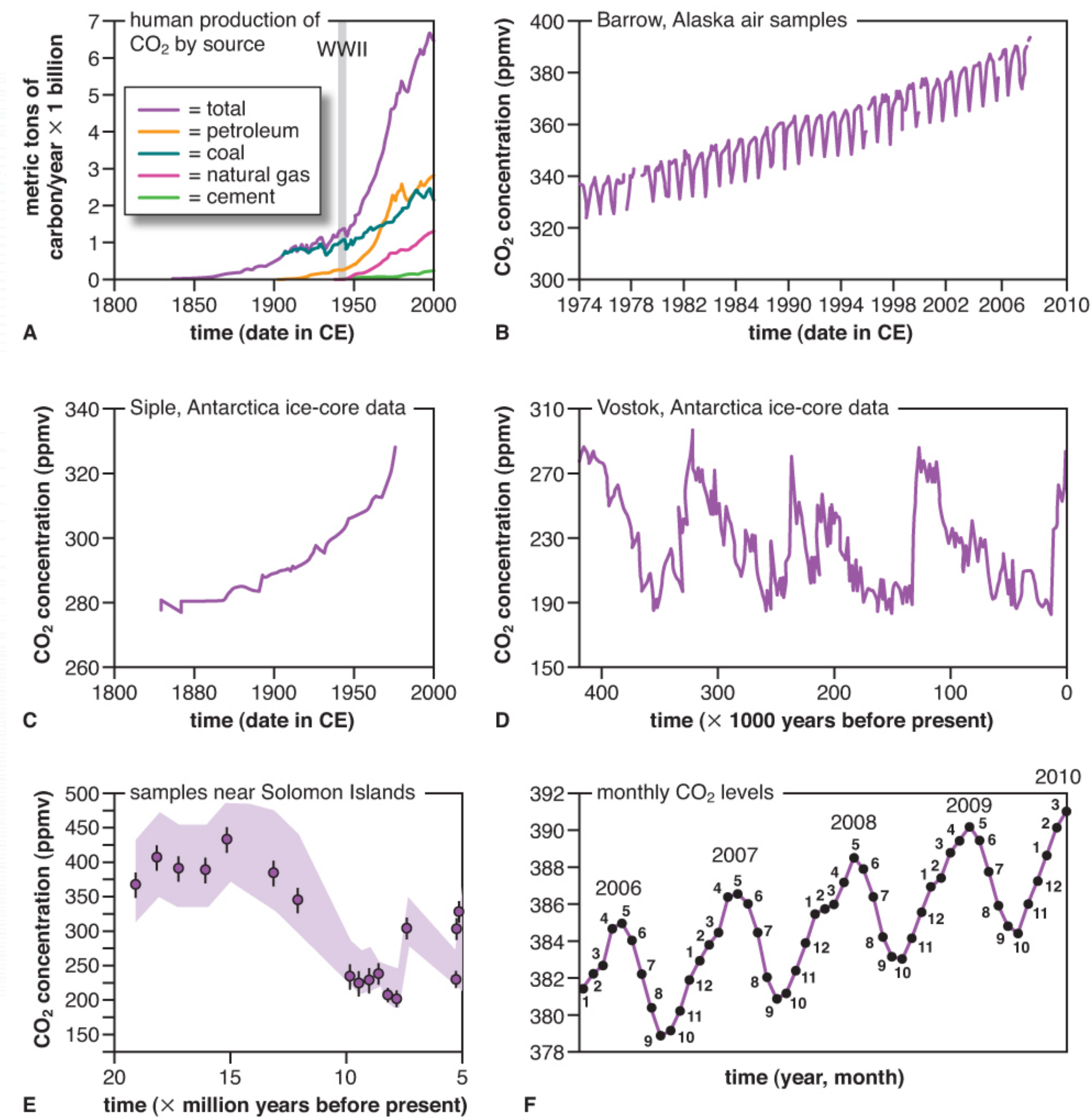


Figure 11.11 Energy consumption and CO₂ levels. **A**, The total production of CO₂ and its sources over the last 200 years. The gray stripe denotes the 5 years of World War II. Manufacturing cement produces CO₂ as well. **B**, The amount of CO₂ measured directly from air in Alaska. **C**, CO₂ levels over the past 200 years measured from ice cores taken in Antarctica. **D**, CO₂ levels over the past 425,000 years measured from ice cores taken in Antarctica. **E**, CO₂ levels over the past 20 million years measured from ocean floor sediment in the South Pacific Ocean. Error bars are +/- standard deviation, and the red shaded area

