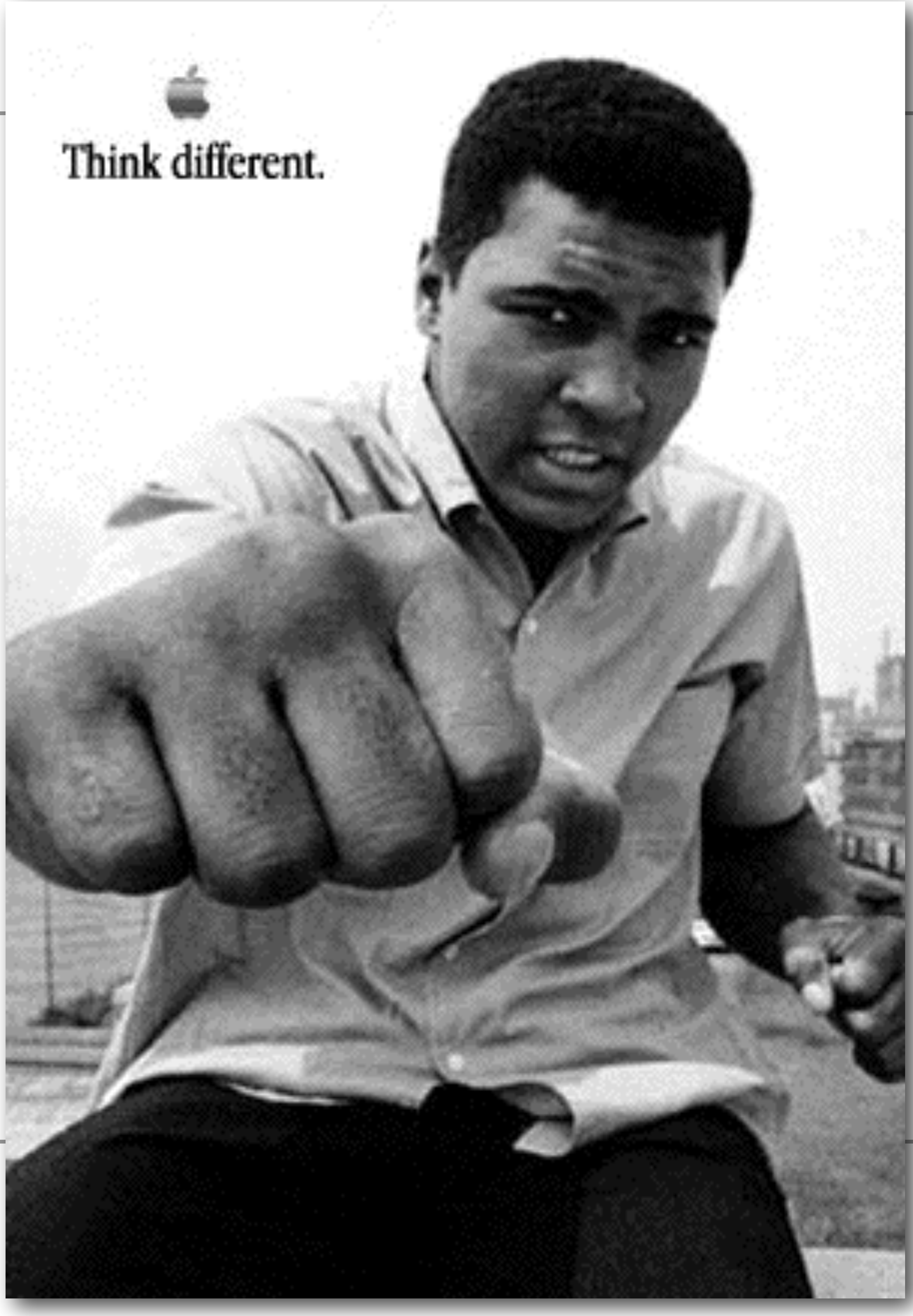
LB144-Pandemic *2022*

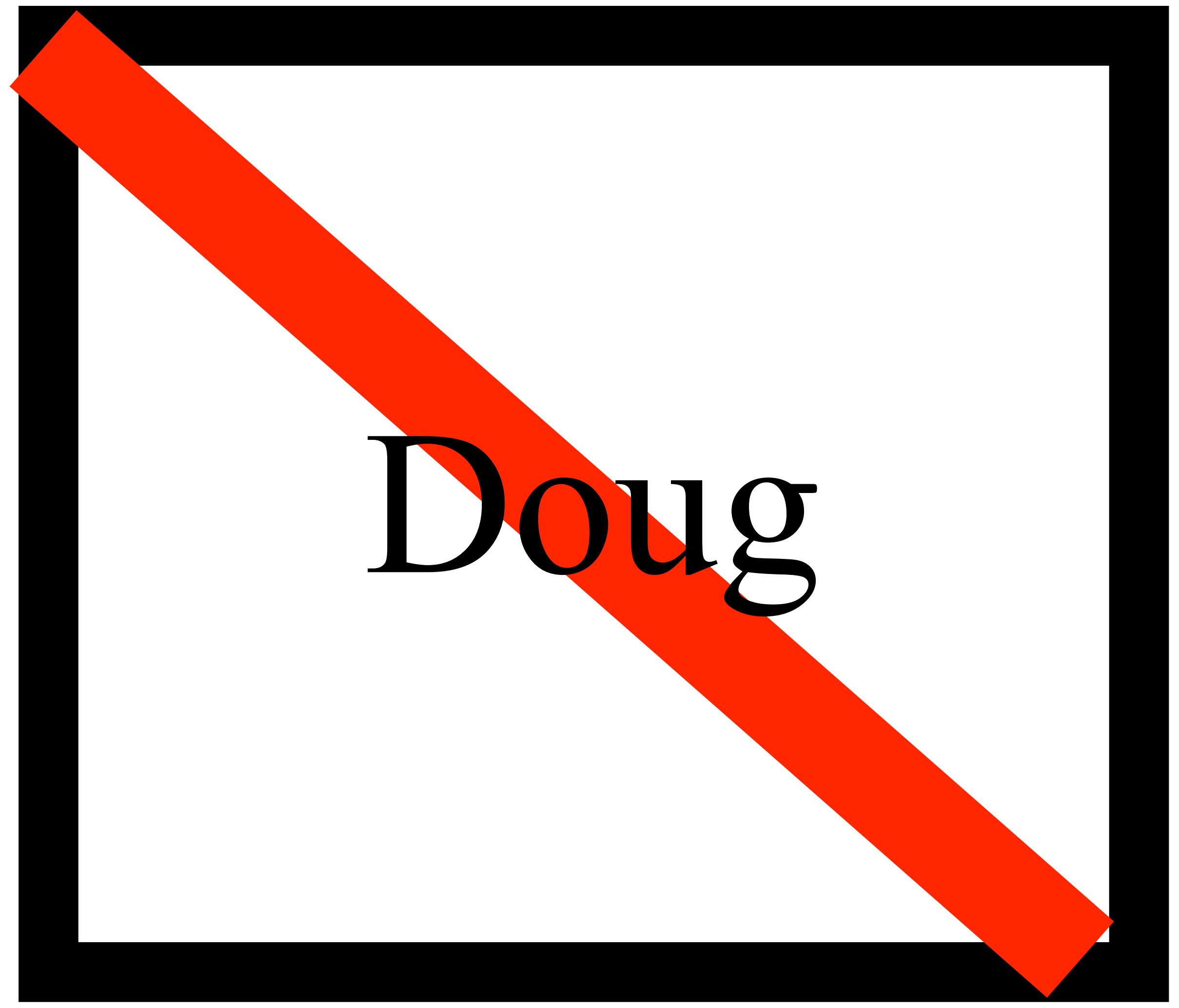


1. Clicker Attendance

- Launch your Top Hat app on your smart phone, or load the TopHat.com website, or text to the course phone number.

2. Sit with your group in lecture & lab

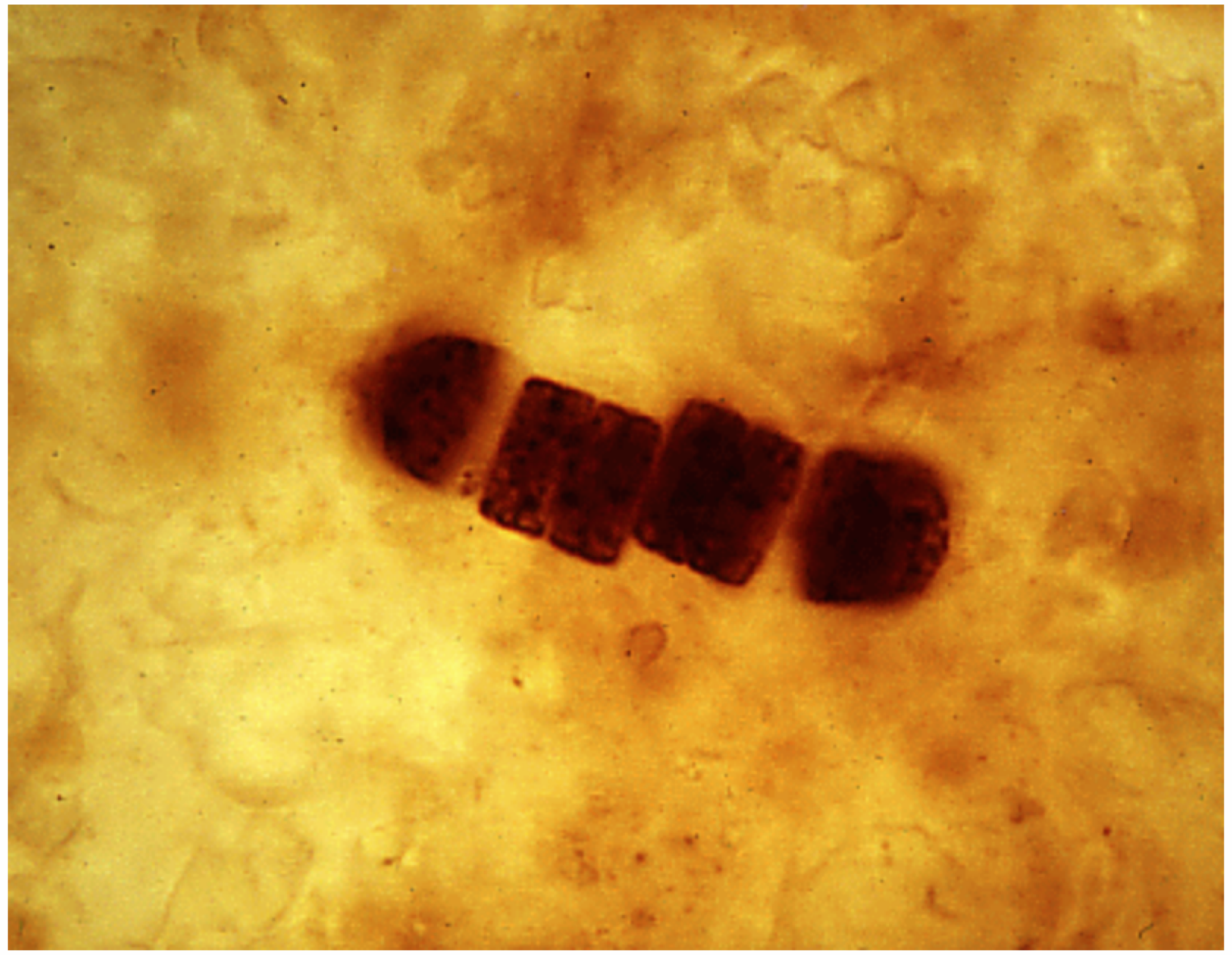
3. To Opt-OUT of being called upon



- Name Card with red stripe means you Opt-OUT (can Opt-OUT 3 times)