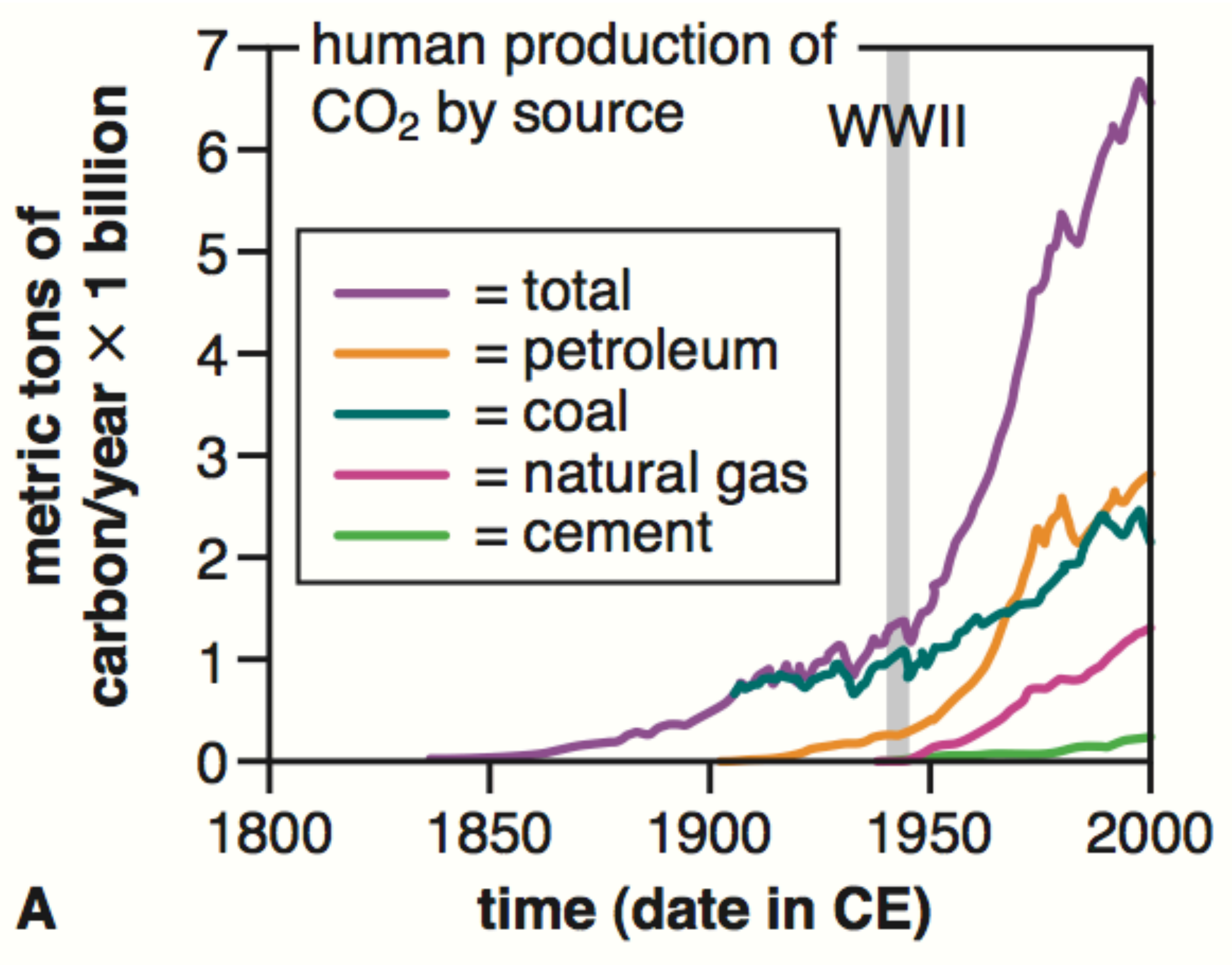


Fig. 11.11

Historic Atmospheric CO₂ Levels

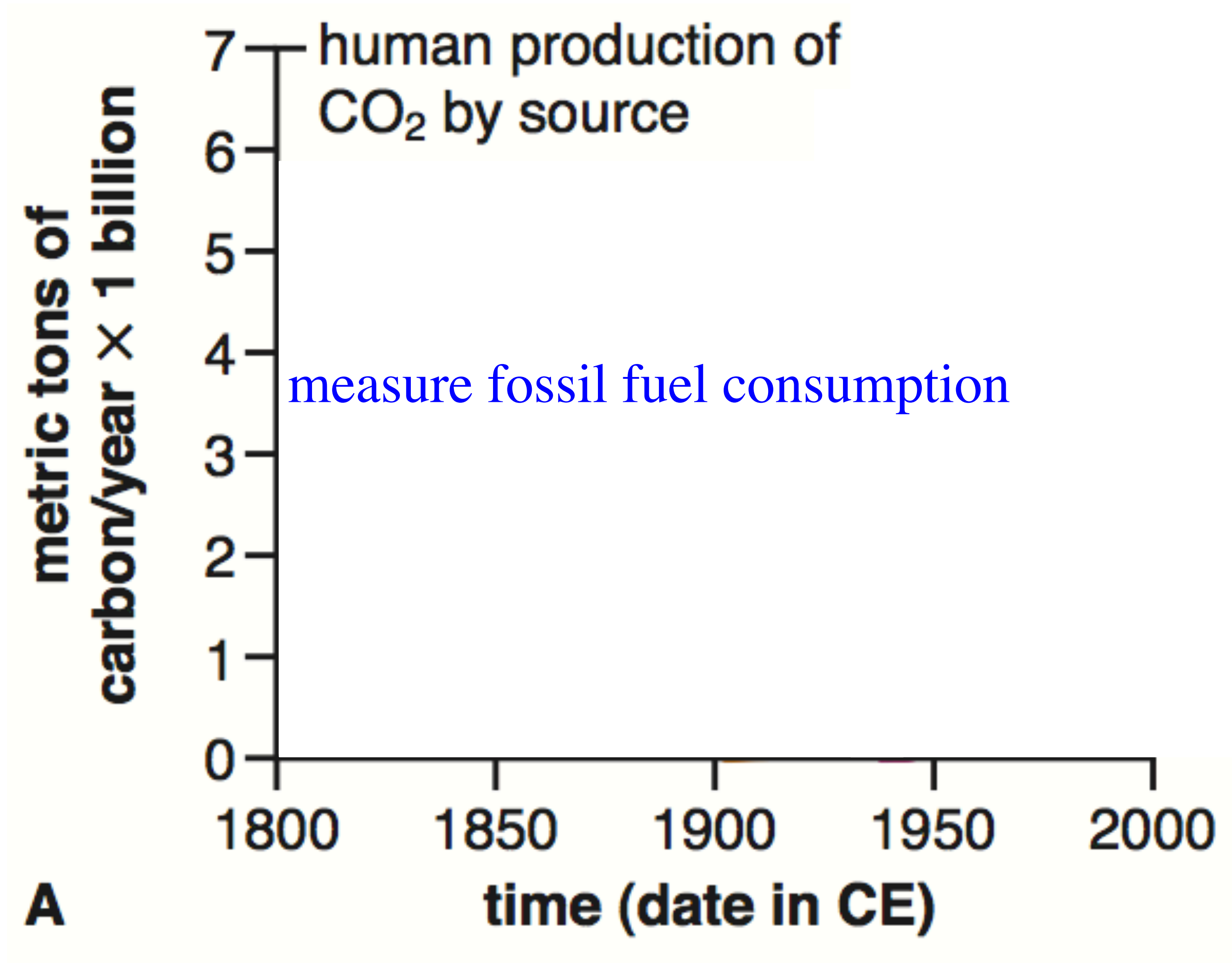


Fig. 11.11

Historic Atmospheric CO₂ Levels

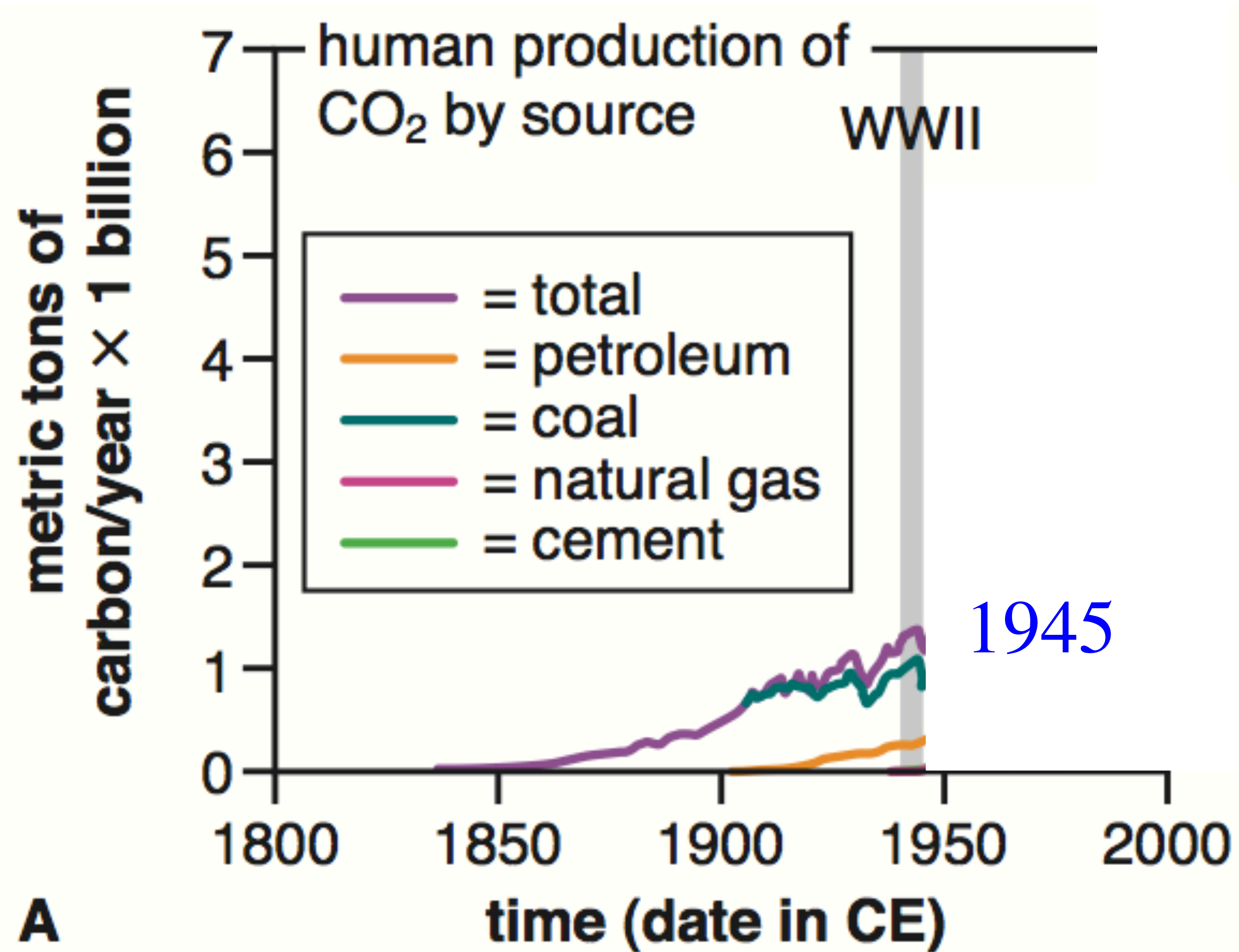


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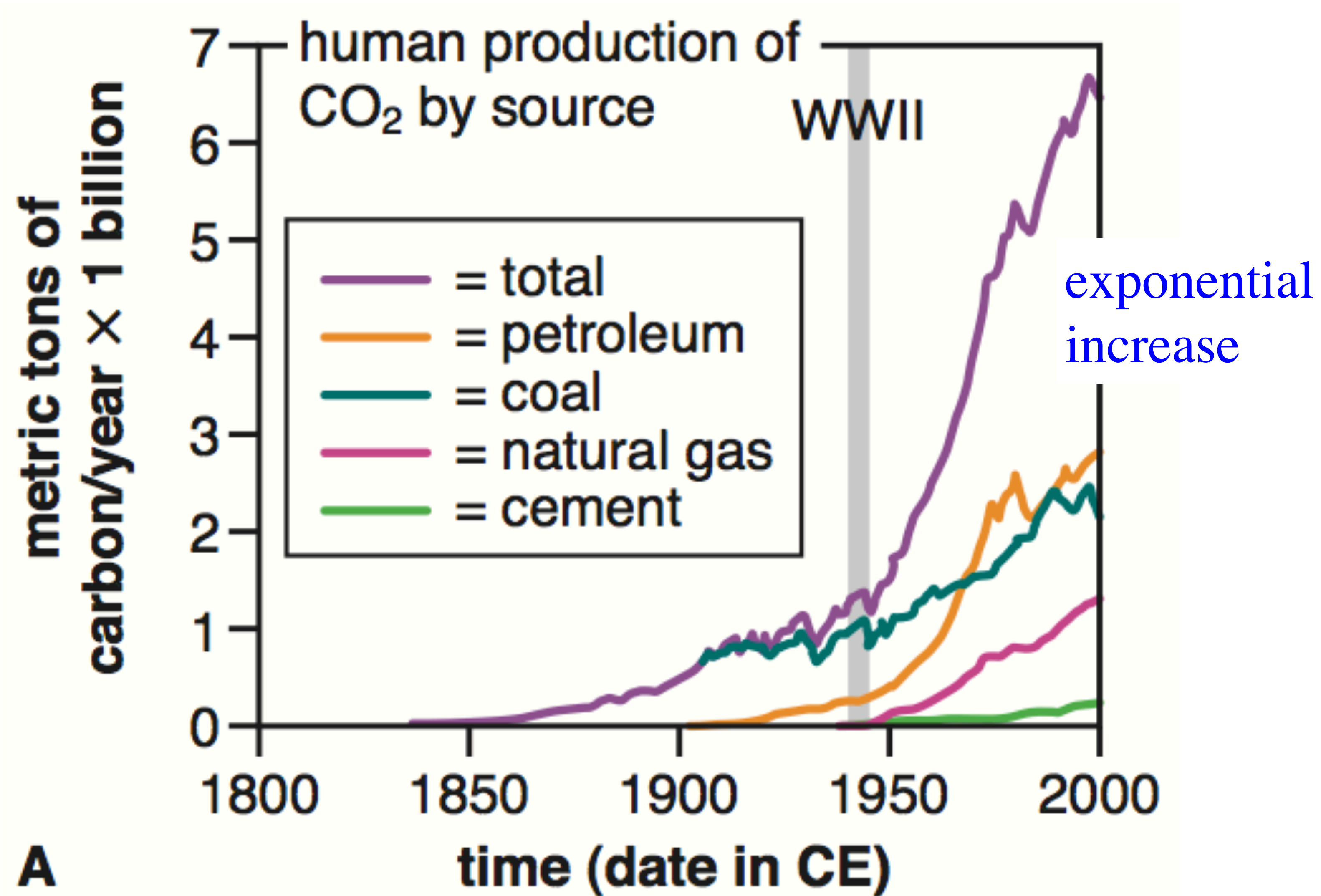


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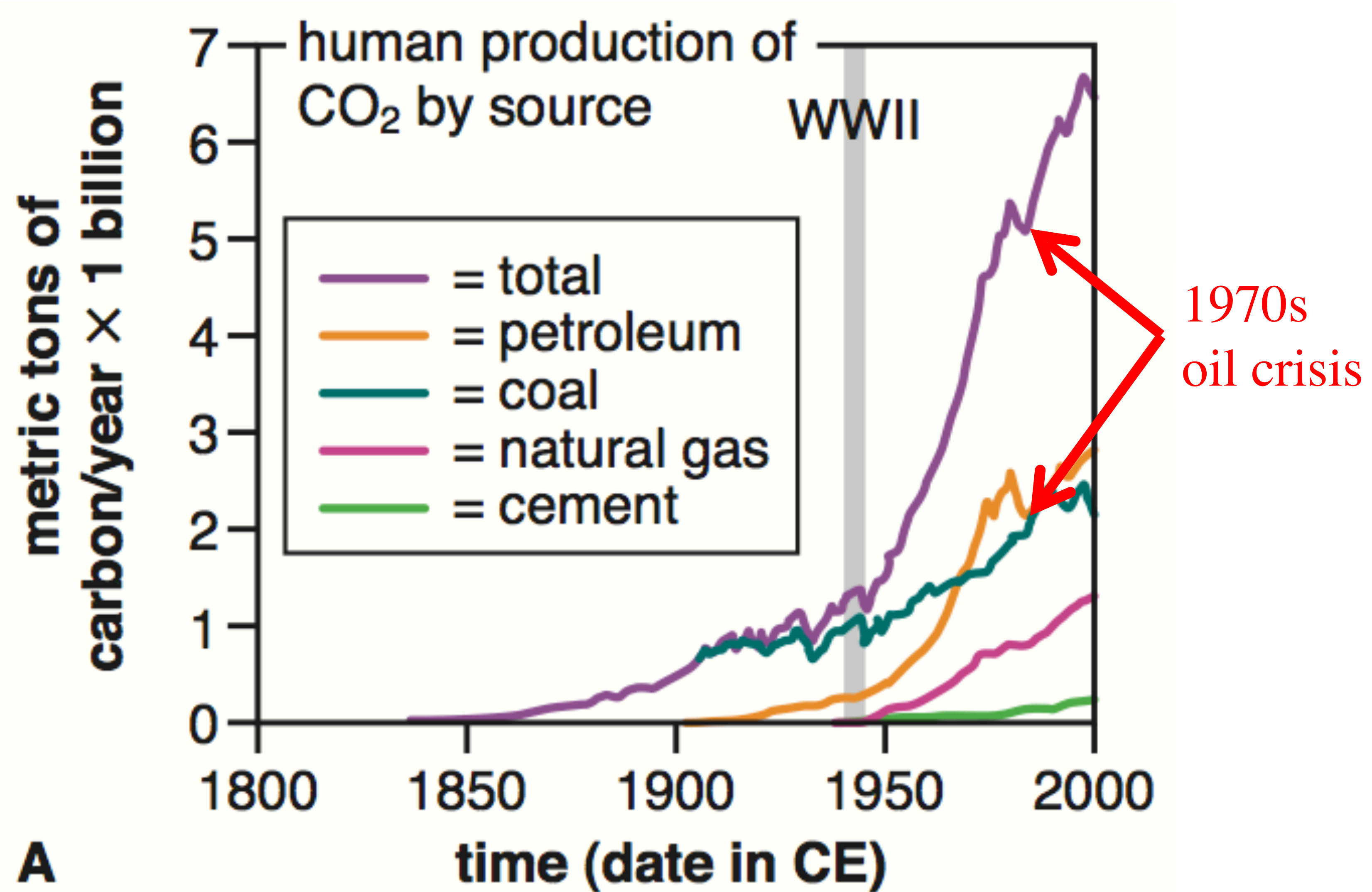


Fig. 11.11

Trifecta

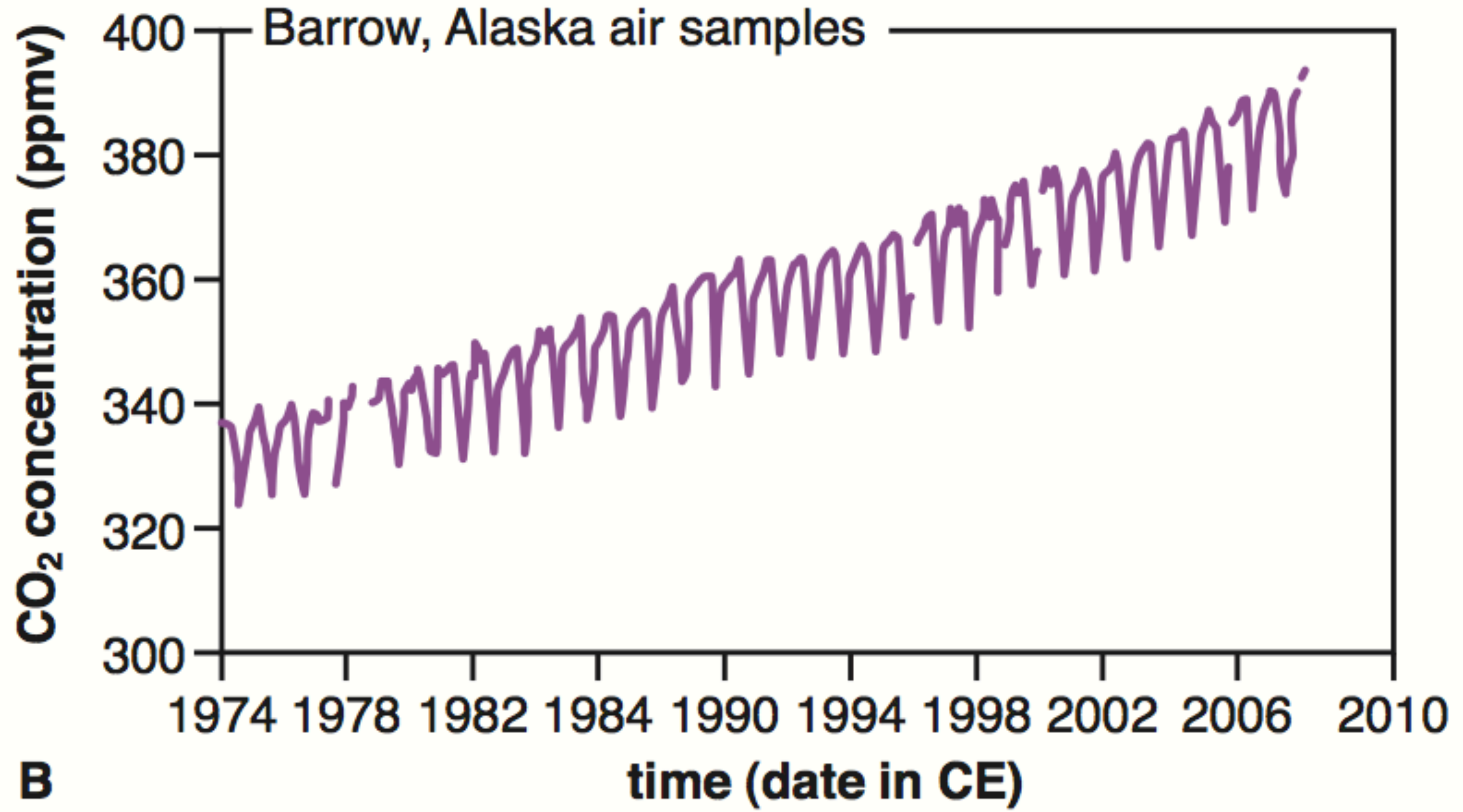


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Historic Atmospheric CO₂ Levels

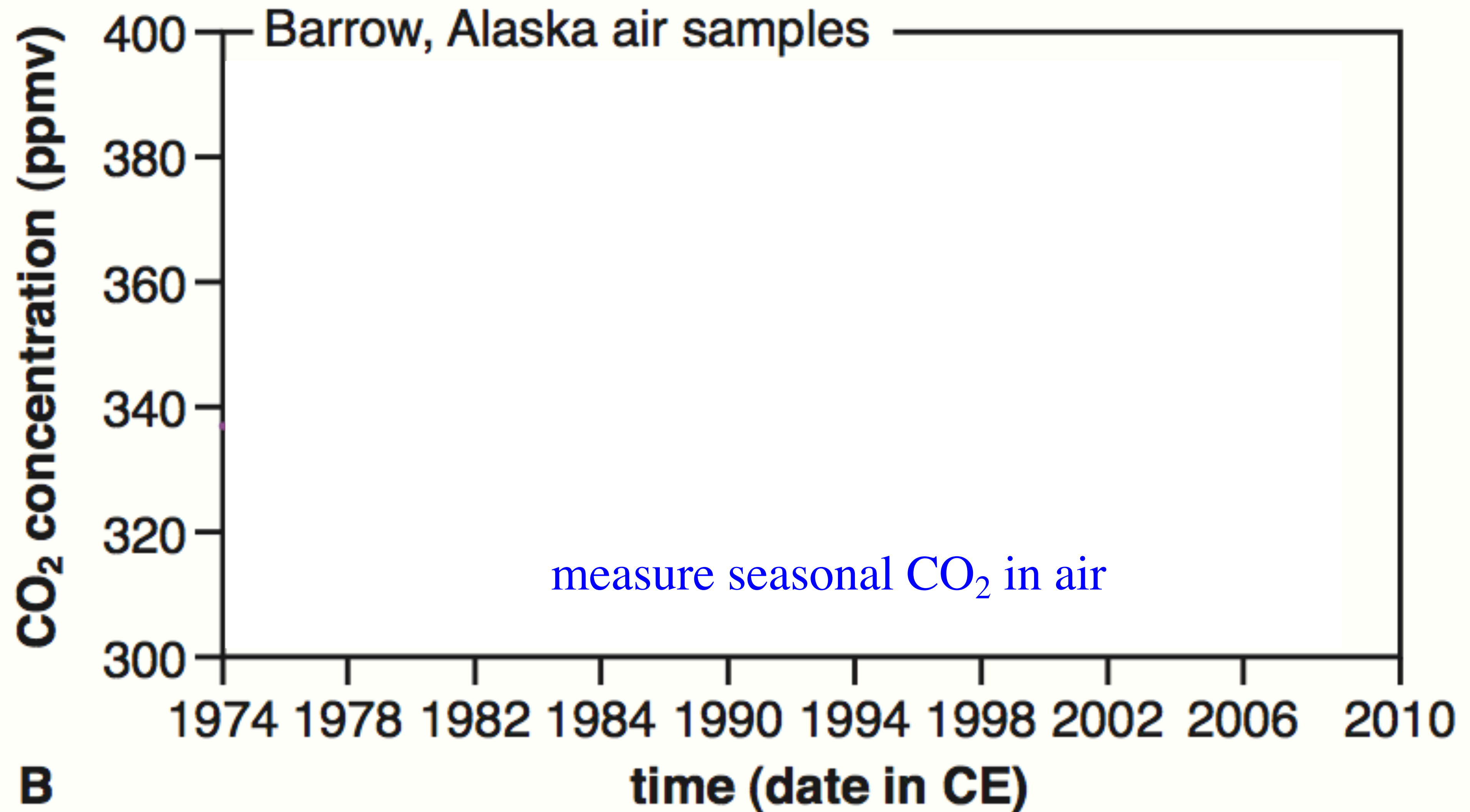


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Historic Atmospheric CO₂ Levels