Remind me to do **Announcements** when 10 minutes remain

Chapter 4: Evolution and Origin of Cells



A vexing problem in biology is trying to use evidence to understand how life first began. Today, all organisms come from preexisting organisms so it is difficult to imagine how the first living cells came into existence. How could **abiotic** (non-living) molecules coalesce to form a living (**biotic**) cell? Just because it is hard to imagine, however, does not mean this problem is beyond scientific investigation. A growing number of scientists (biologists, chemists, biochemists, and biophysicists) have designed very clever experiments to improve our understanding about the origin of life. Chapter 4 focuses on the molecular aspects of evolution with special attention to the formation of complex living cells from simpler abiotic components. After clearly defining evolution, you will examine data that reveal how non-living chemicals can exhibit traits resembling simple cells. In Chapter 4, you will analyze data that illuminate the origin of eukaryotic cells from prokaryotic ancestors as well as the origins of chloroplasts and mitochondria which are DNA-containing organelles. The four Sections of Chapter 4 focus on evolution at the molecular level.

Micrograph of one billion year old fossilized microbe. Photo courtesy of William Schopf, UCLA

you are here		Big Ideas of biology				
		Information	Evolution	Cells	Homeostasis	Emergent Properties
levels of the biological hierarchy	molecules	1	4	7	10	13
	cells	2	5	8	11	14
	organisms I	3	6	9	12	15
	organisms II	16	19	22	28	25
	populations	17	20	23	29	26
	ecological systems	18	21	24	30	27

Budgeting homework time (70 min): In Ch. 4, the first 2/3's of section 4.2 is 3000 words in length which should take 15 minutes if you just read it. But when done properly, when you pause to review figures, read and think about a few of the Integrating Questions, and take careful notes, this homework assignment should take you more like 70 minutes (and that's if you are not distracted).

1. _______ **Read Chapter 4's** section 4.2 "Could abiotic molecules form biologically important molecules before life evolved?" and as you read it on your computer be sure to take handwritten notes*. You should focus mostly, and only take detailed notes for, the first 2/3s of the section. You can stop taking notes once you complete the yellow Integrating Questions 5 & 6. Read the remaining section regarding RNA and directed evolution, but no notes are needed on this, just be amazed at what is said.

2. _______ **Try to answer some Integrating Question and Review Questions.** As you read the ICB textbook always attempt to answer at least one of the yellow **Integrating Questions** each time you get to a set of them. Also try to answer the green Review questions.

3. _______ (Trifecta): **Prepare to explain (aloud) Figures 4.5, 4.6, and 4.8 in class** (Purpose, Methods, Findings)

4. _______ **Advanced**: Click on "Explore More on Abiotic Production of Organic Molecules".

4.2 Could abiotic molecules form biologically important molecules before life evolved?

Biology Learning Objectives

- Use evidence to support the scientific hypothesis that life evolved from abiotic forces and phenomenon.
- Define the fundamental properties of living systems.
- Describe how RNA molecules can function as enzymes.

A Reading...

Perhaps no other question has challenged humans more than the origin of life. For many centuries, answers were based on religious perspectives and lacked scientific foundations. As discussed in Ethical, Legal, Social Implications 4.1, religion and science view the world in mutually exclusive ways, but a person can believe in God and accept evolution. Over time, scientists turned their attention to the fundamental question about our existence. This chapter addresses how life could have evolved from nonliving chemicals and molecules. You will examine original data that make a compelling case for the origin of life that does not require belief in the supernatural or God.

It is difficult to picture the universe as an expanding collection of elements that coalesced into balls of fire and clay to form suns and planets. Imagine primitive Earth spinning on its axis and orbiting our sun. Next, contemplate how proteins, nucleic acids, carbohydrates, and lipids came into being before life evolved. These four building blocks of life are produced by cells every second of every day now, but before life began, how did these biological molecules appear on Earth and coalesce into a living cell?

The universe is composed of the elements you see on the periodic table of the elements. These atoms do not self-assemble into complex biological molecules when you mix them in a test tube containing carbon, nitrogen, oxygen, and hydrogen. A fundamental principle of biology, which is often referred to as the **cell theory**, states that all cells come from preexisting cells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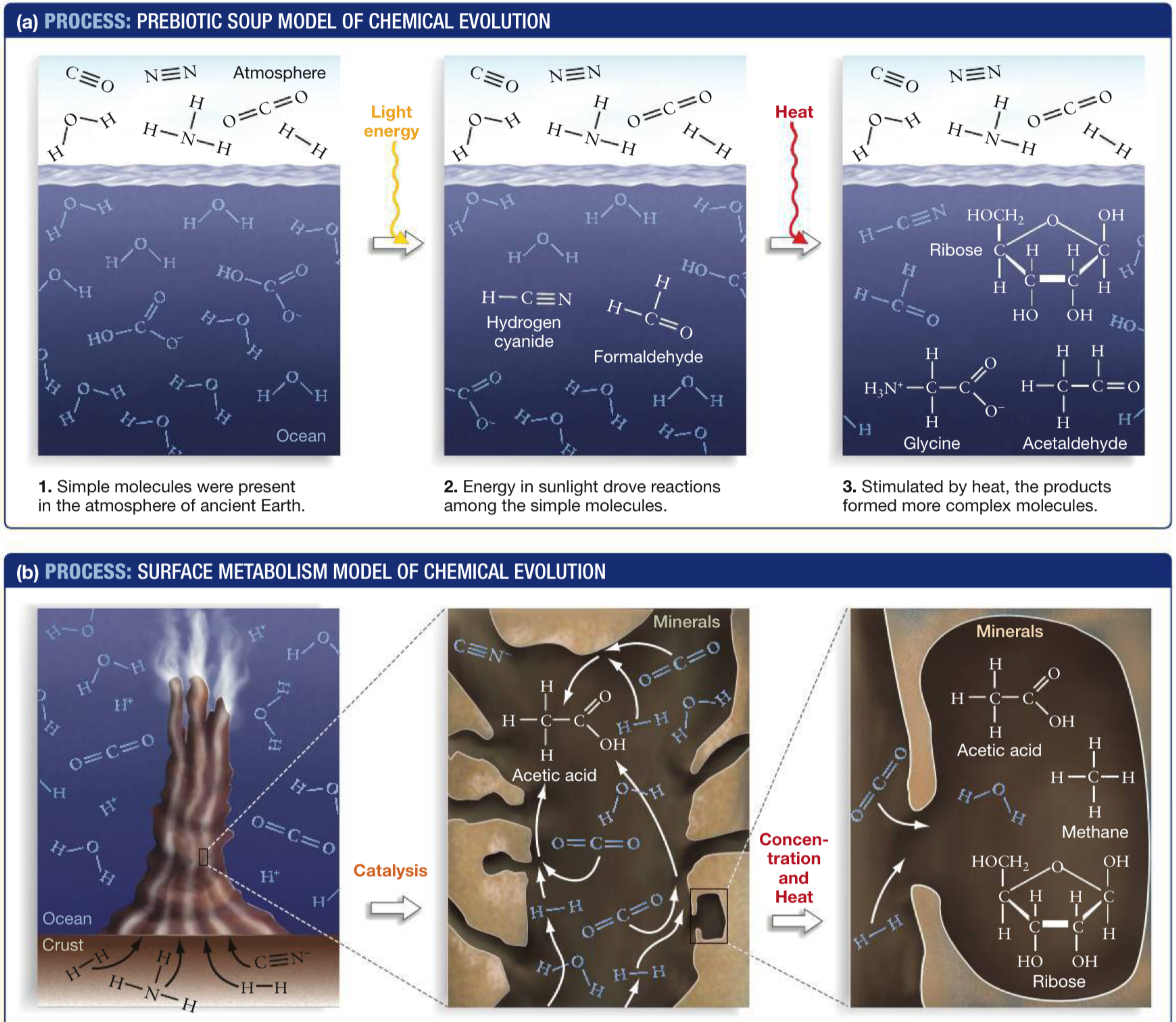
PROF. COLIN W. DEVEY
Marine Geologist, University of Kiel


(a) PROCESS: PREBIOTIC SOUP MODEL OF CHEMICAL EVOLUTION
Atmosphere
Ocean
Light energy
Hydrogen cyanide
Formaldehyde
Heat
Ribose
Glycine
Acetaldehyde
1. Simple molecules were present in the atmosphere of ancient Earth.
2. Energy in sunlight drove reactions among the simple molecules.
3. Stimulated by heat, the products formed more complex molecules.
(b) PROCESS: SURFACE METABOLISM MODEL OF CHEMICAL EVOLUTION
Ocean
Crust
Catalysis
Minerals
Acetic acid
Concen-tration and Heat
Minerals
Acetic acid
Methane
Ribose

(Trifecta)

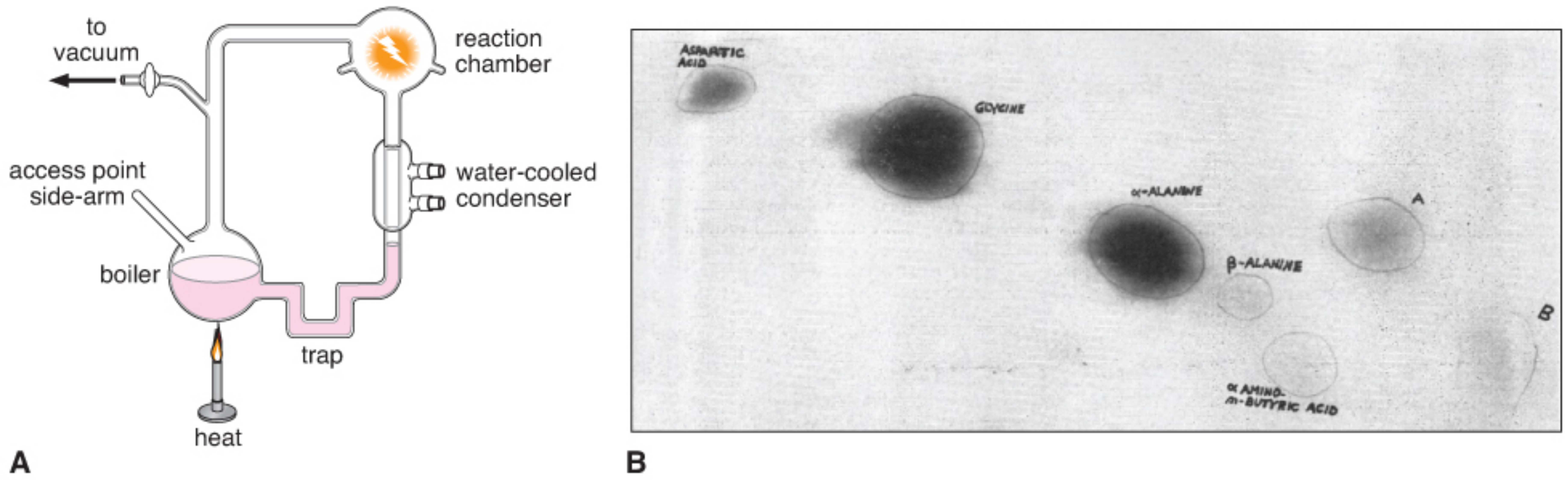


Figure 4.5 Miller's experiment to simulate primitive Earth. **A,** Modified drawing from Miller showing the parts of his ancient world device. **B,** Thin layer chromatography results after running the primitive earth experiment for 1 week. (Hand-written labels and circles by Miller.) From Stanley L. Miller. 1953. Figure 1. Stanley L. Miller. 1953. A Production of amino acids under possible primitive earth conditions. Science. 117: 528 – 529. Reprinted with permission from AAAS.

Stanley Miller's
abiotic gases -> amino acids and lipids

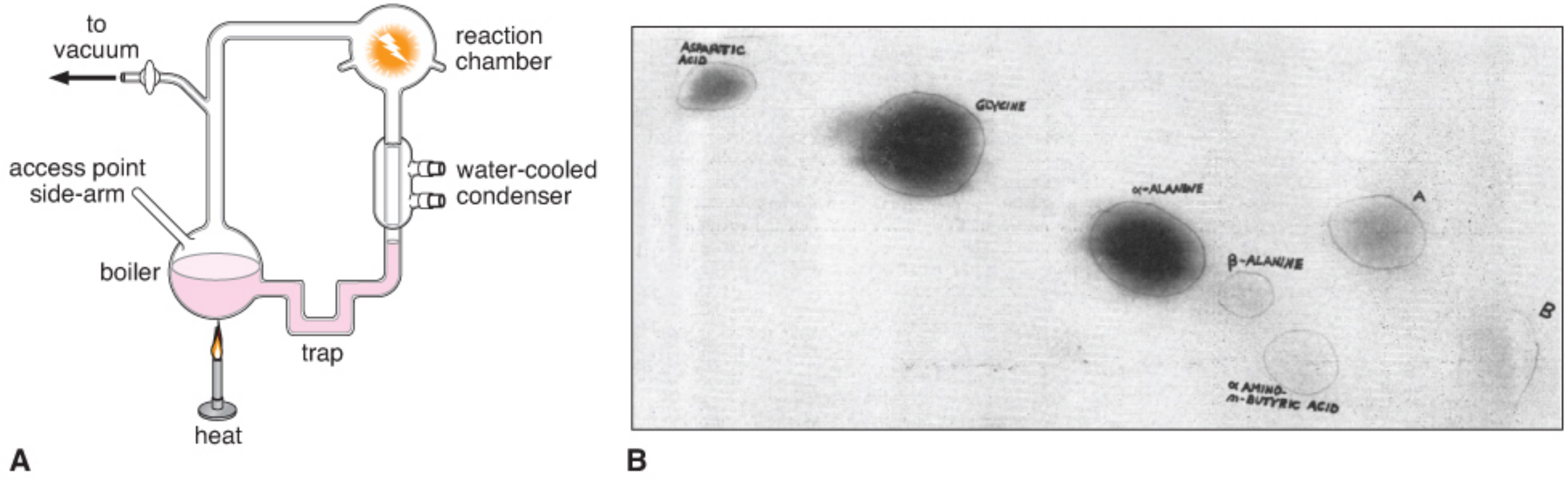


Figure 4.5 Miller's experiment to simulate primitive Earth. **A,** Modified drawing from Miller showing the parts of his ancient world device. **B,** Thin layer chromatography results after running the primitive earth experiment for 1 week. (Hand-written labels and circles by Miller.) From Stanley L. Miller. 1953. Figure 1. Stanley L. Miller. 1953. A Production of amino acids under possible primitive earth conditions. Science. 117: 528 – 529. Reprinted with permission from AAAS.

The Miller Volcanic Spark Discharge Experiment

Adam P. Johnson,[1] H. James Cleaves,[2] Jason P. Dworkin,[3] Daniel P. Glavin,[3] Antonio Lazcano,[4] Jeffrey L. Bada[5]*

In 1953, Miller (*1*) published a short paper describing the spark discharge synthesis of amino acids from a reducing gas mixture thought to represent the atmosphere of the early Earth. This experiment showed that the basic molecules of life could be synthesized from simple molecules, suggesting that Darwin's "warm little pond" was a feasible scenario.

After Miller's death on 20 May 2007, we found several boxes containing vials of dried residues. Notebooks (*2*) indicated that the vials came from his

We were interested in the second apparatus because it possibly simulates the spark discharge synthesis by lightning in a steam-rich volcanic eruption (*6*) (Fig. 1A). Miller identified five different amino acids, plus several unknowns, in the extracts from this apparatus (*3*). Product yields appeared somewhat higher than those in the classical configuration, although Miller never confirmed this. We reanalyzed 11 vials in order to characterize the diversity of products synthesized in this apparatus.

and found to have a lower diversity of amino acids (table S1). The yield of amino acids synthesized in the volcanic experiment is comparable to, and in some cases exceeds, those found in the experiments Miller conducted (*1*, *3*, *5*). Hydroxylated compounds were preferentially synthesized in the volcanic experiment. Steam injected into the spark may have generated OH radicals that reacted with either the amino acid precursors or the amino acids themselves (*7*).

Geoscientists today doubt that the primitive atmosphere had the highly reducing composition Miller used. However, the volcanic apparatus experiment suggests that, even if the overall atmosphere was not reducing, localized prebiotic synthesis could have been effective. Reduced gases and lightning associated with volcanic eruptions in hot spots or island arc–type systems could have been prevalent on the early Earth before extensive continents formed (*8*). In these volcanic plumes, HCN, aldehydes, and ketones may have been produced, which, after washing out of the atmosphere, could have become involved in the synthesis of organic molecules (*3*, *4*, *8*). Amino acids formed in volcanic island systems could have accumulated in tidal areas, where they could be polymerized by carbonyl sulfide, a simple volcanic gas that has been shown to form peptides under mild conditions (*9*).

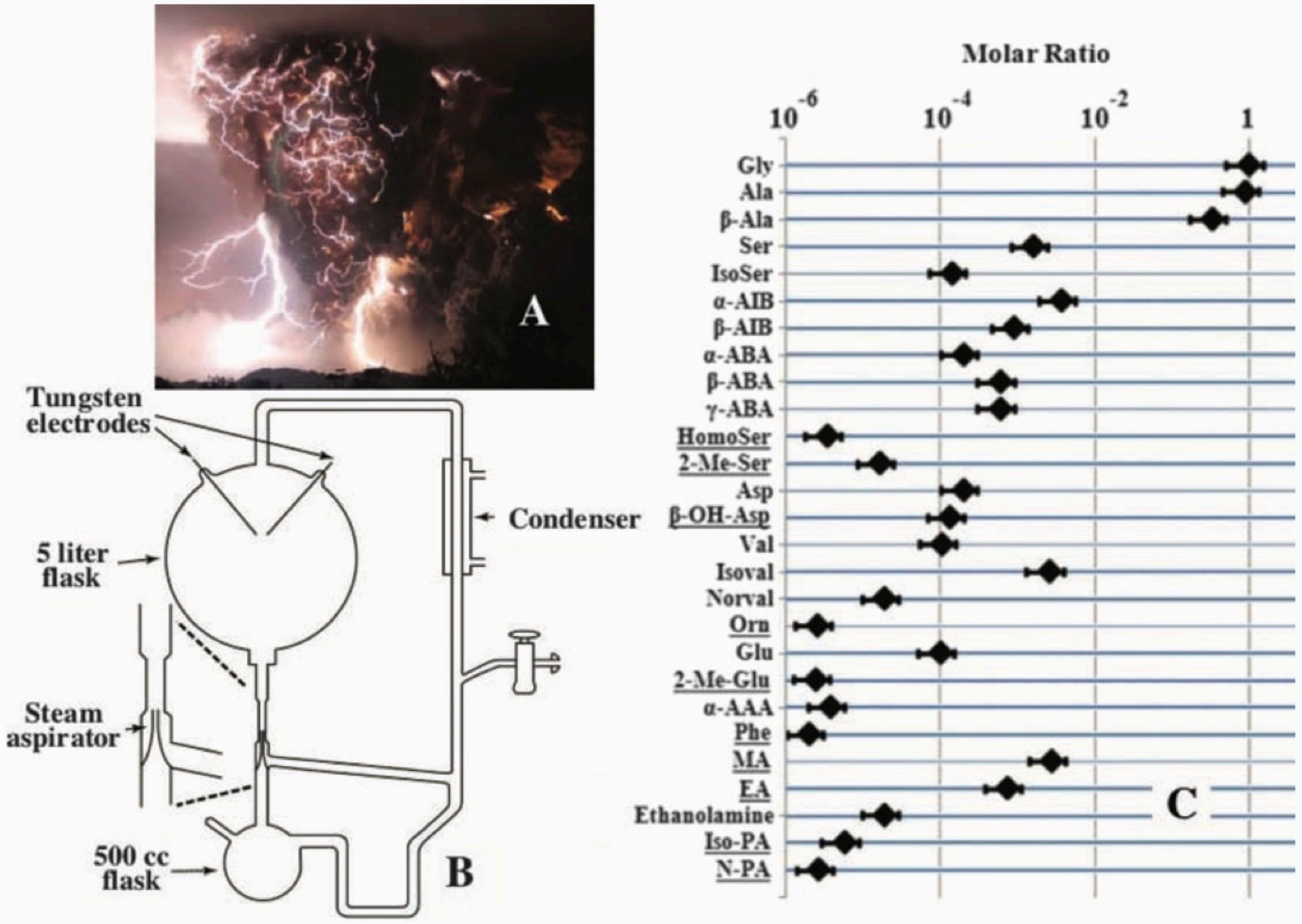


Fig. 1. (**A**) Lightning associated with the 3 May 2008 eruption of the Chaiten volcano, Chile. [Photo credit: Carlos Gutierrez/UPI/Landov] (**B**) The volcanic spark discharge apparatus used by Miller (*3*). Gas quantities added were 200 torr of CH_4, 200 torr of NH_3, and 100 torr of H_2 [these would have dissolved in the water according to their solubilities (*2*)]. Water was added to the 500-cm^3 (cc) flask and boiled, and the apparatus sparked with a Tesla coil for 1 week; (**C**) Moles (relative to glycine = 1) of the various amino acids detected in the volcanic apparatus vials [see (*2*) and table S1 for abbreviations]. Amino acids underlined have not been previously reported in spark discharge experiments. Values for amines are minimum values because of loss due to their volatility during workup.