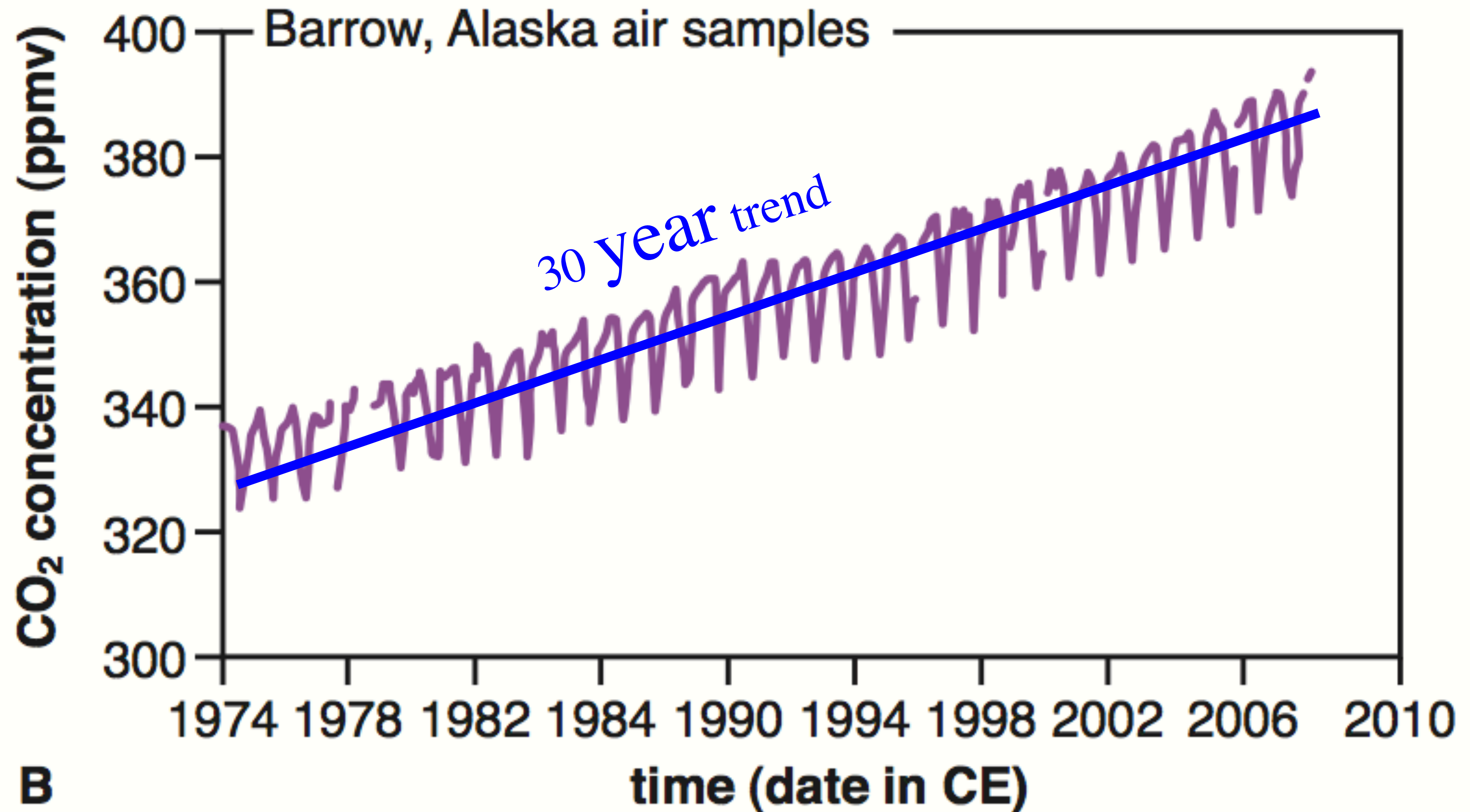


Fig. 11.11

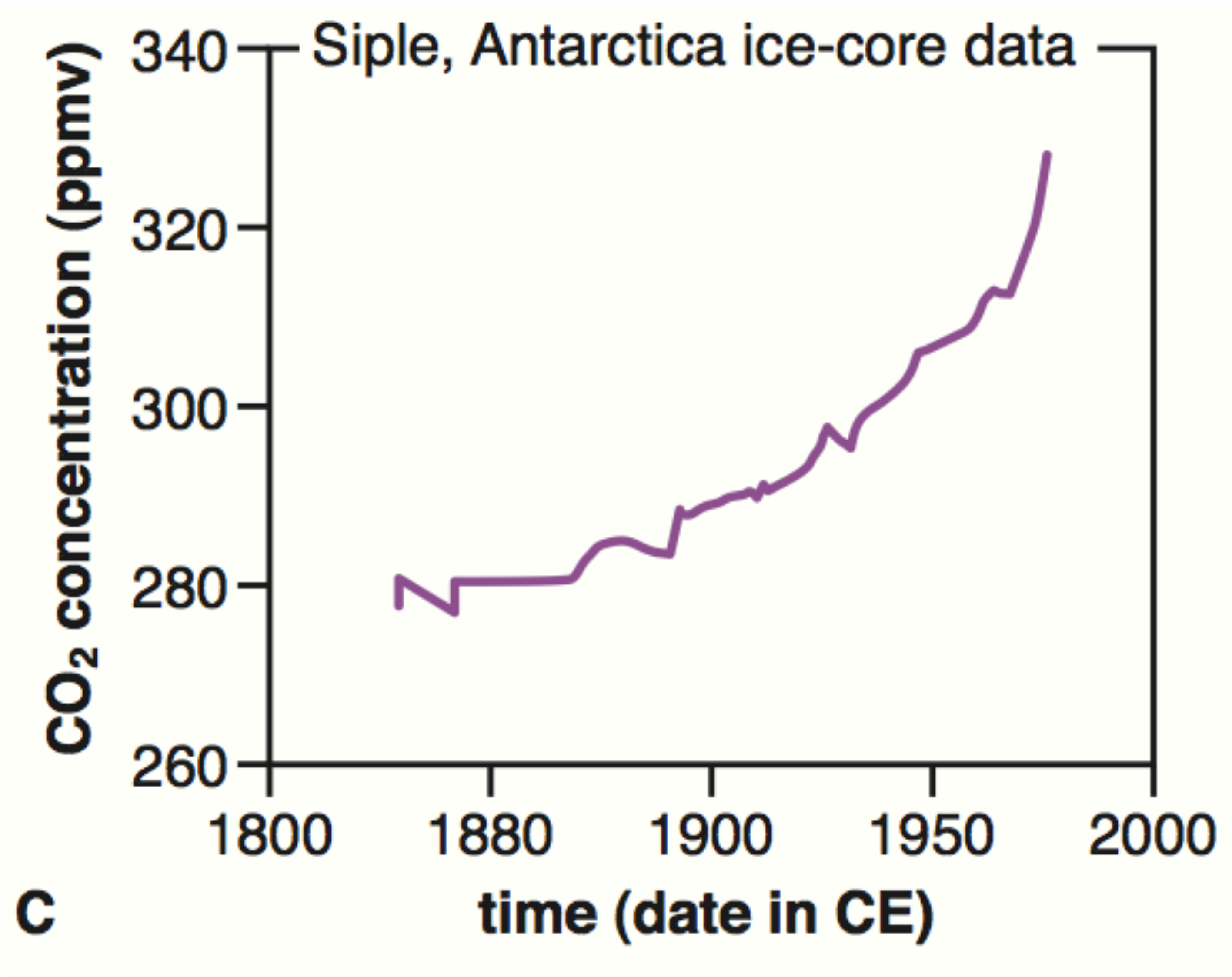


Fig. 11.11

Historic Atmospheric CO₂ Levels

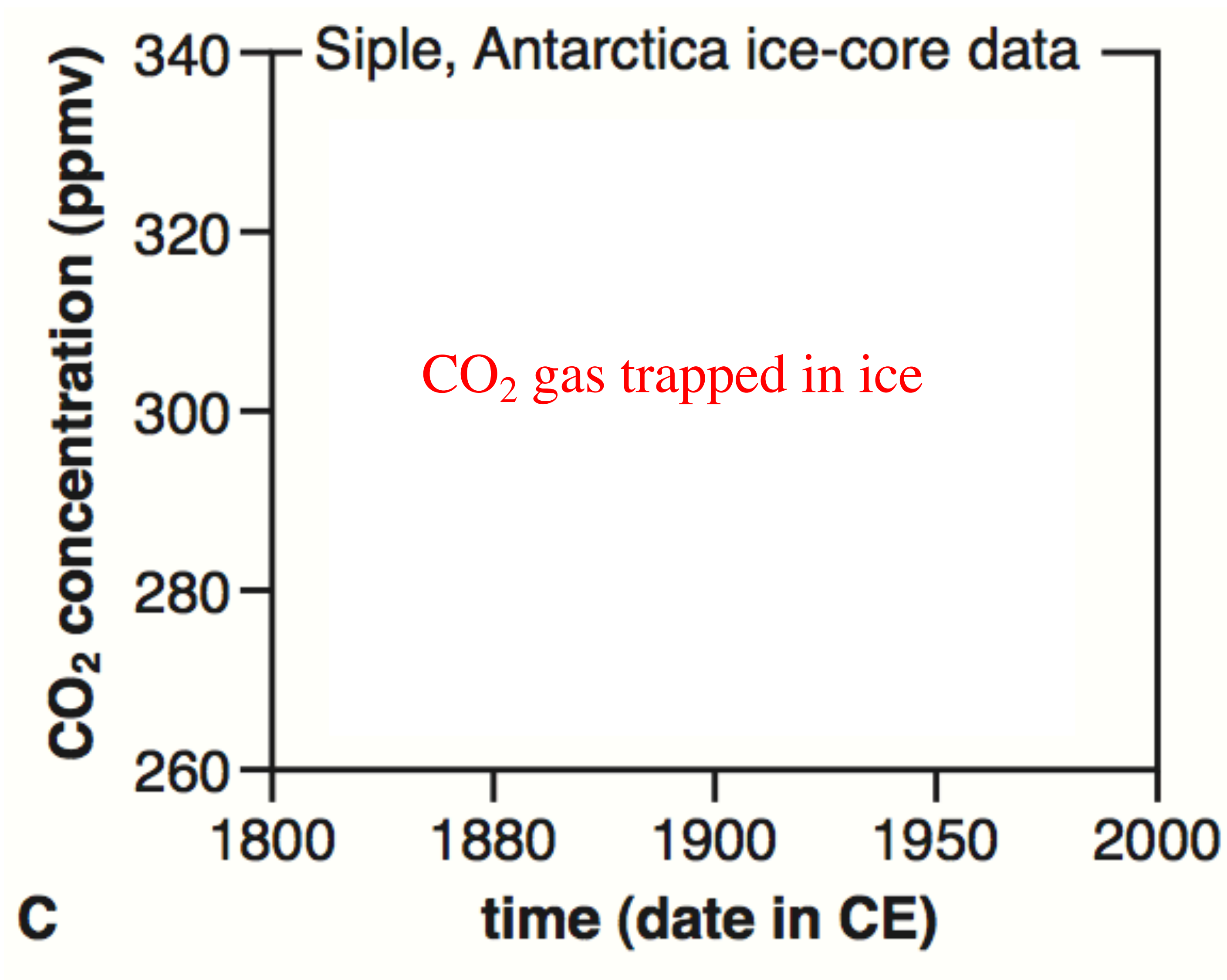


Fig. 11.11

Historic Atmospheric CO₂ Levels

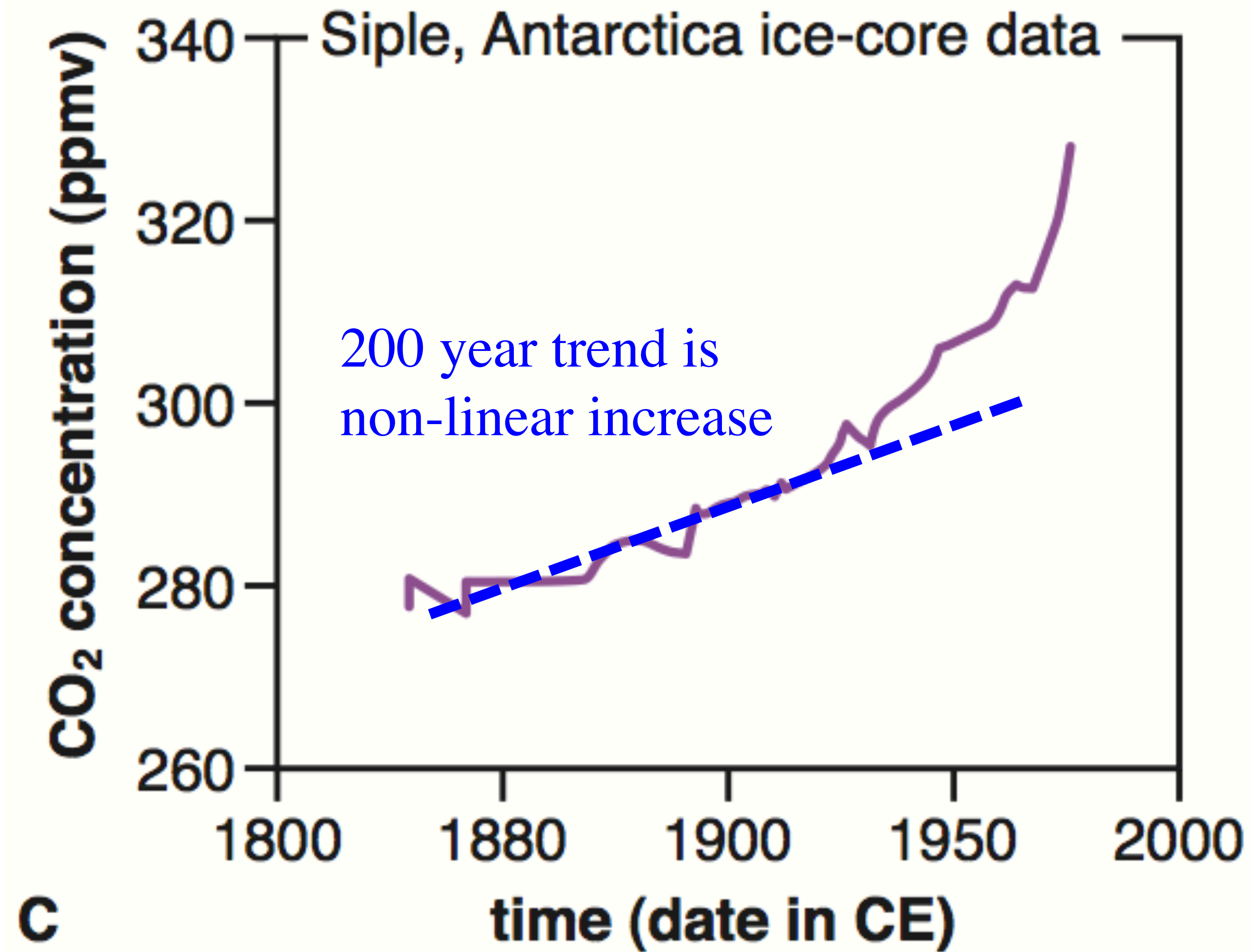


Fig. 11.11

Historic Atmospheric CO₂ Levels