References and Notes

1. S. L. Miller, *Science* **117**, 528 (1953).
2. Analytical details and additional data are available as supporting material on *Science* Online.
3. S. L. Miller, *J. Am. Chem. Soc.* **77**, 2351 (1955).
4. A. Lazcano, J. L. Bada, *Origins Life Evol. Biosph.* **33**, 235 (2003).
5. D. Ring, W. Yecheskel, N. Friedmann, S. L. Miller, *Proc. Natl. Acad. Sci. U.S.A.* **69**, 765 (1972).
6. S. R. McNutt, C. M. Davis, *J. Volcanol. Geotherm. Res.* **102**, 45 (2000).
7. D. Ring, S. L. Miller, *Origins Life Evol. Biosph.* **15**, 7 (1984).
8. R. D. Hill, *Origins Life Evol. Biosph.* **22**, 277 (1991).
9. L. Leman, L. Orgel, M. Reza Ghadiri, *Science* **306**, 283 (2004).

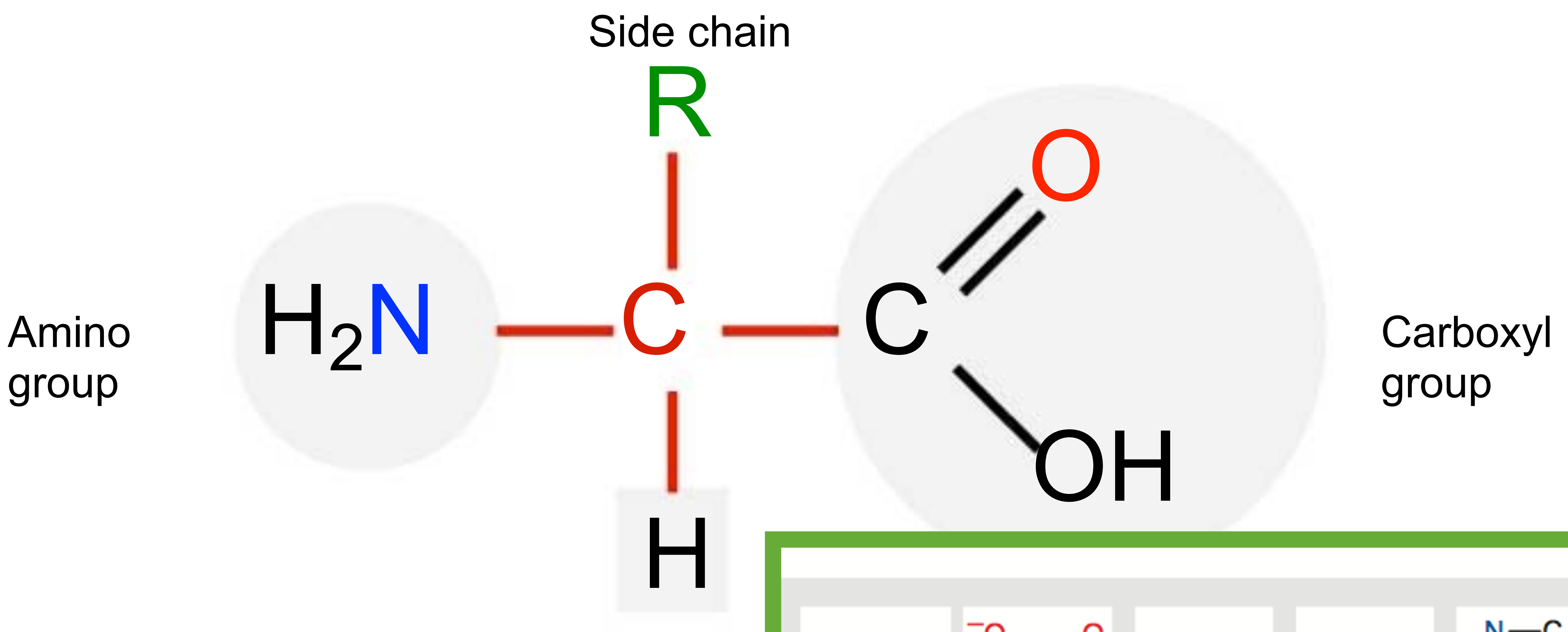
Supporting Online Material
www.sciencemag.org/cgi/content/full/322/5900/404/DC1
Materials and Methods
Figs. S1 and S2
Table S1
References and Notes

9 June 2008; accepted 8 August 2008

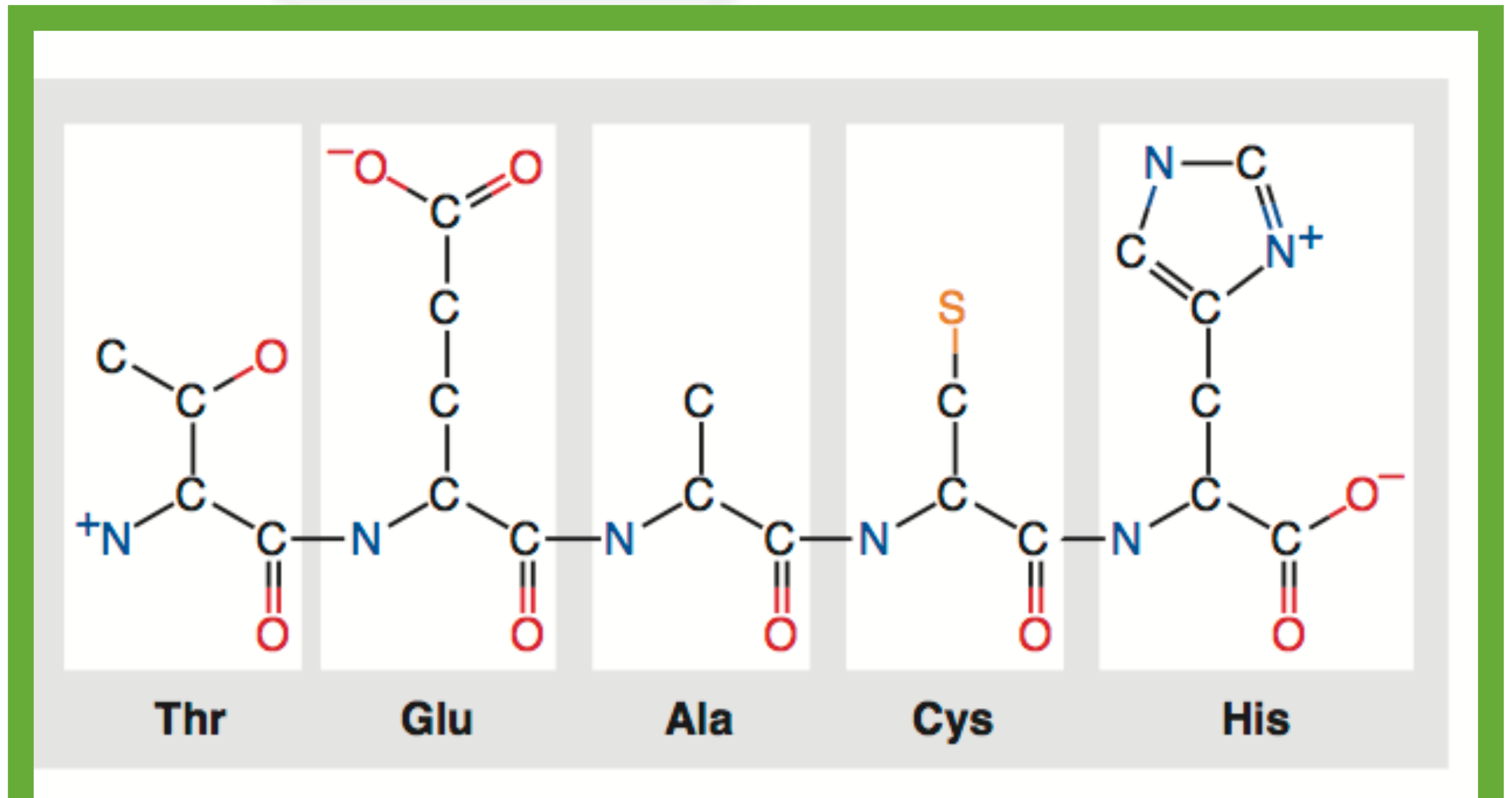
Molecules of the Prebiotic Soup

- Amino acids are the monomers that are the building blocks of proteins.
  - **Carbon** bonded to four functional groups, including a variable R-group.
  - Readily form in **Stanley Miller experiment** and have been found on meteorites striking earth.

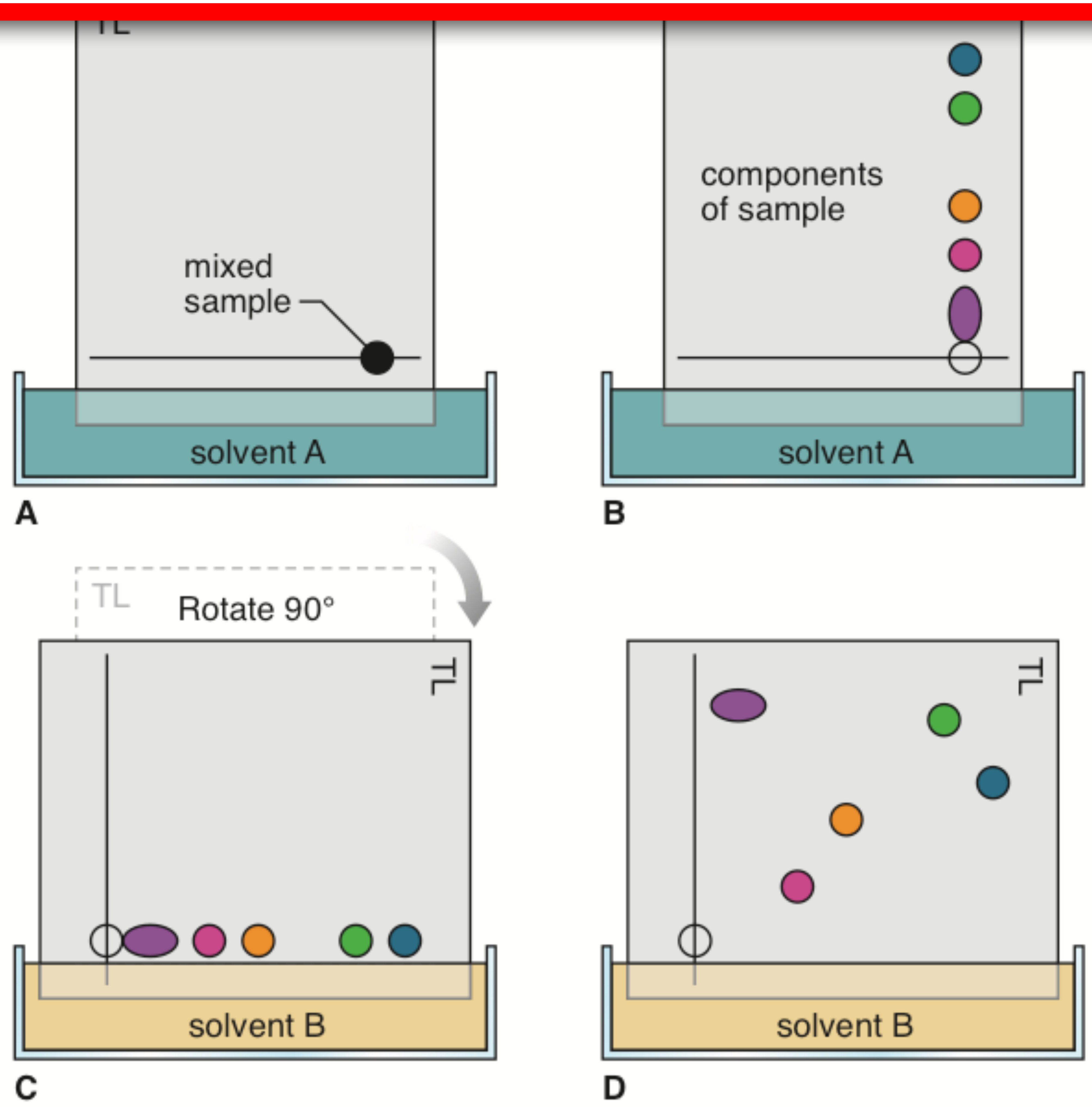
All **amino acids** have the same general structure.



Non-ionized form



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



Miller’s Primitive Earth Apparatus

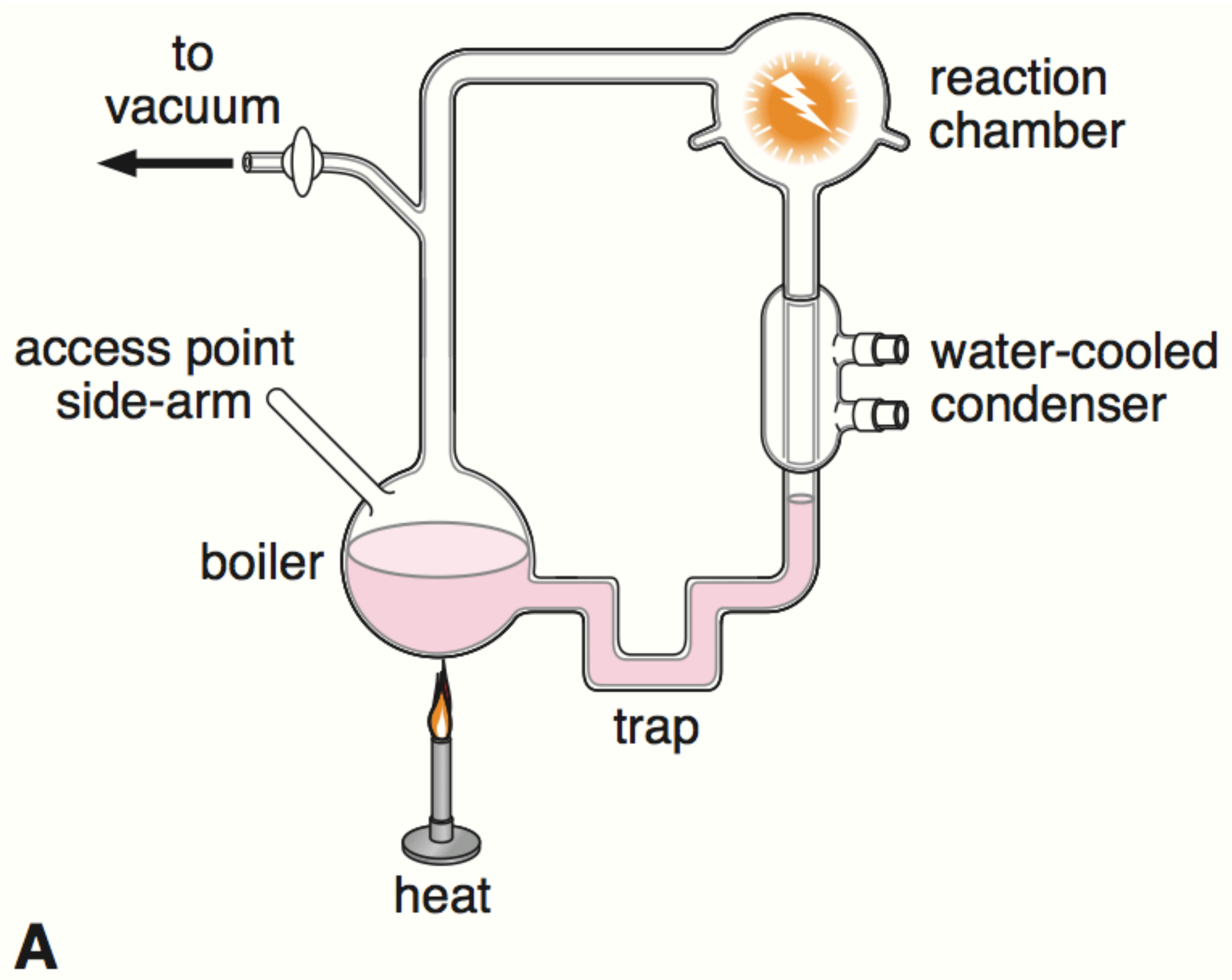


Fig. 4.5

modified from Stanley L. Miller. 1953

Miller's Primitive Earth Apparatus

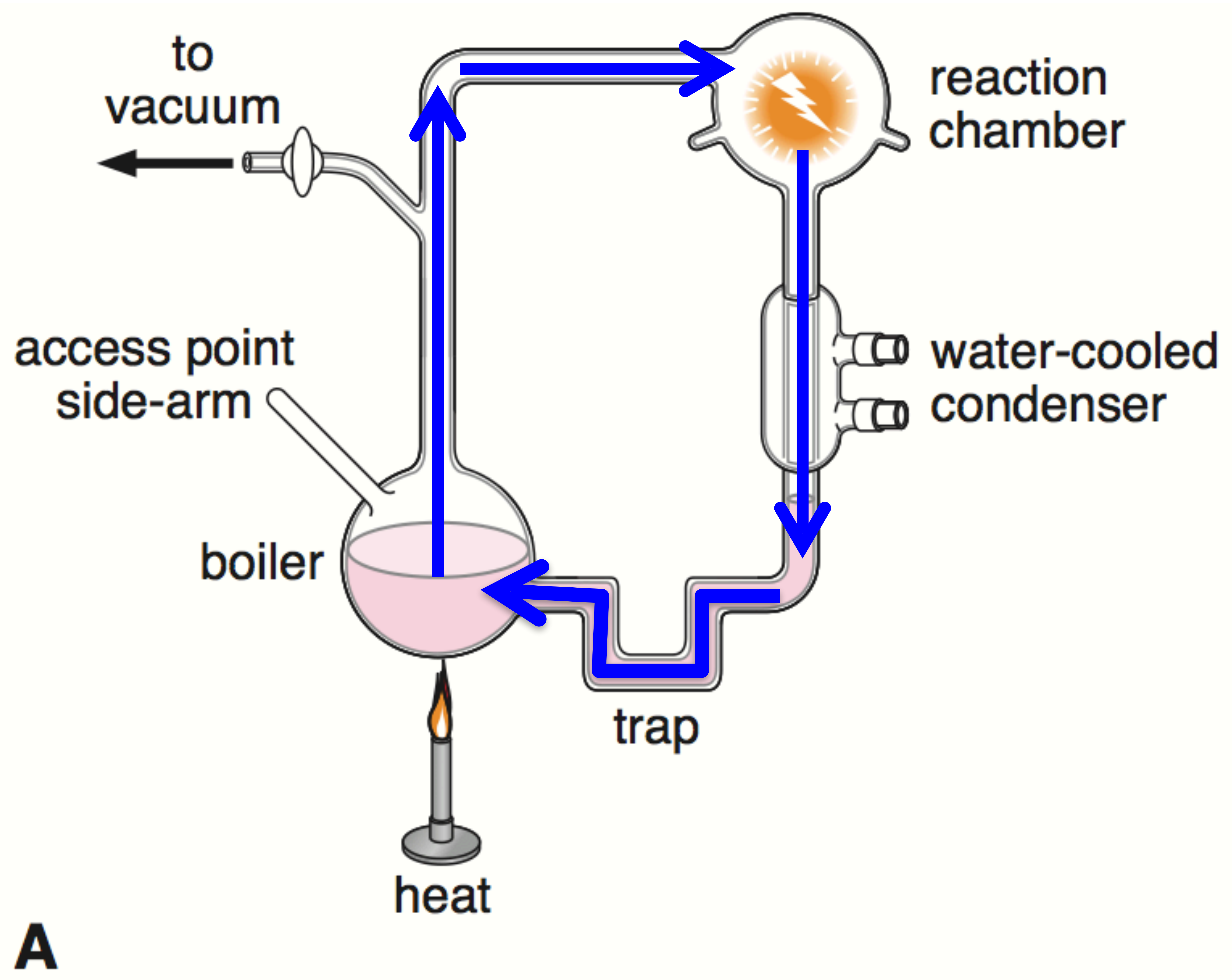
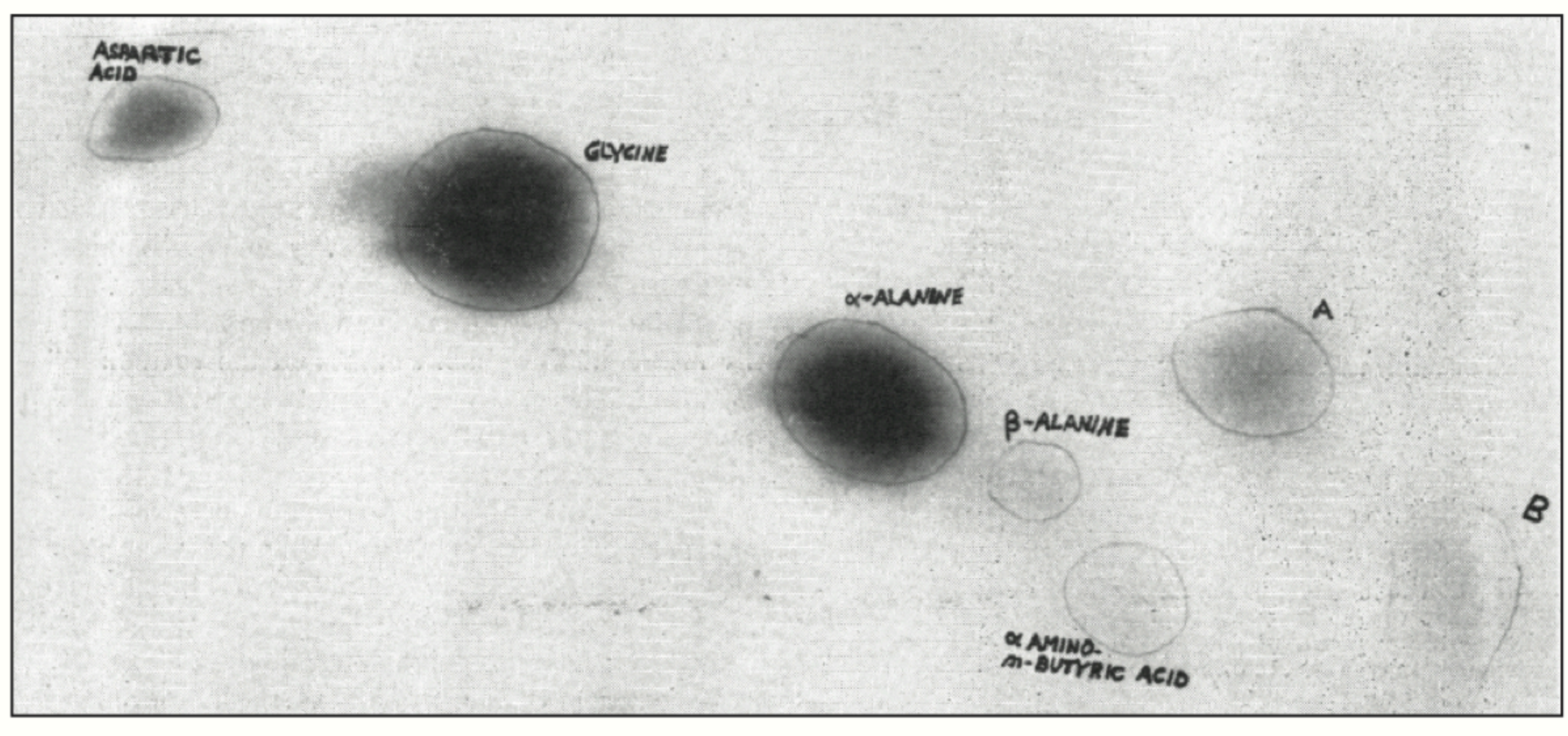