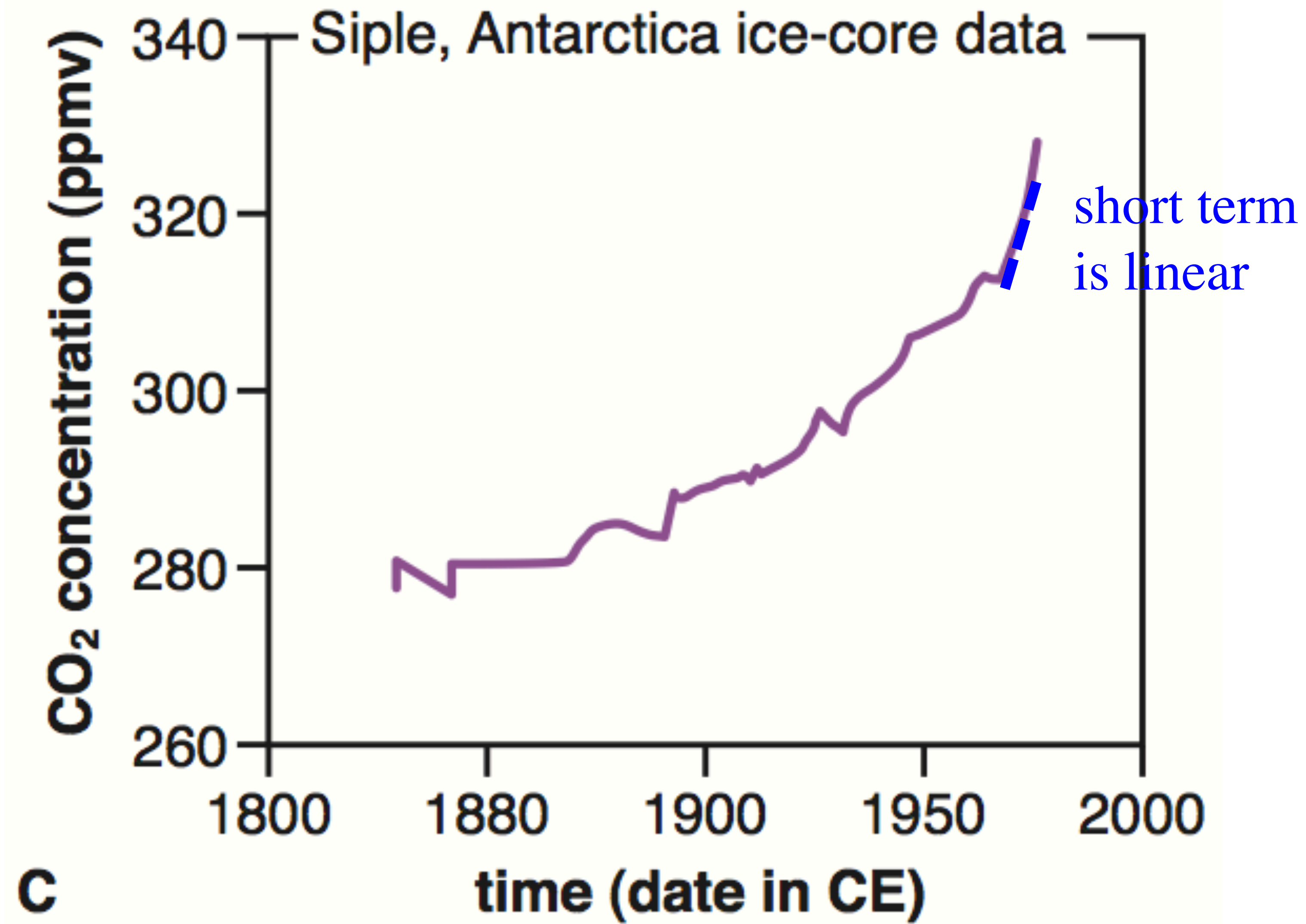


Fig. 11.11

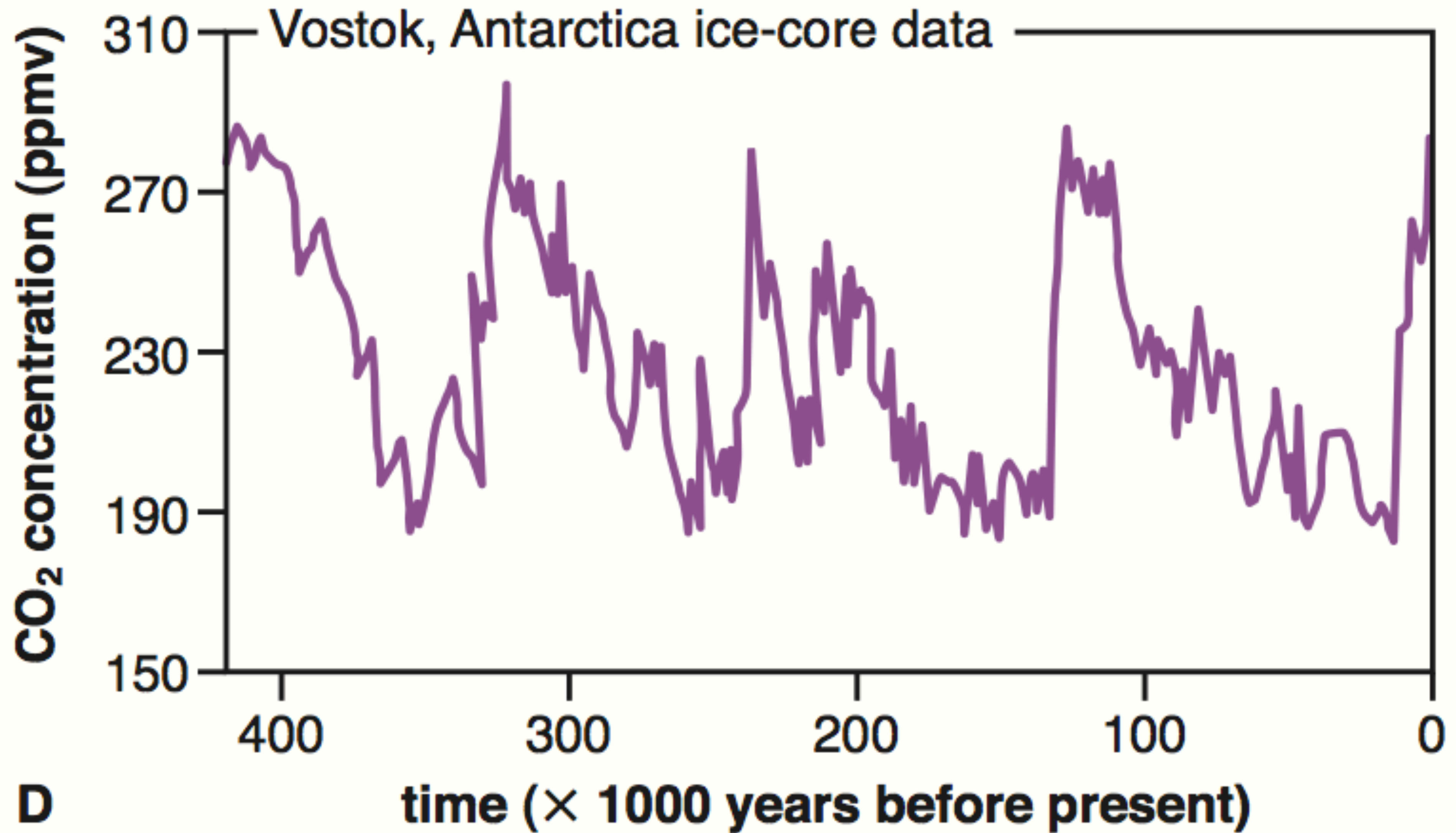


Fig. 11.11

Historic Atmospheric CO₂ Levels

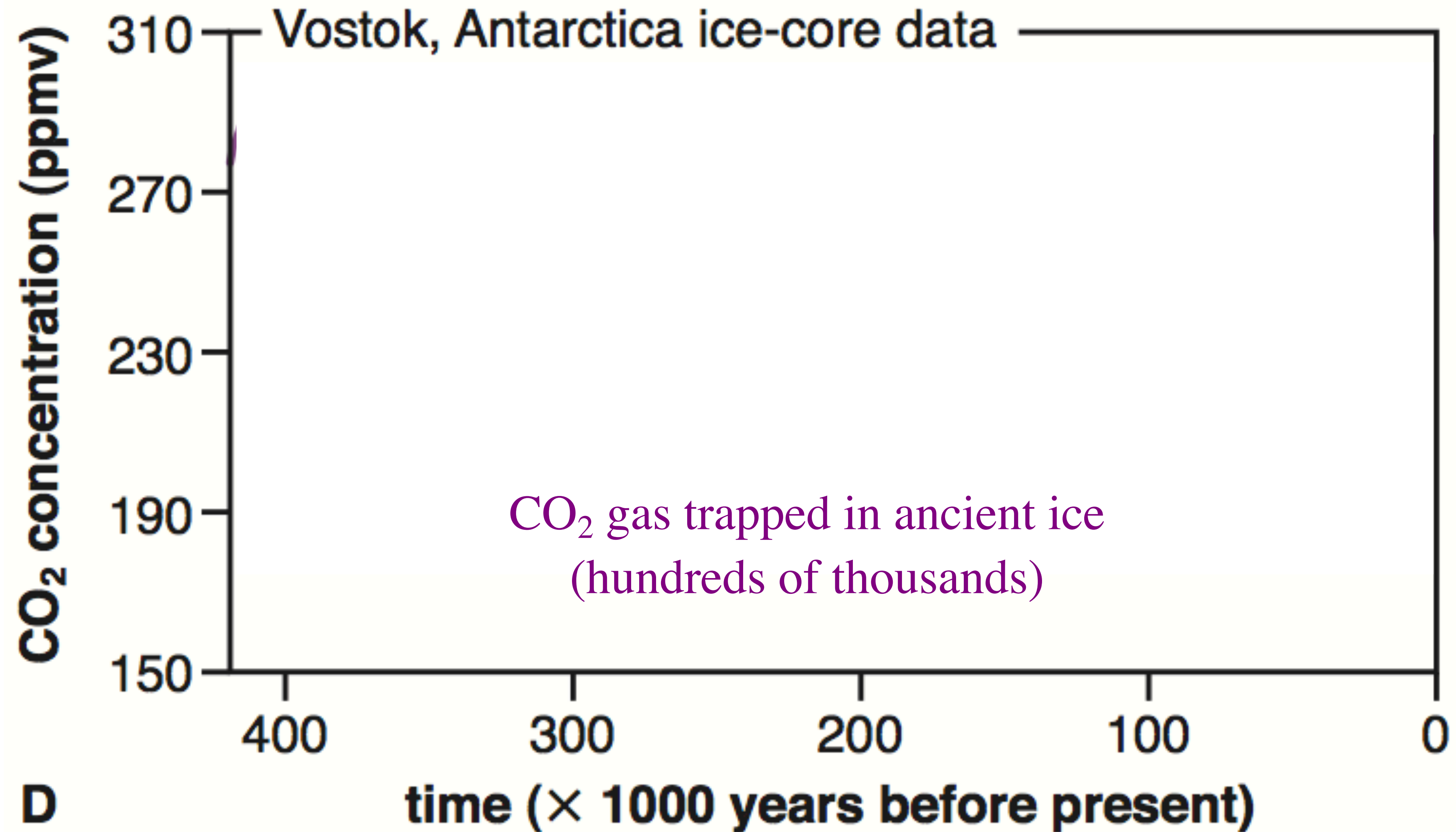


Fig. 11.11

Historic Atmospheric CO₂ Levels

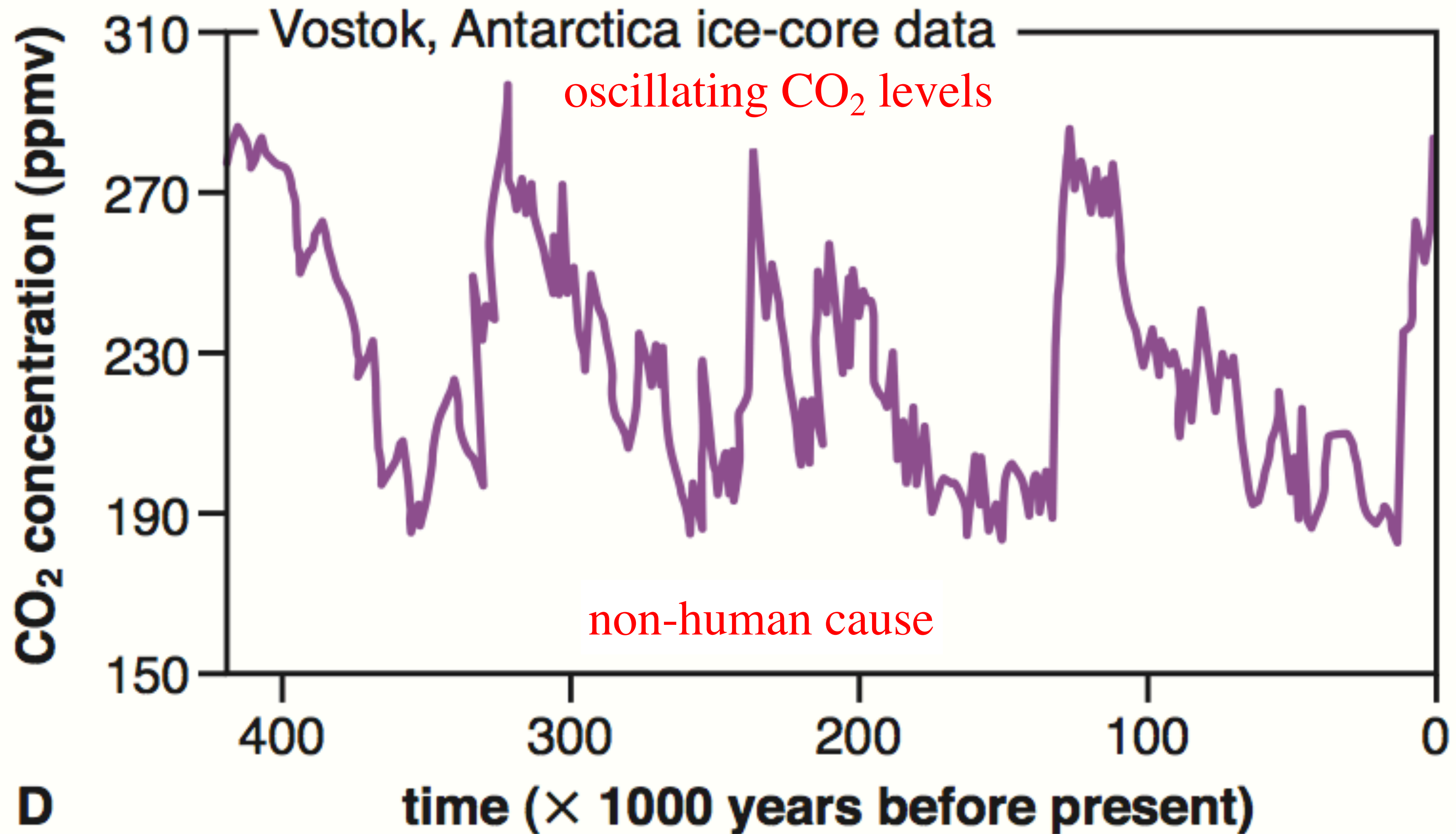


Fig. 11.11

Historic Atmospheric CO₂ Levels