Fig. 4.5

modified from Stanley L. Miller. 1953

Products from Miller's Experiment



B

Fig. 4.5

modified from Stanley L. Miller. 1953

Separated by 2D TLC

thin layer chromatography results

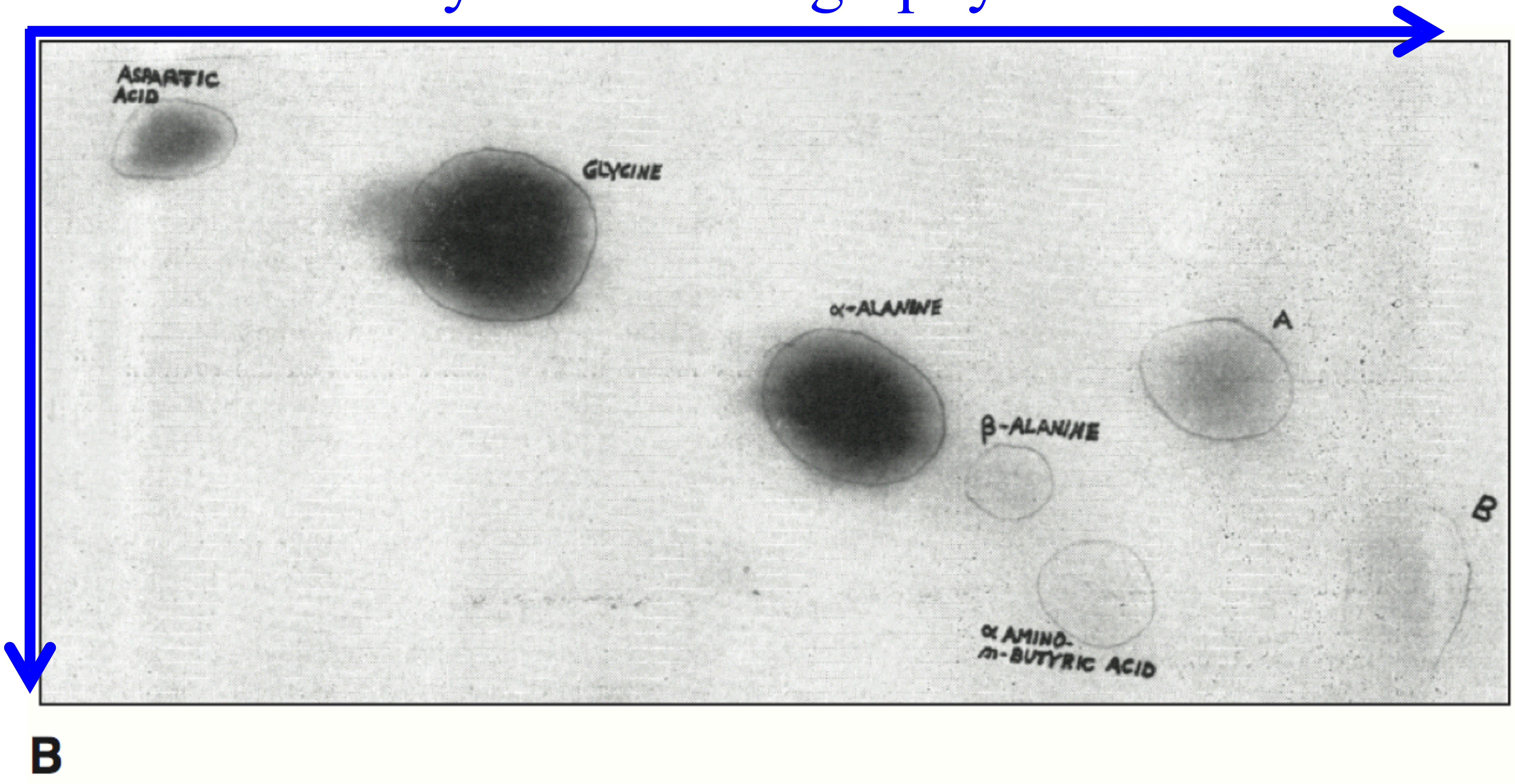
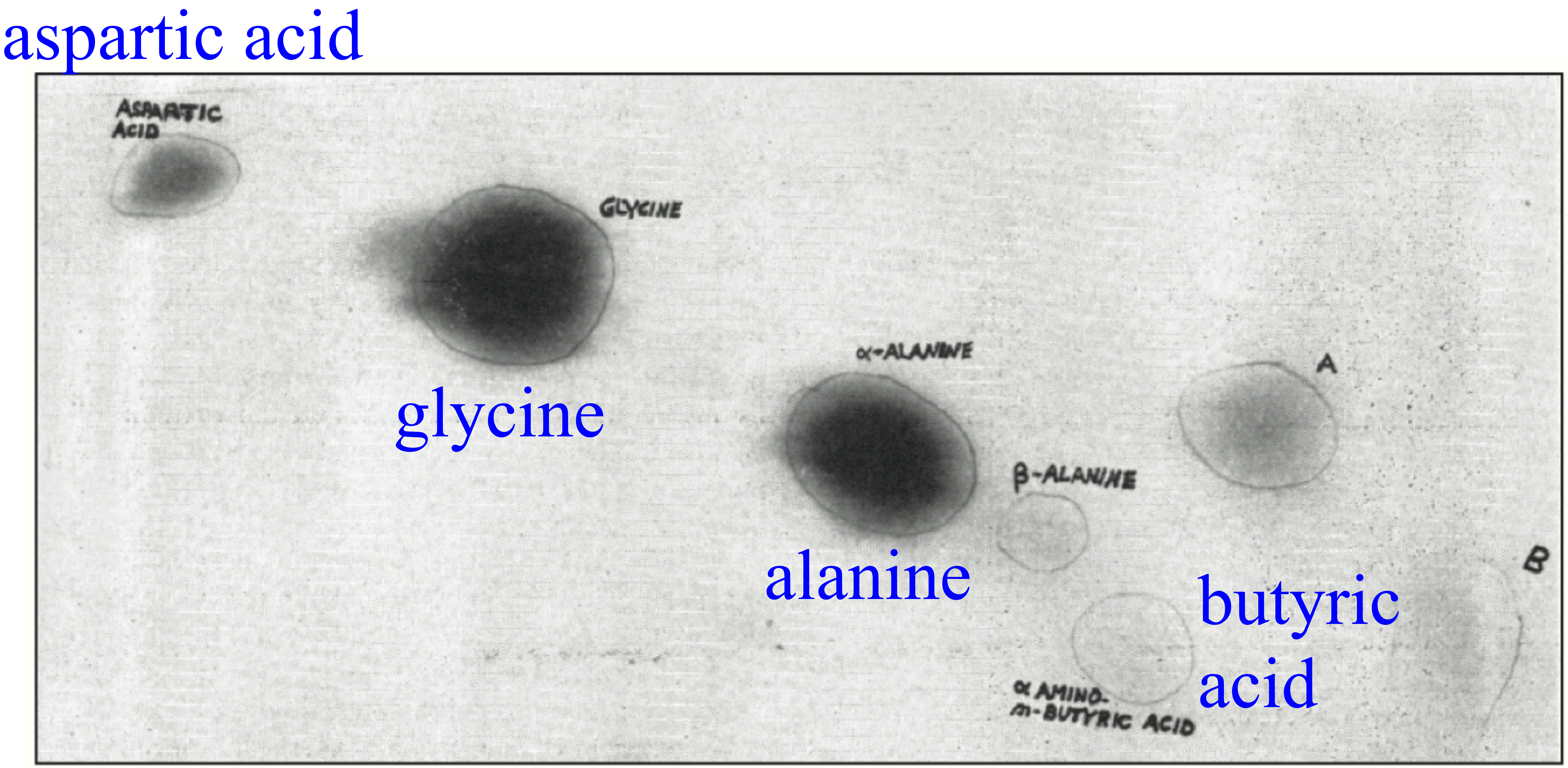


Fig. 4.5

modified from Stanley L. Miller. 1953

Separated by 2D TLC



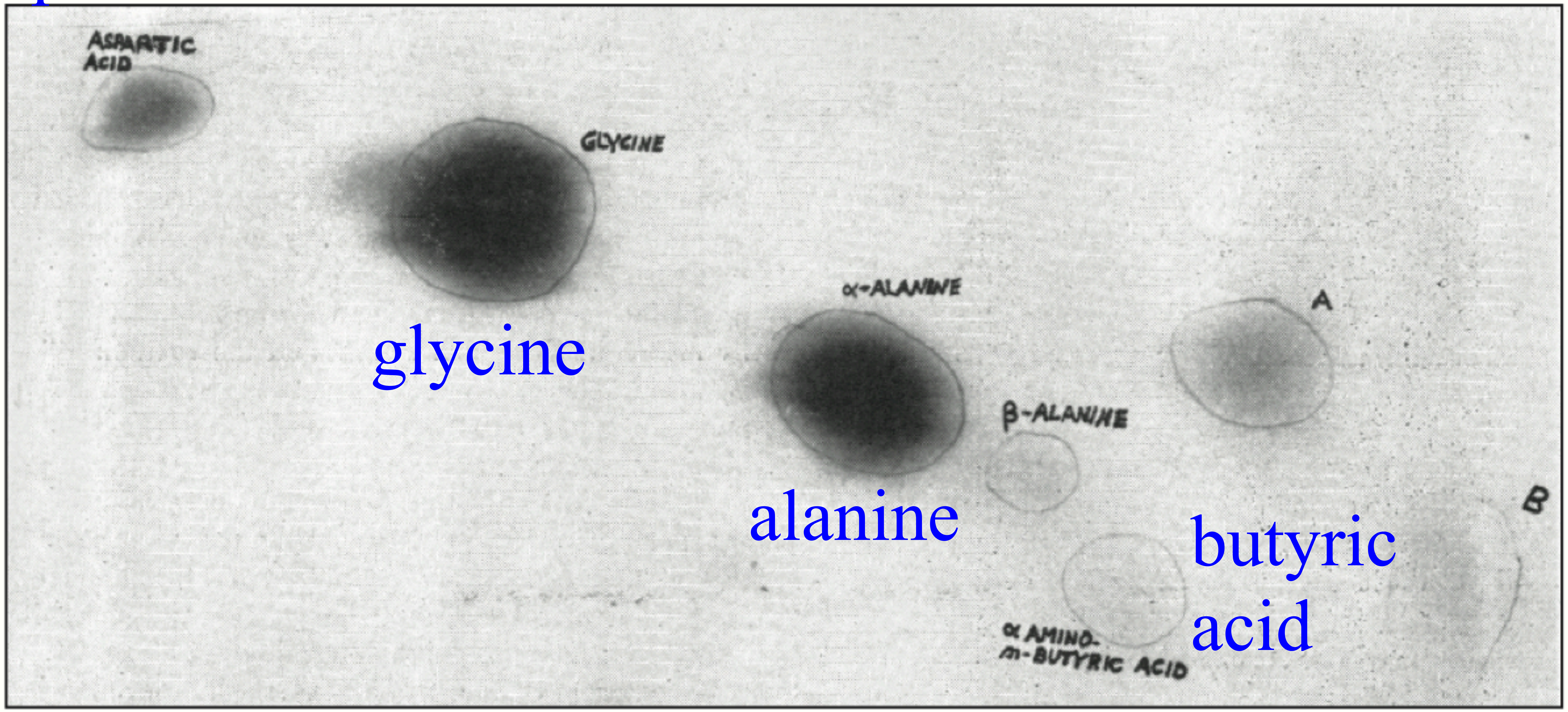
B

Fig. 4.5

modified from Stanley L. Miller. 1953

Separated by 2D TLC

aspartic acid



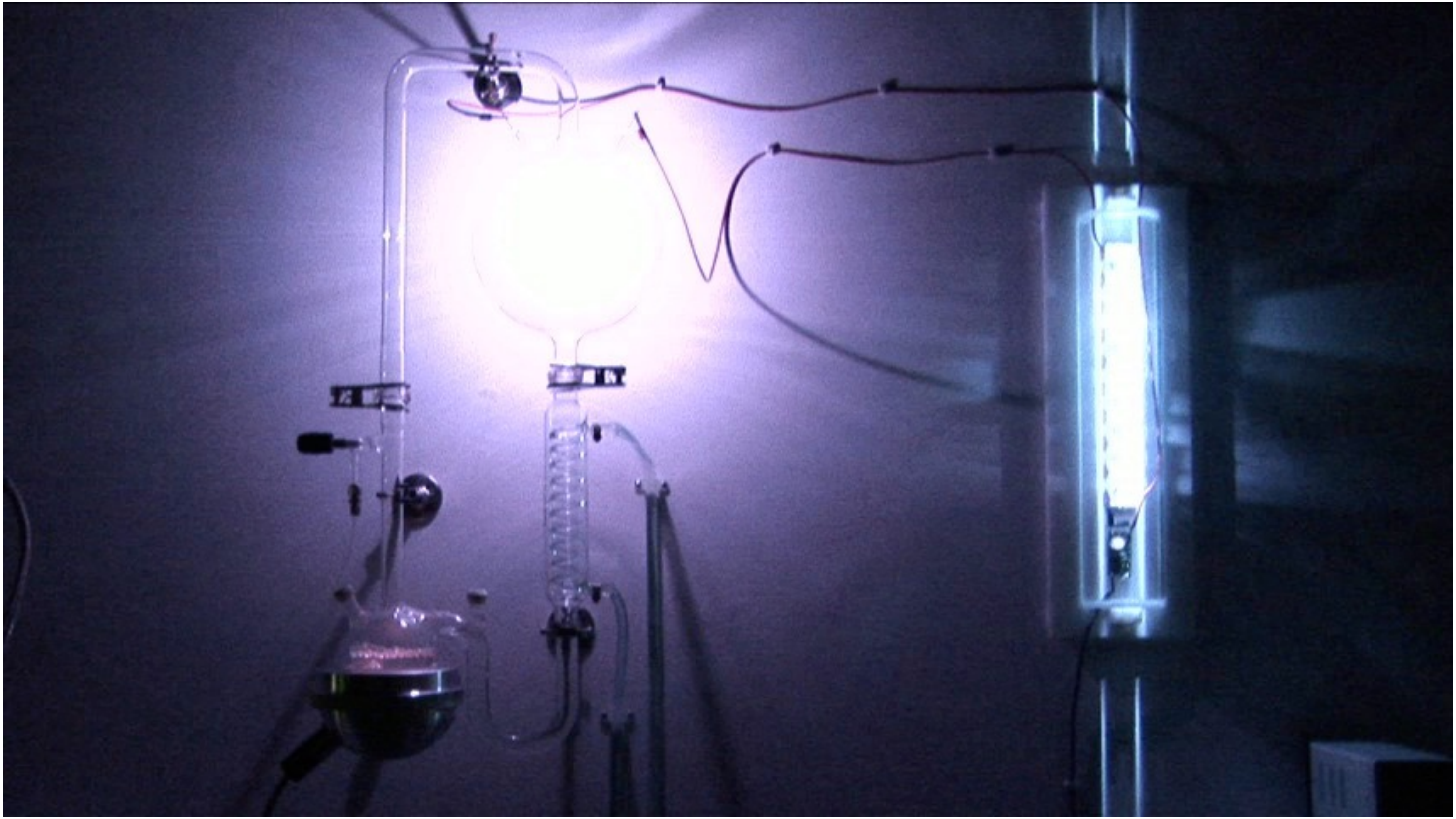
B amino acids and fatty acids produced abiotically

Fig. 4.5

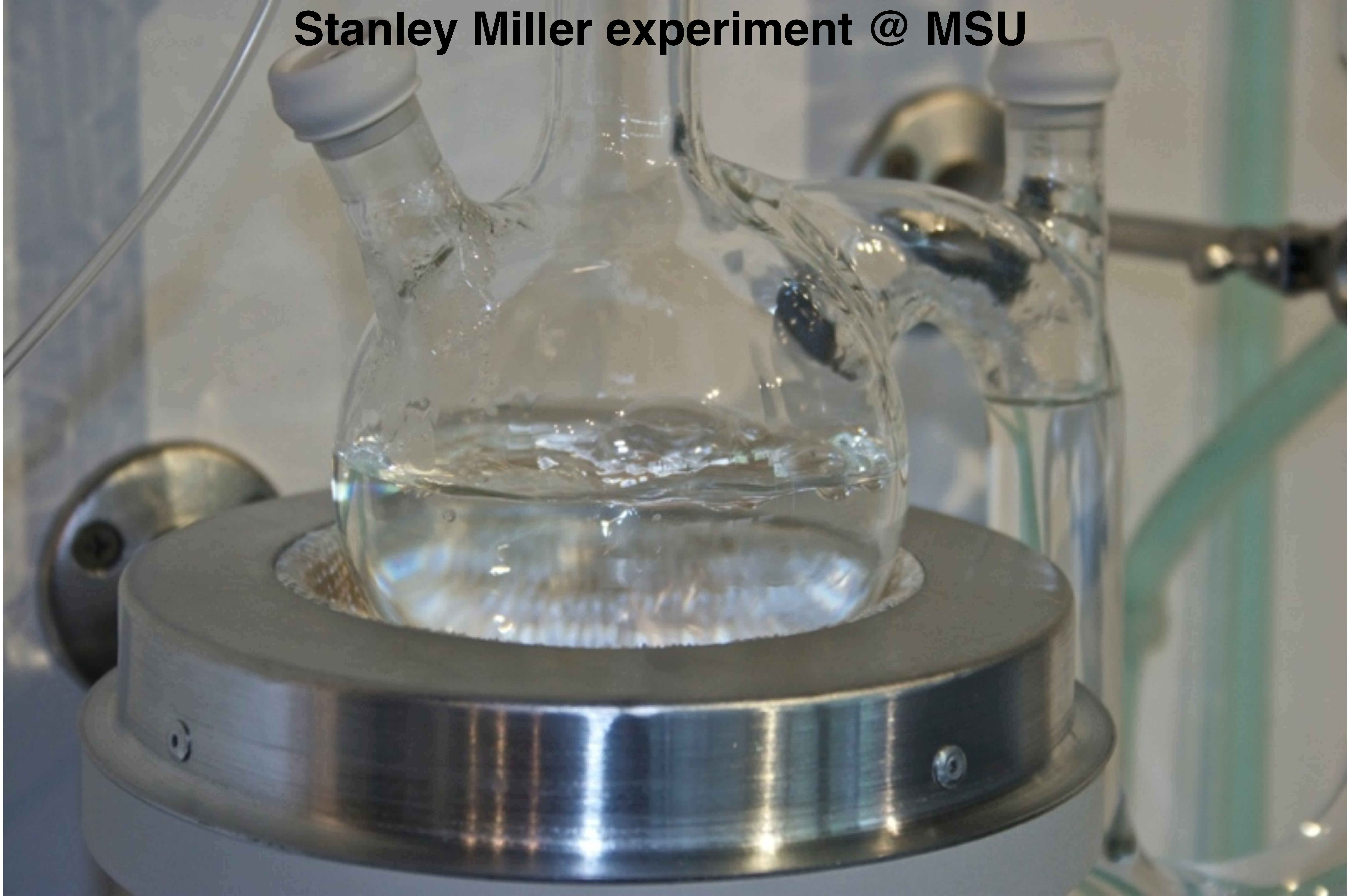
modified from Stanley L. Miller. 1953

http://vimeo.com/32106116

Stanley Miller experiment @ MSU



Stanley Miller experiment @ MSU



Stanley Miller experiment @ MSU

(Trifecta)