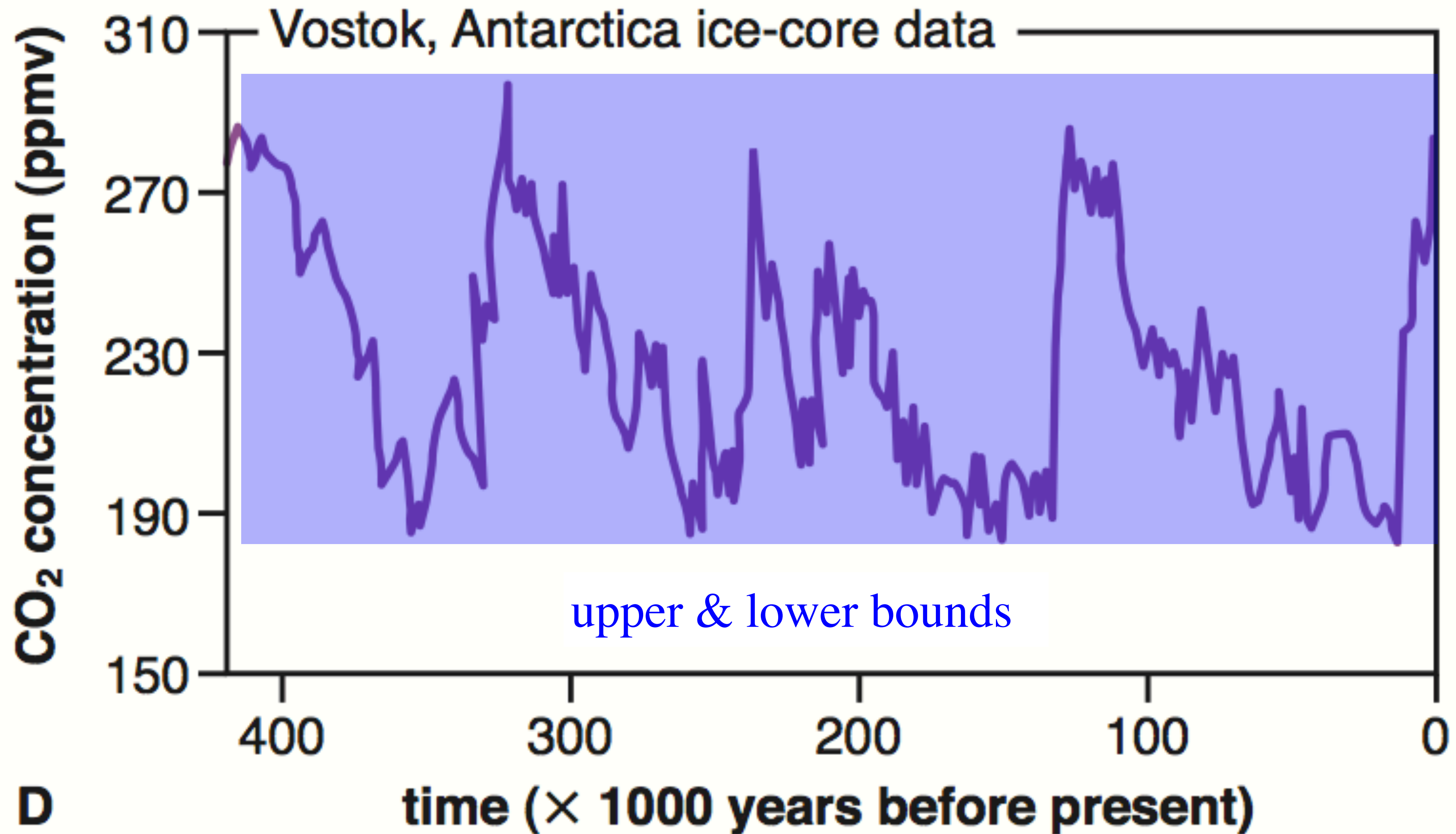


Fig. 11.11

Historic Atmospheric CO₂ Levels

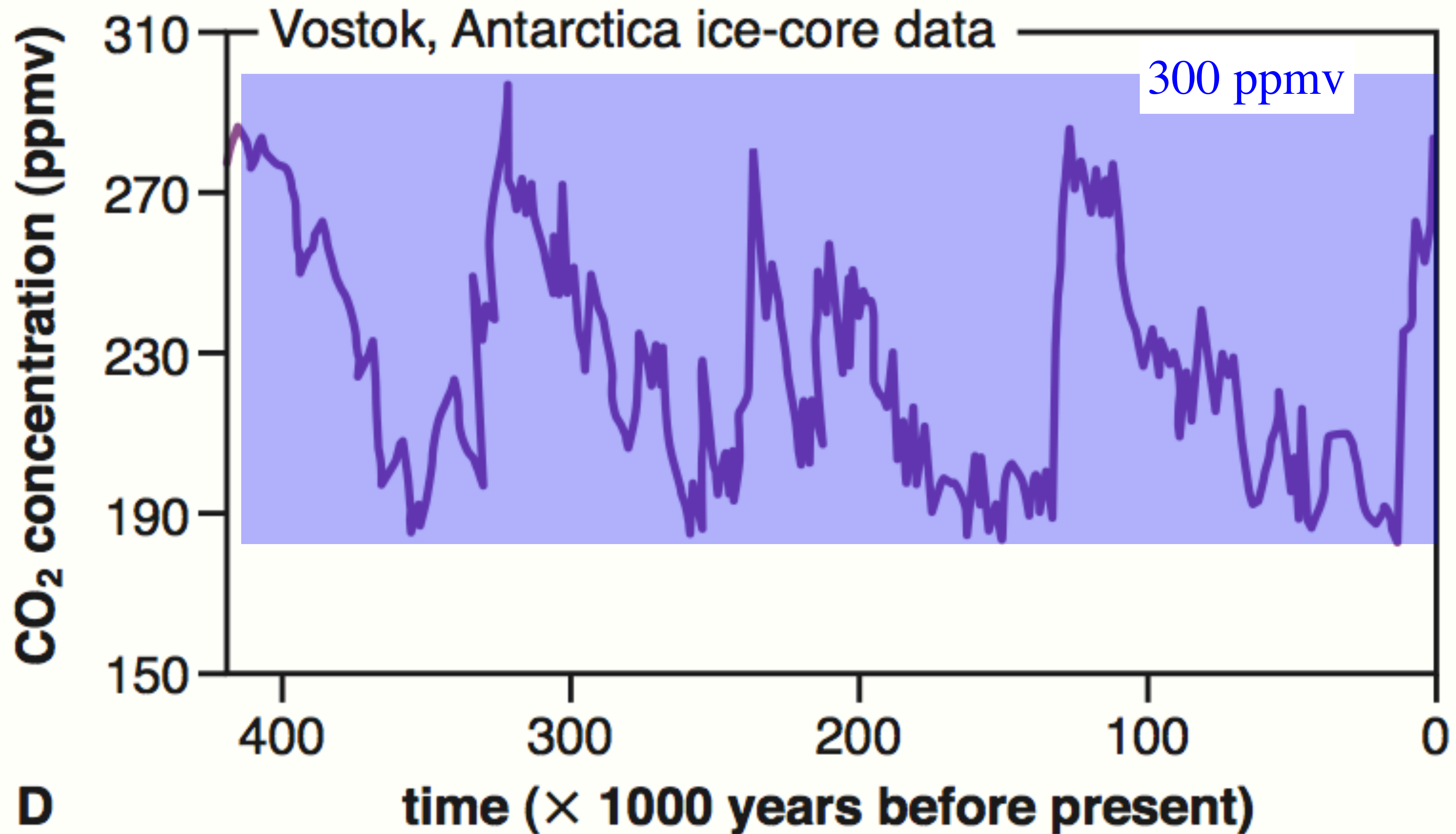


Fig. 11.11

Current Levels Highest in 400K Years

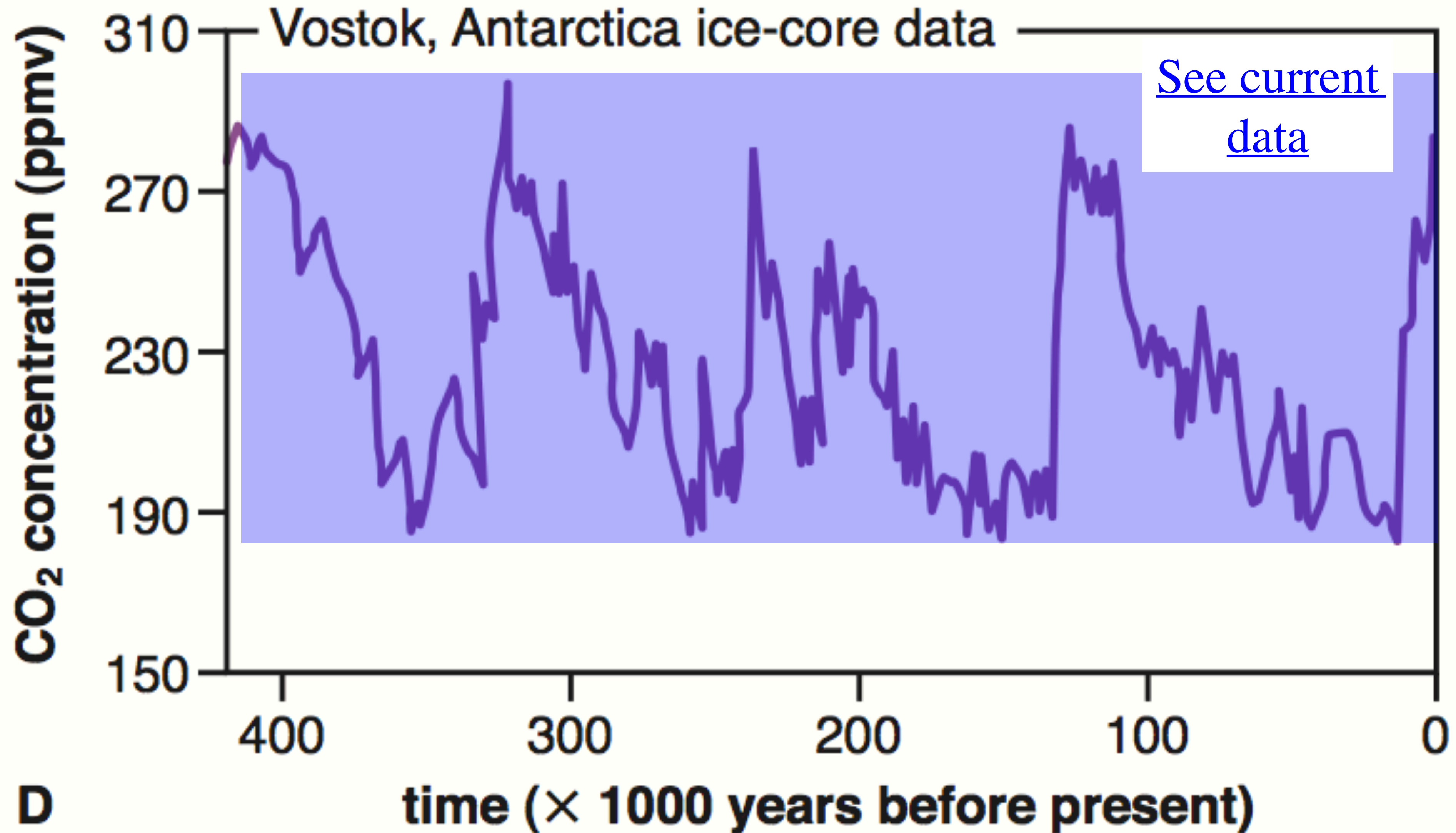


Fig. 11.11

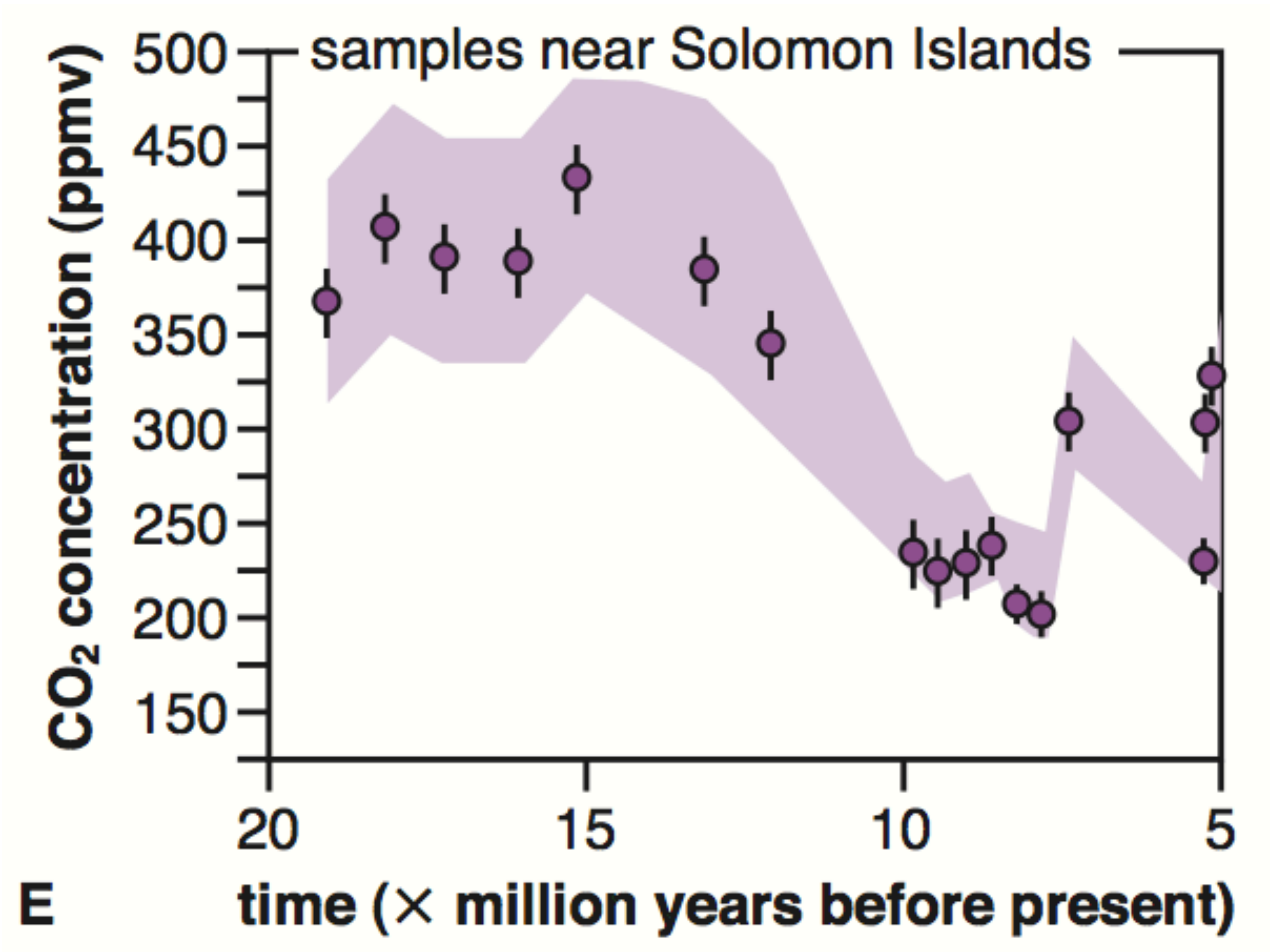


Fig. 11.11

Historic Atmospheric CO₂ Levels

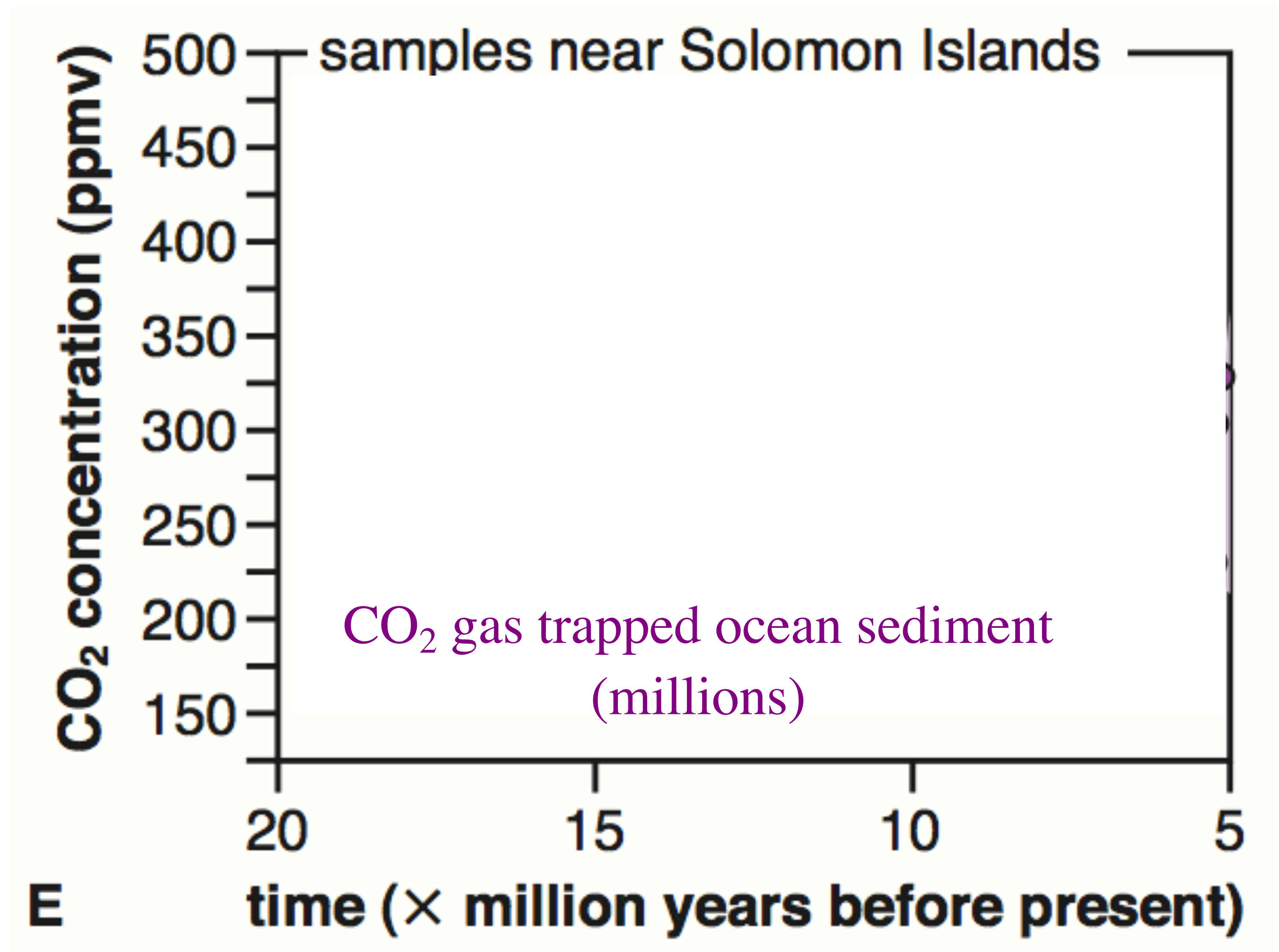


Fig. 11.11

Historic Atmospheric CO₂ Levels

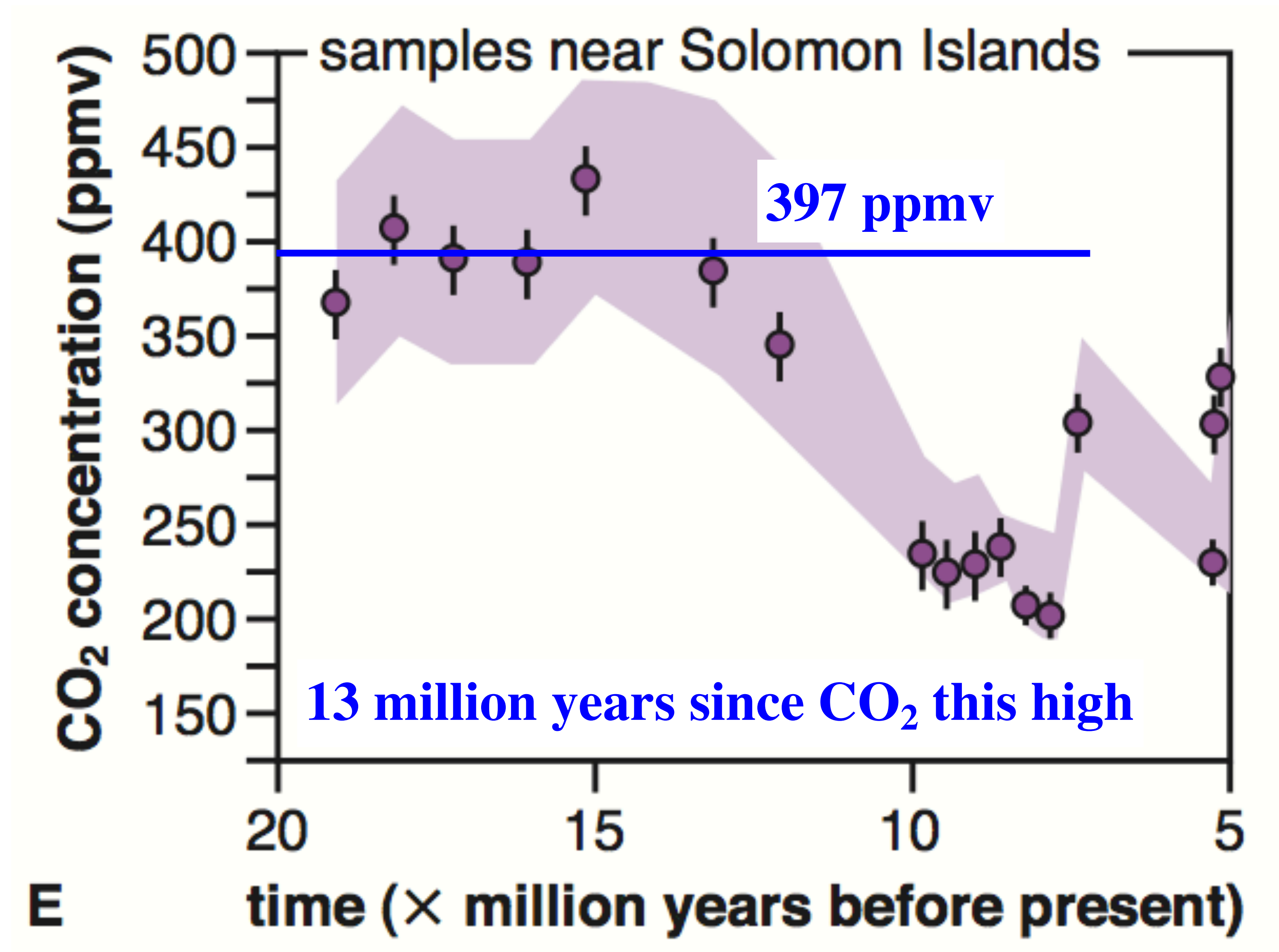
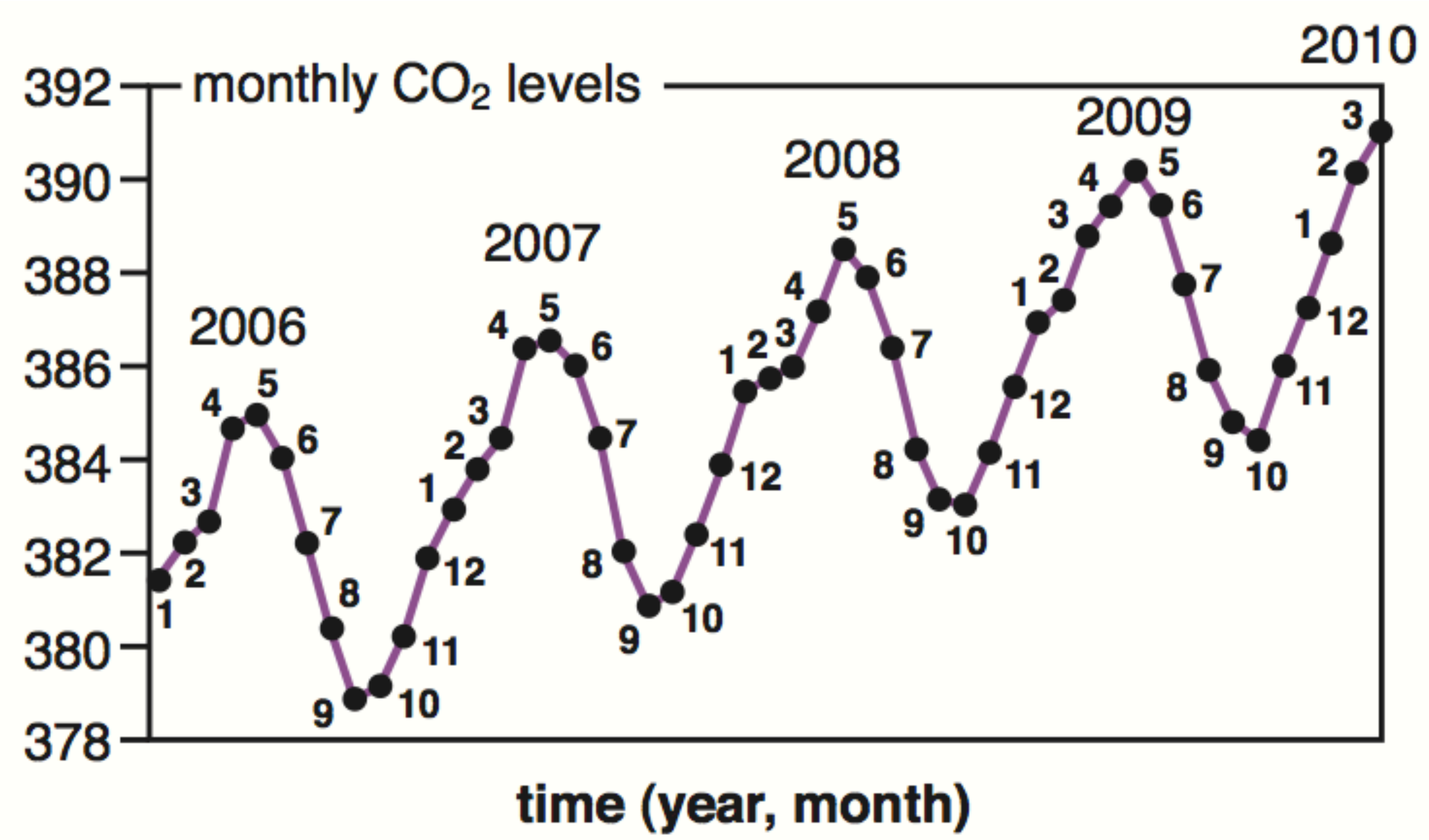


Fig. 11.11



F

Fig. 11.11

Historic Atmospheric CO₂ Levels

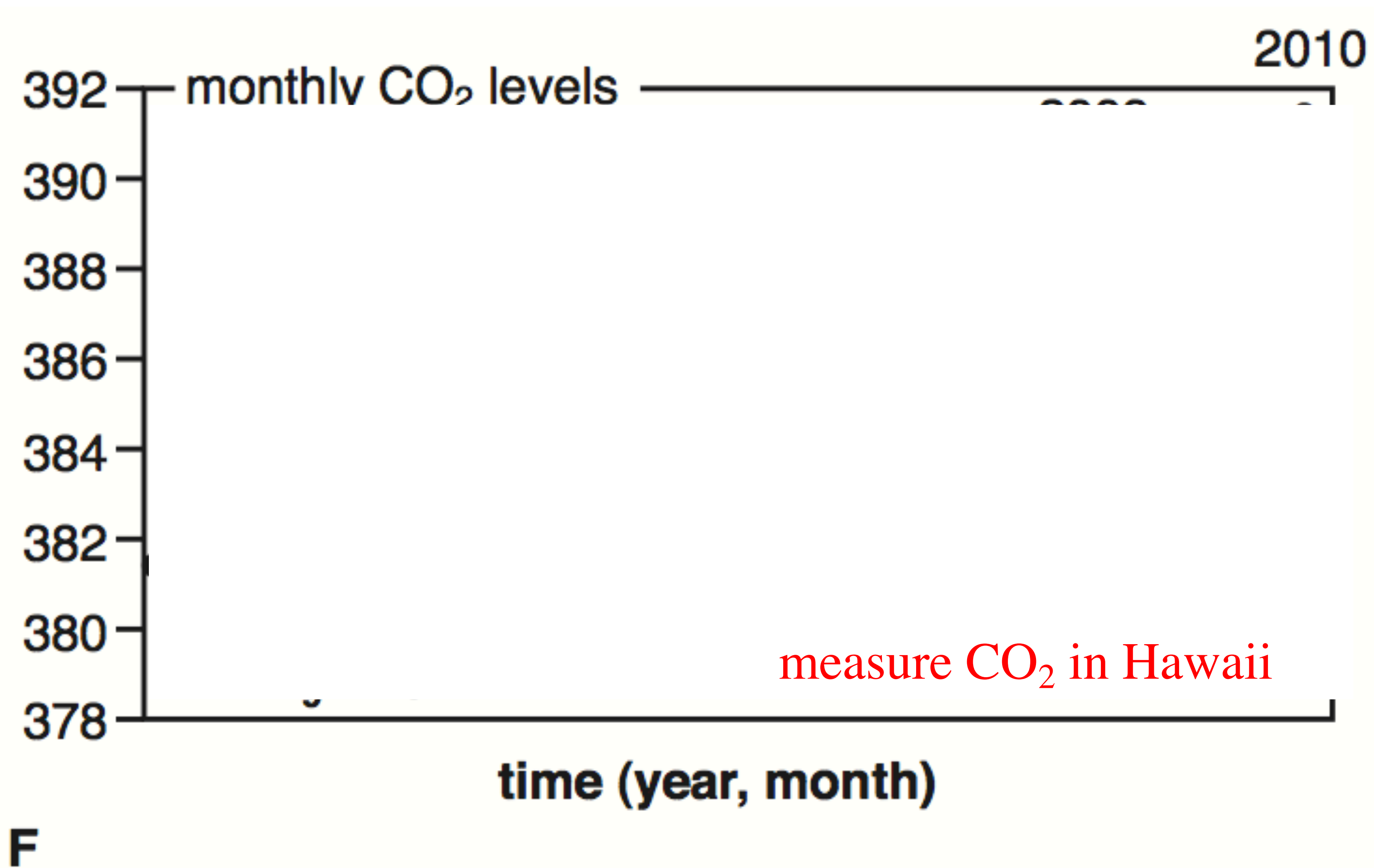
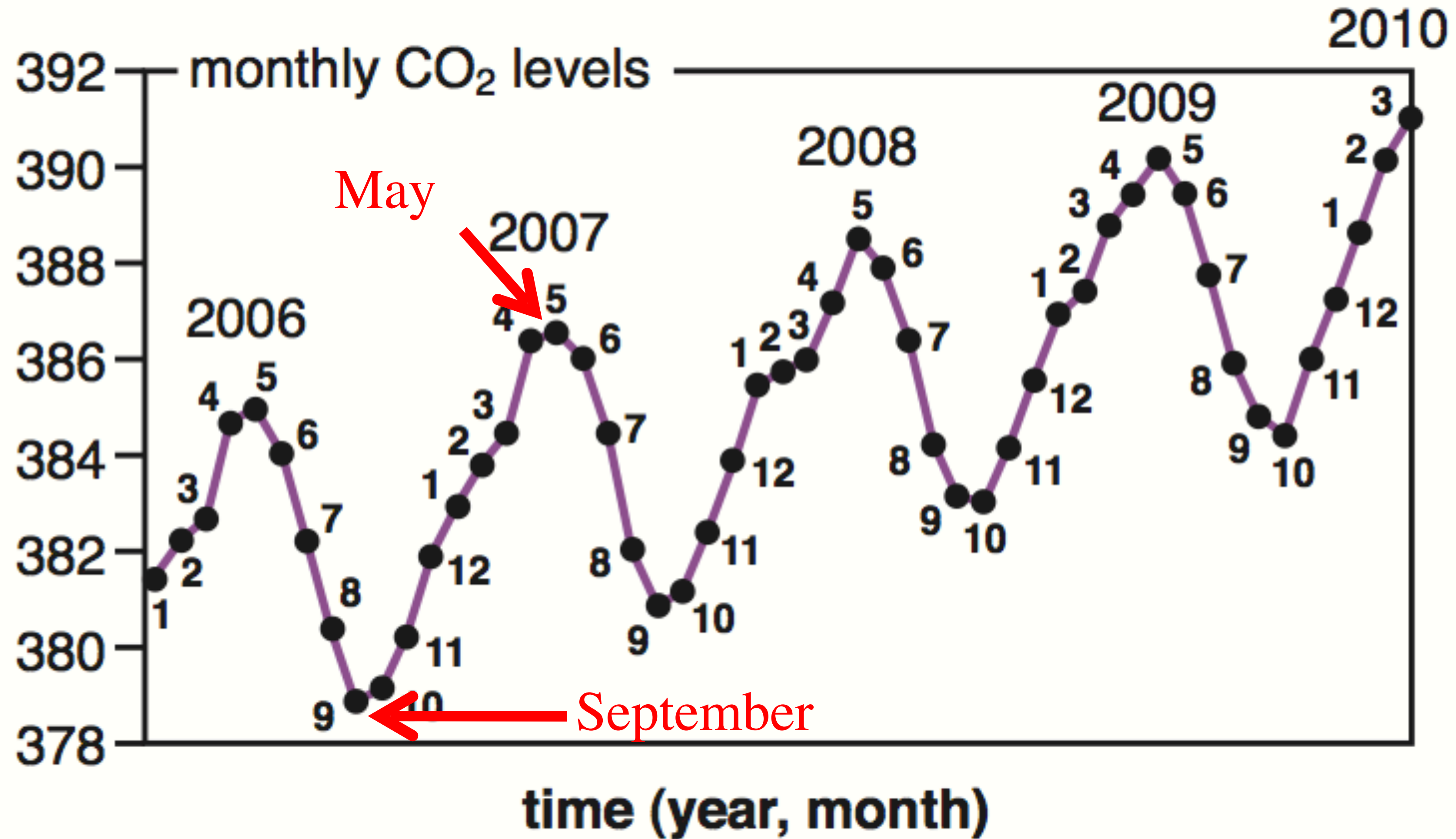


Fig. 11.11

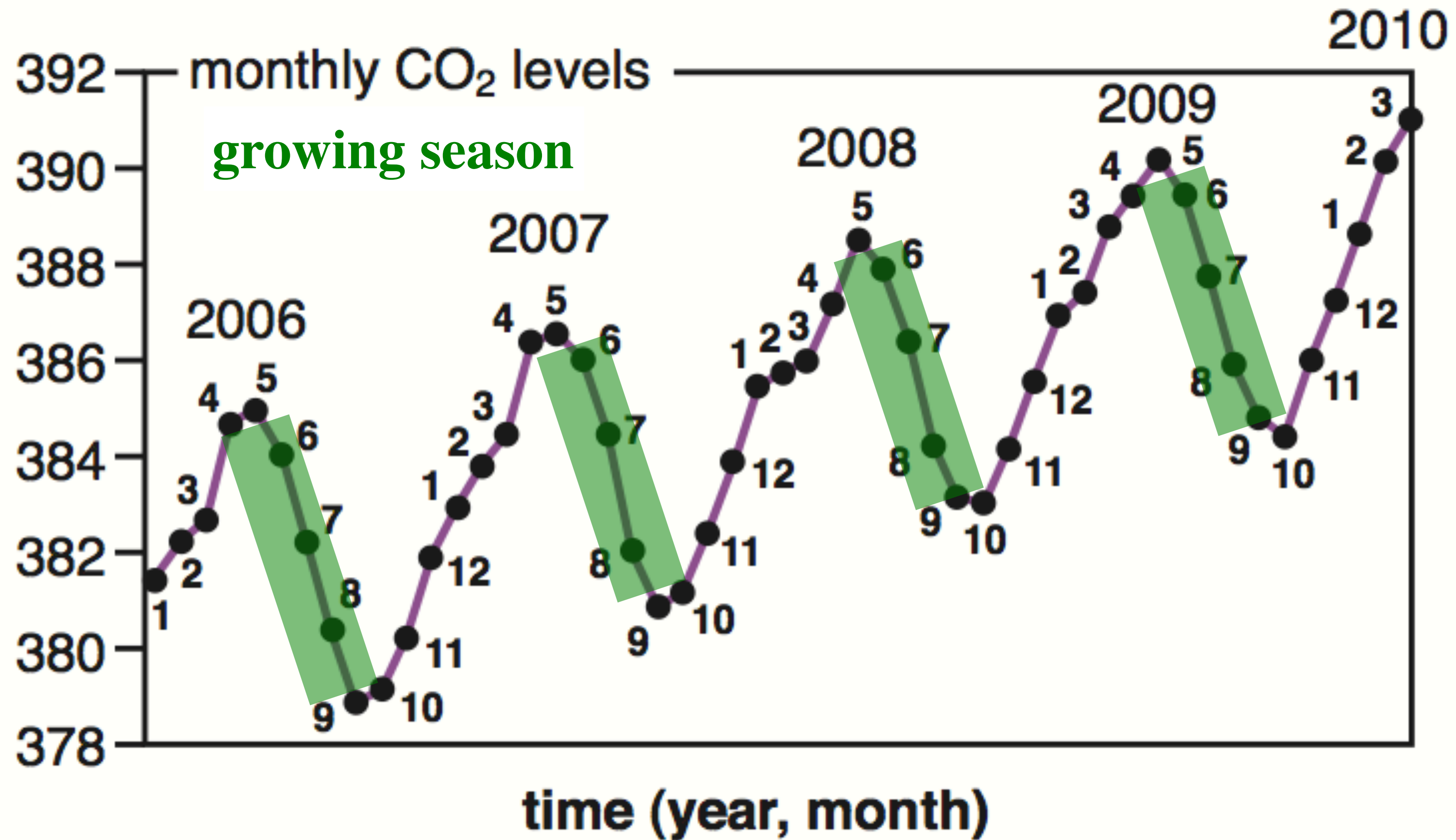
Historic Atmospheric CO₂ Levels



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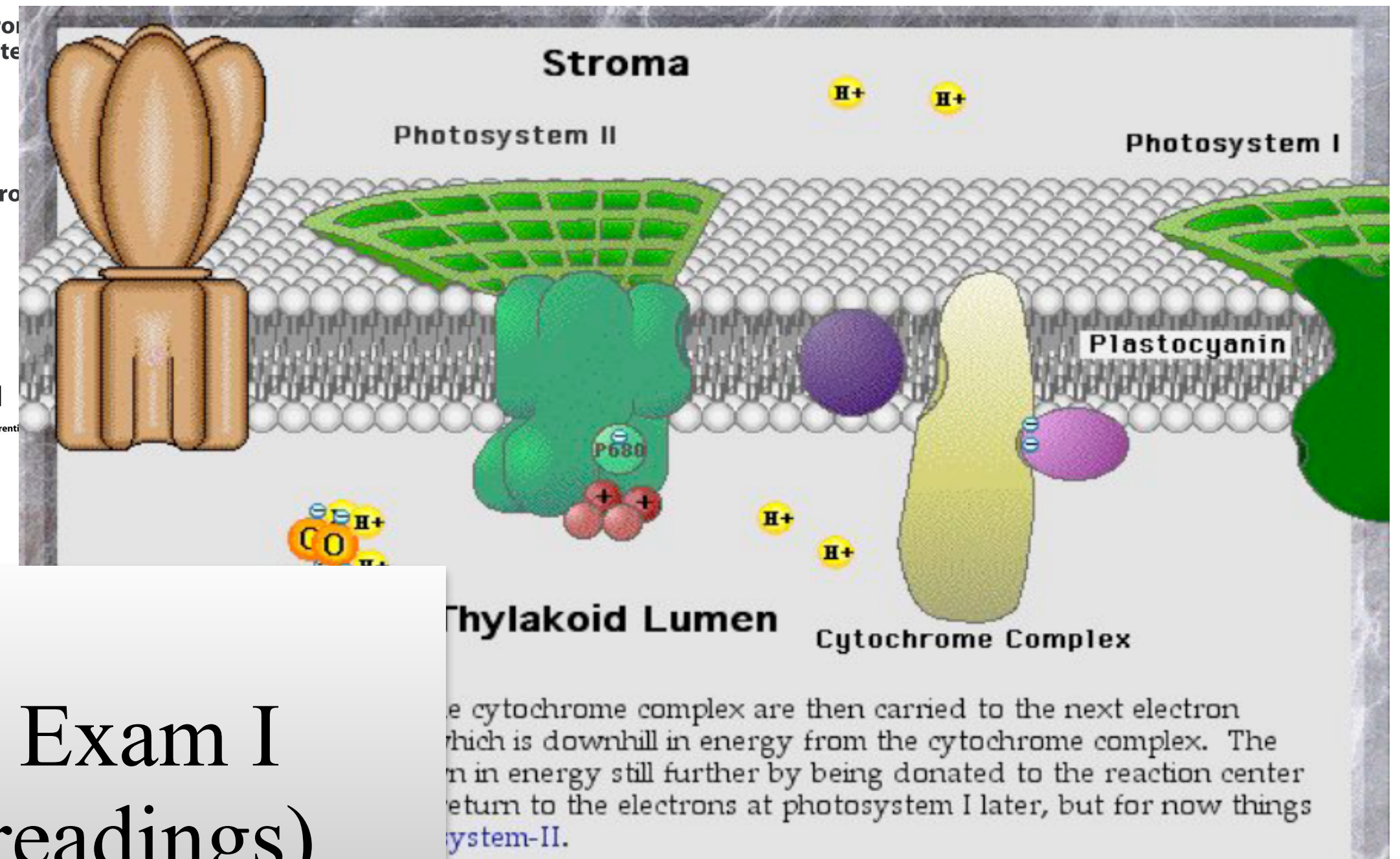
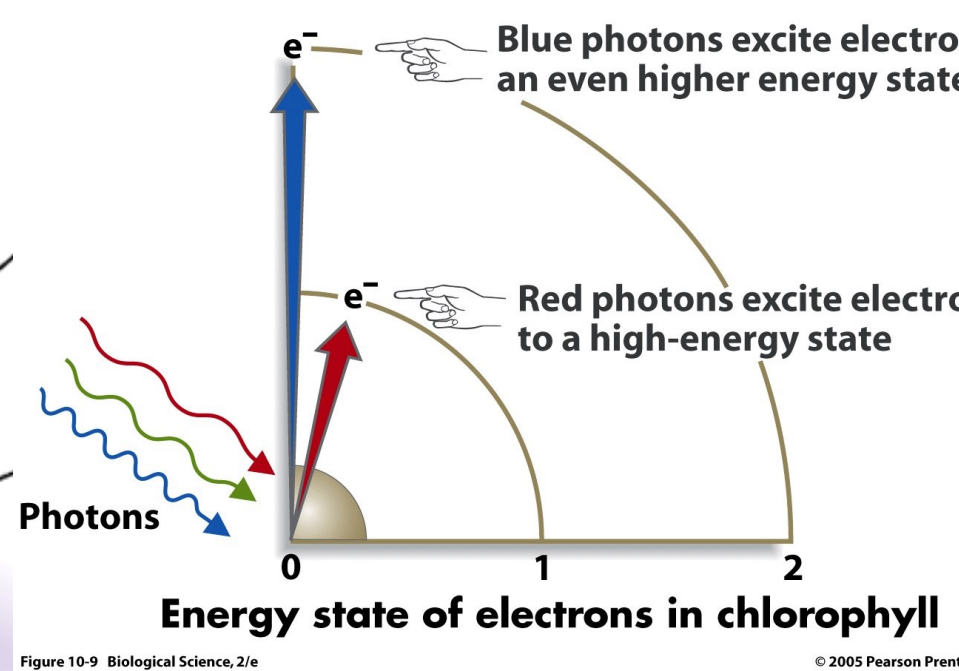
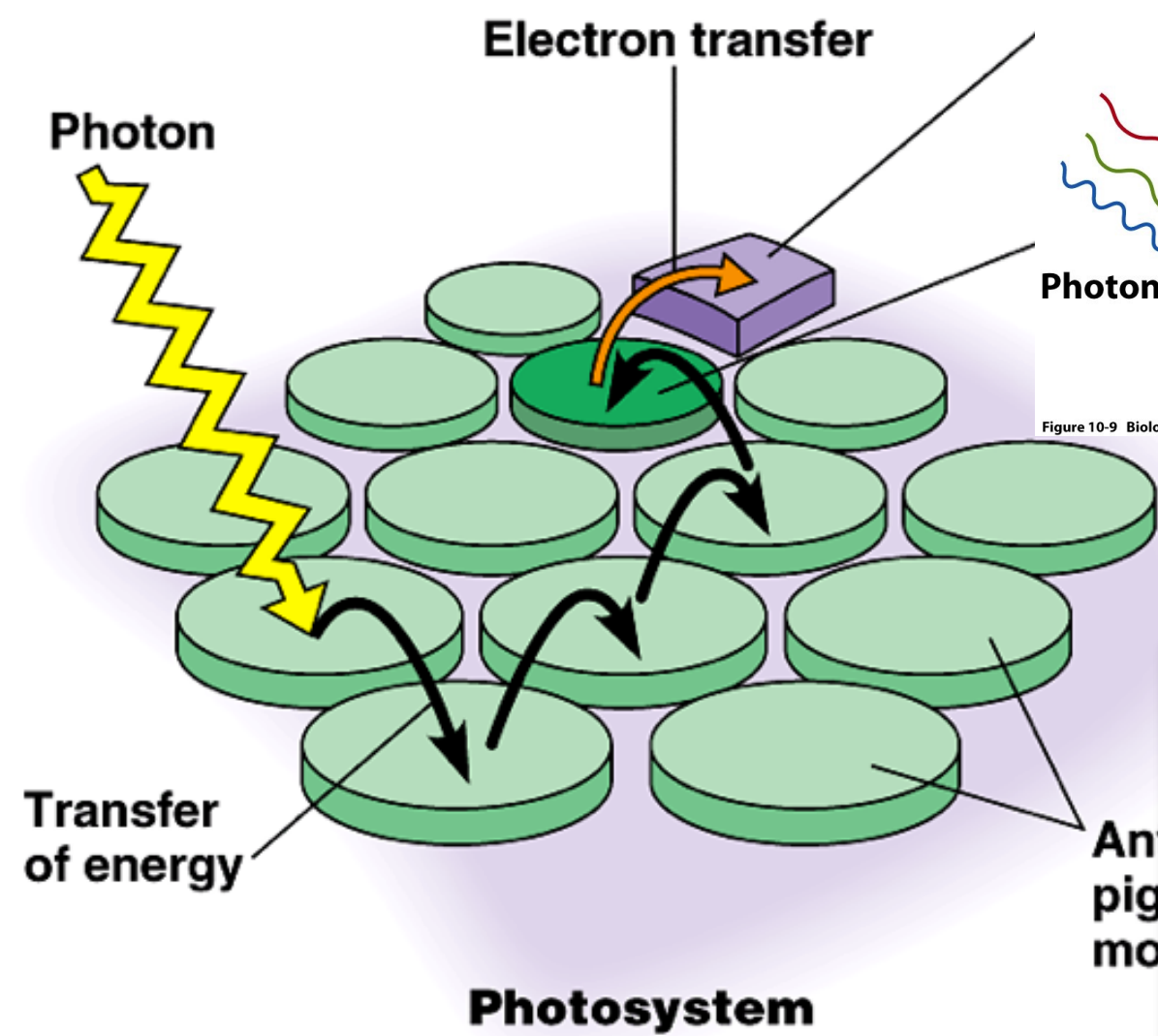
Fig. 11.11

Historic Atmospheric CO₂ Levels



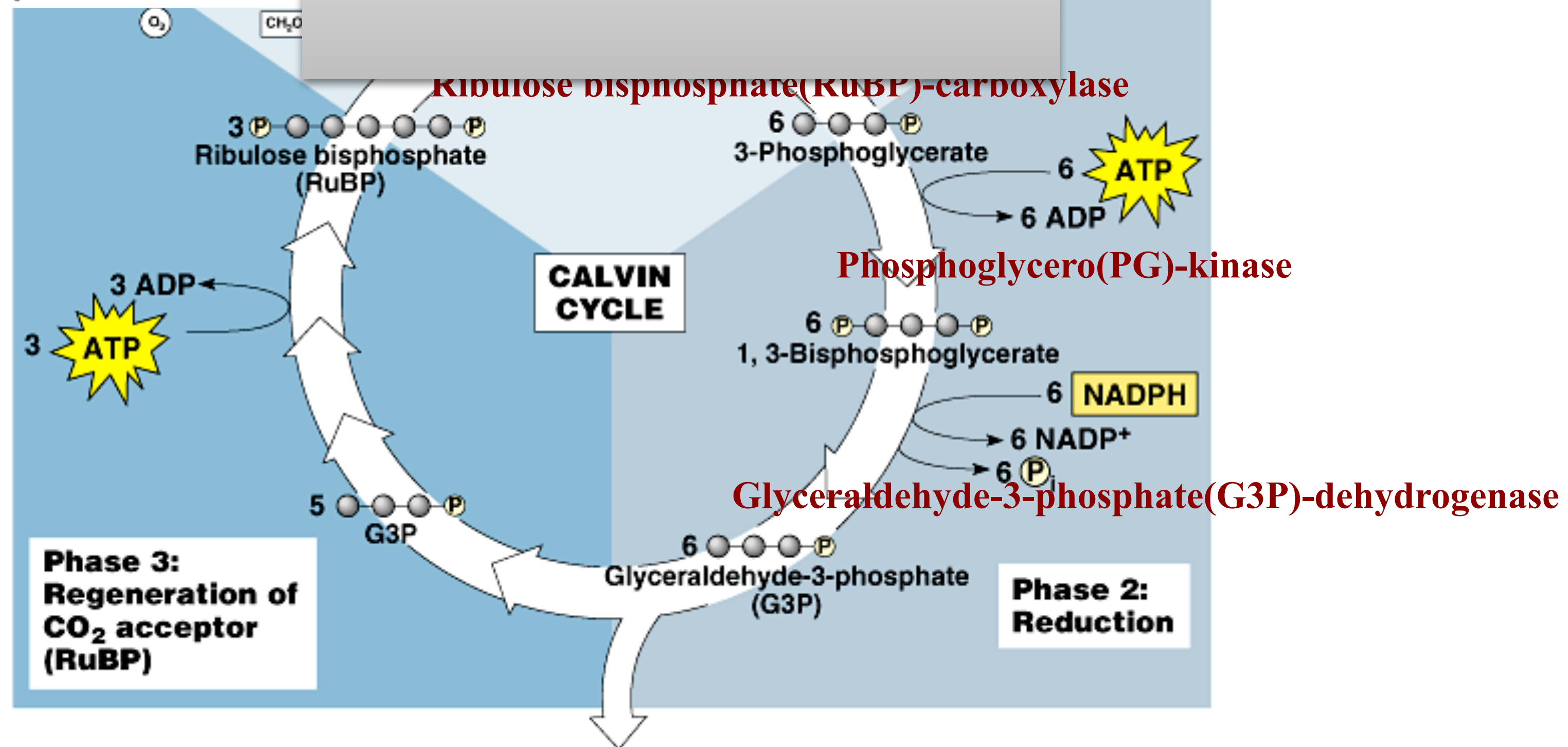
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Fig. 11.11



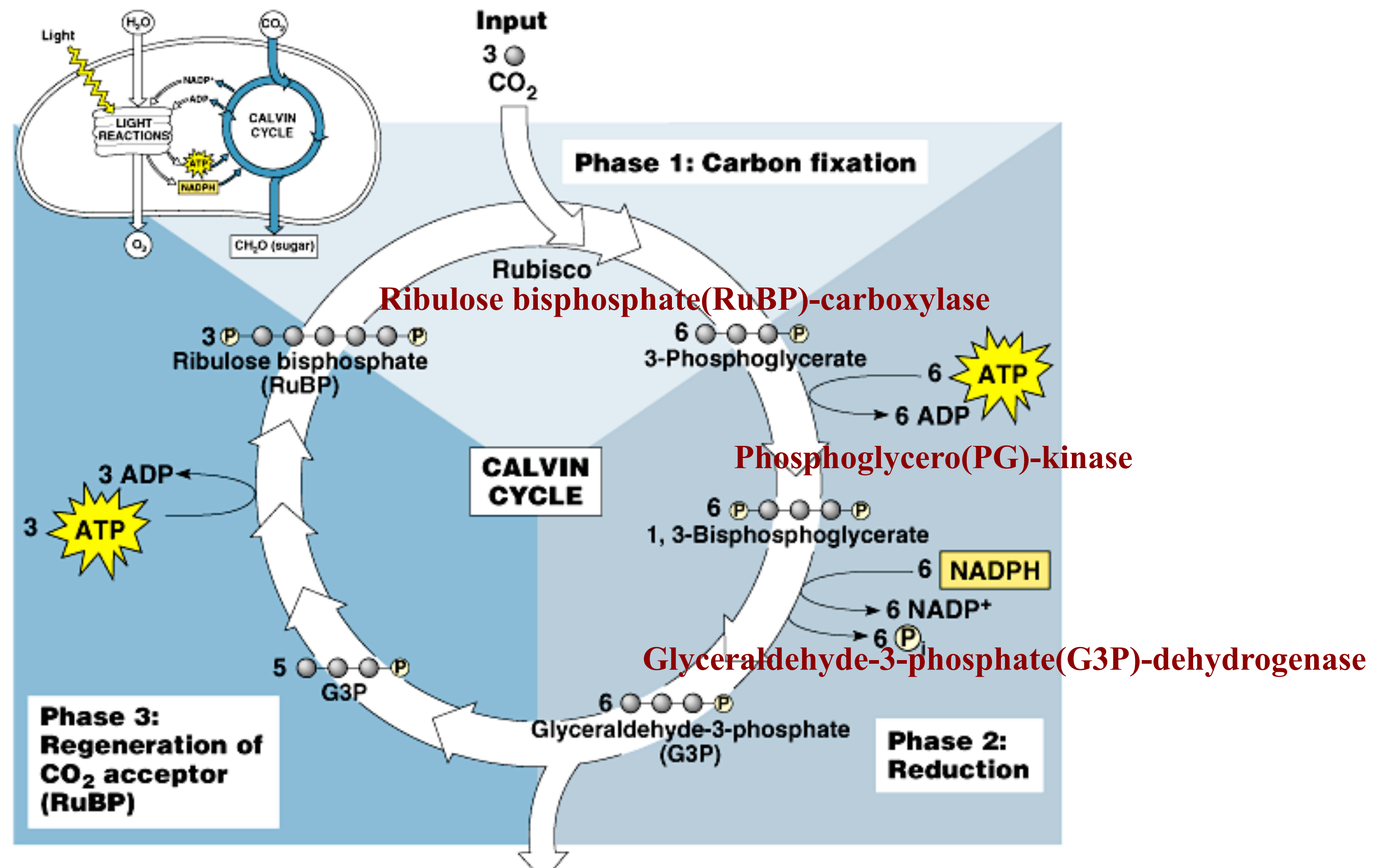
So, about Exam I
(the OSB readings)

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Learning Questions for the day (focus)

- **How does Calvin Cycle** work?
 - What are the reactants?
 - When is energy involved?
 - What are the stages called, what happens?



So, about Exam I (the ICB readings)

Reading 1: Ch1-ICB 1.2
Dr. Fred Griffith
Dr. Oswald Avery
Figure 1.4 Avery
Table 1.1 Avery

Reading 2: Ch.4-ICB 4.1 Charles Darwin
Figure 4.1 Cartoon acorns
ELSI Figure 4.1 Darwin monkey

Reading 3: Ch.4-ICB: 4.2
Dr. Stanley Miller
Figure 4.5 Miller experiment
Figure 4.6 NASA experiment with meteors
Figure 4.8 ribozyme experiment (big gel)

Reading 4: Ch.4-ICB: 4.3(1st half), 4.4
Figure 4.11 Microspheres and clay vesicle formation
Figure 4.12 Microscopy of spontaneous vesicles with cargo (Green & red-stained).
Figure 4.13 vesicle growth and reproduction
Figure 4.17 Vesicle pH after adding micelles

Reading 5: Margulis endosymbiosis

Reading 8: Ch.11-ICB: 11.1
Joseph Priestley (Figure 11.2A sprig of mint)
Theodor Wilhelm Engelmann (Figure 11.2B algae and Zeiss)
Robin Hill (Figure 11.2C Oxygen evolved by isolated chloroplasts)
Daniel Arnon (Figure 11.4 Photosynthesis is a summation of three parts & Figure 11.8 ATP production from light energy)
Hans Heldt (Figure 11.5 Comparison of pH in stroma and thylakoid space)

Reading 9: Ch.11-ICB: 11.2
Figure 11.11 Energy consumption and CO₂ levels.
M.B. Allen (Figure 11.12 Carbon fixation capacity)
Melvin Calvin and Andrew Benson (Figure 11.13 Incorporation of radioactive carbon into organic molecules)
Figure 11.15 Physiological regulation of rubisco

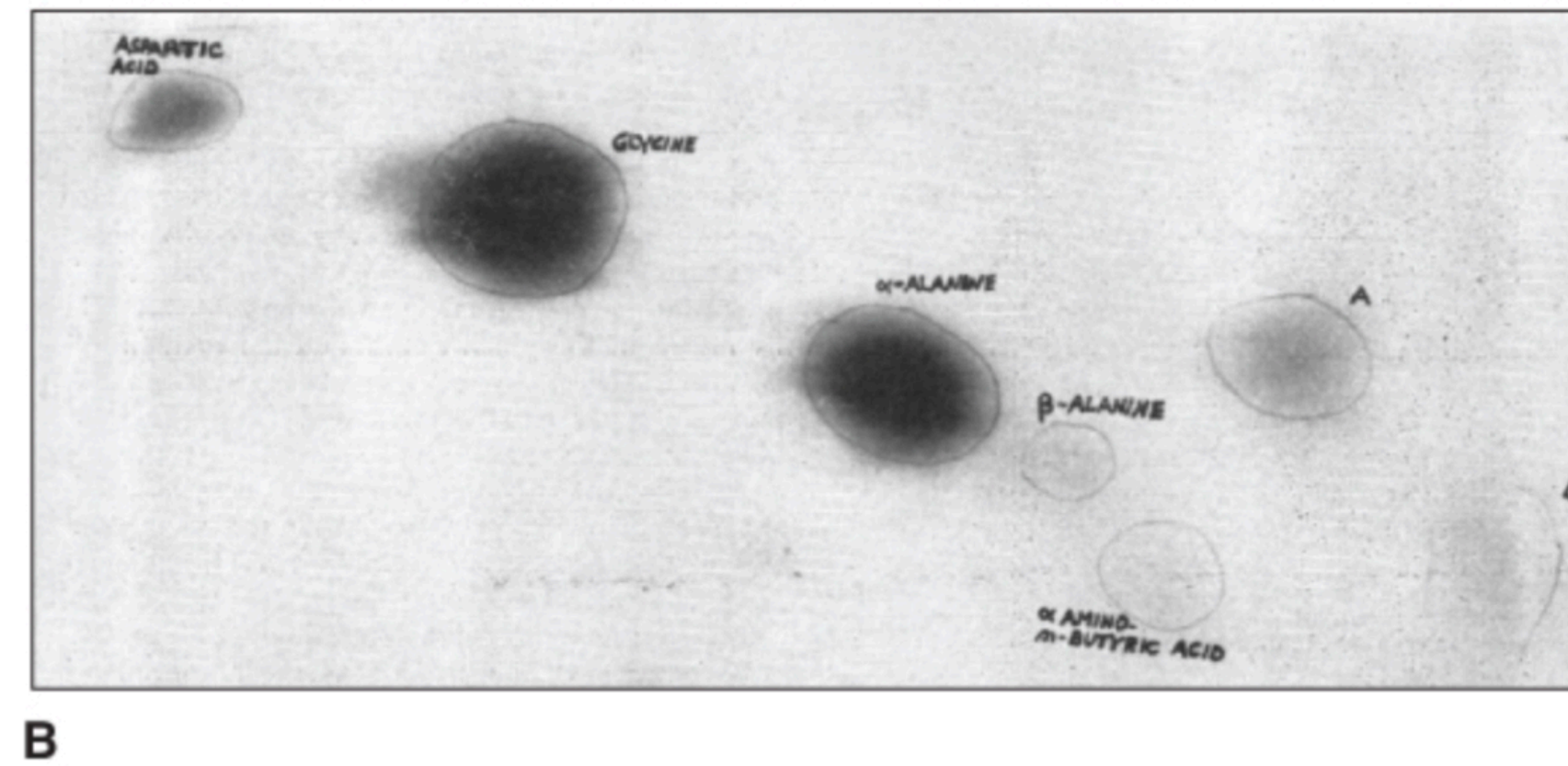
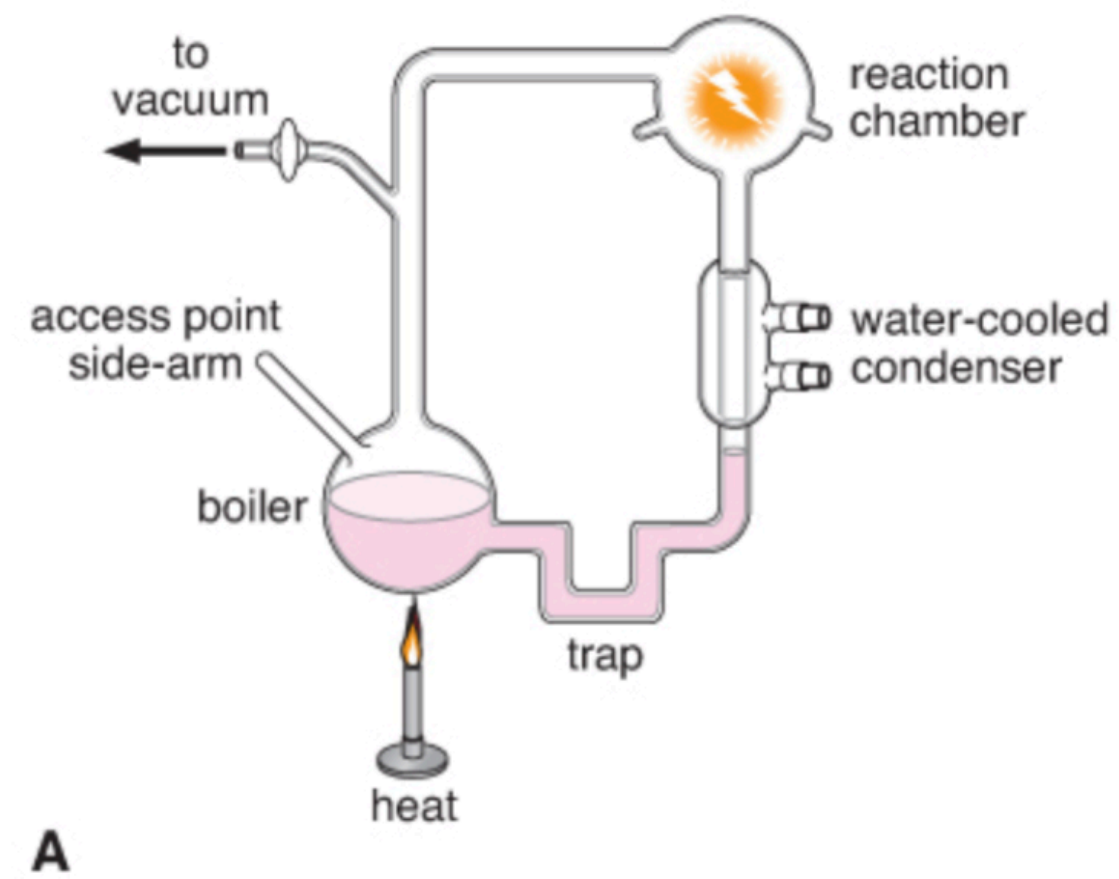
1. Dr. Oswald Avery
2. Dr. Fred Griffith
3. Figure 1.4 Avery
4. Table 1.1 Avery
5. Dr. Stanley Miller (Figure 4.5)
6. Figure 4.6 NASA experiment with meteors
7. Figure 4.8 Ribozyme experiment
8. Figure 4.11 Microspheres and clay vesicle formation
9. Figure 4.17 Vesicle pH after adding micelles
10. Dr. Lynn Margulis
11. Theodor Engelmann (Figure 11.2B)
12. Hans Heldt (Figure 11.5)
13. Figure 11.11 Energy consumption and CO₂ levels.
14. Melvin Calvin and Andrew Benson (Figure 11.13)
15. Figure 11.15 Physiological regulation of rubisco

15 people/figures to
Trifecta on Exam I
(need textbook & lecture info)

Possible exam question format

Predict 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



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