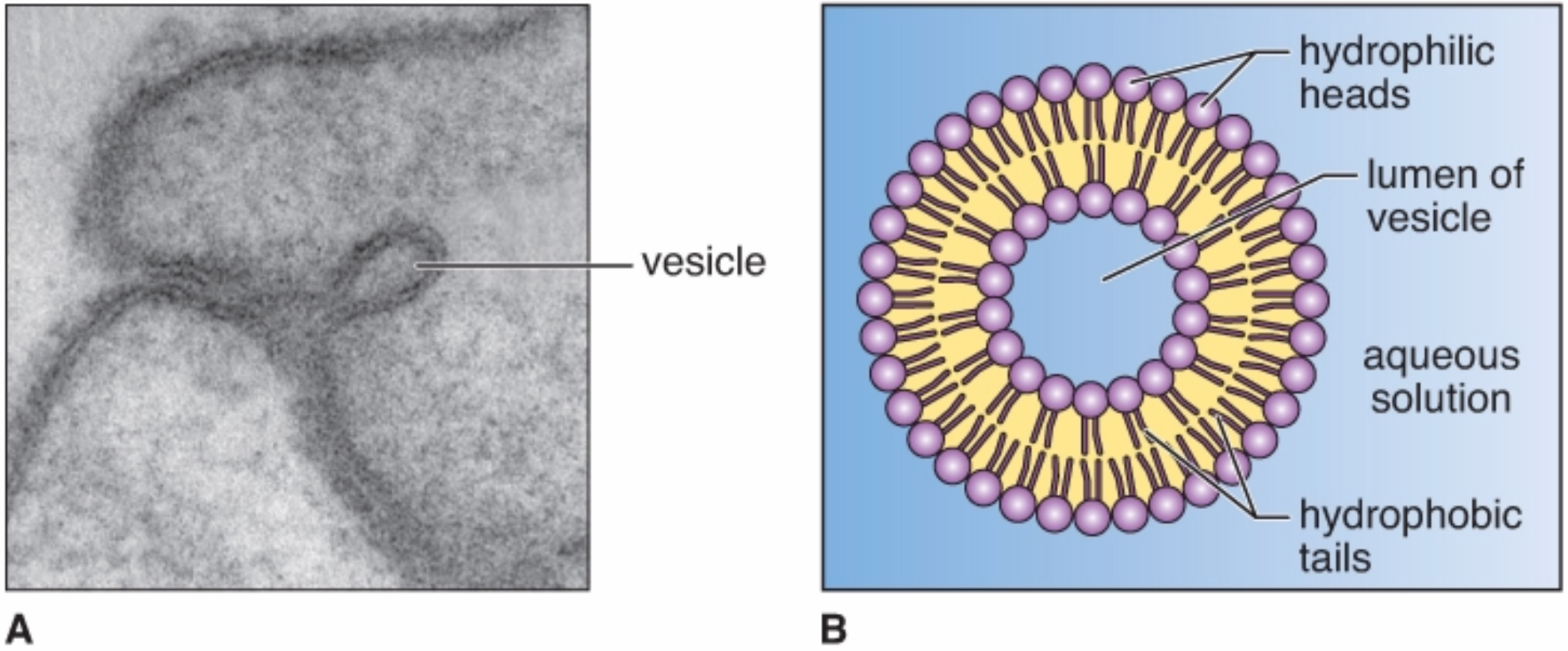
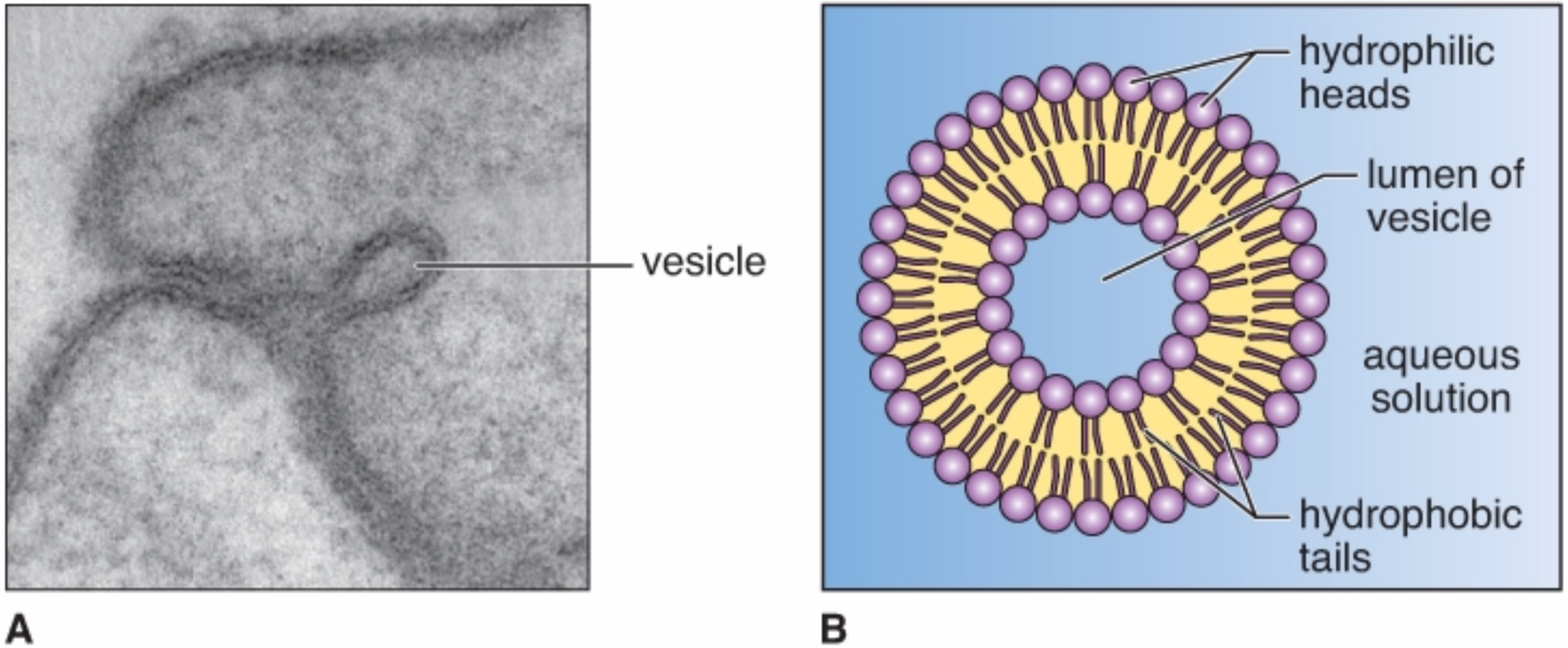


Figure 4.6 Vesicles made of lipids similar to those formed in NASA's experiments. Electron micrograph **(A)** and line drawing **(B)** of vesicles. Vesicles are spheres made of two lipid layers or a bilayer. The center cavity of a vesicle is called its lumen. A.http://www.zonapse.net/sitebuildercontent/sitebuilderpictures/vesicle.jpg B. Original art.

NASA:
UV light helps form lipids and vesicles



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SPACEFLIGHT

SpaceX Set to Launch Private Moon Lander, Along with NASA 'Flashlight' Probe

If it lands safely, ispace's Hakuto-R M1 will be the first privately led lander to operate on the Moon, signaling a new era in lunar exploration.

By George Dvorsky | Published 3 hours ago

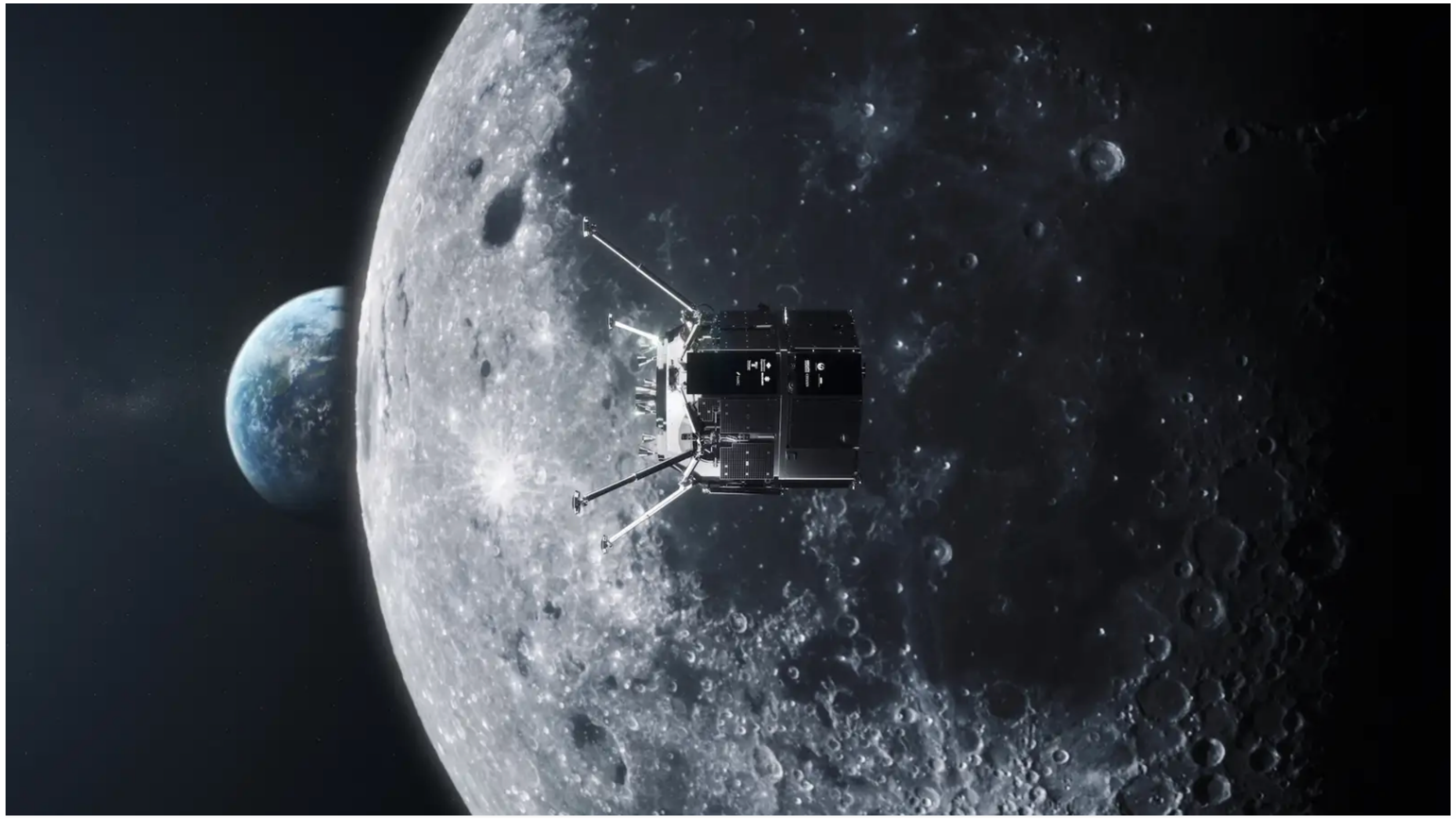
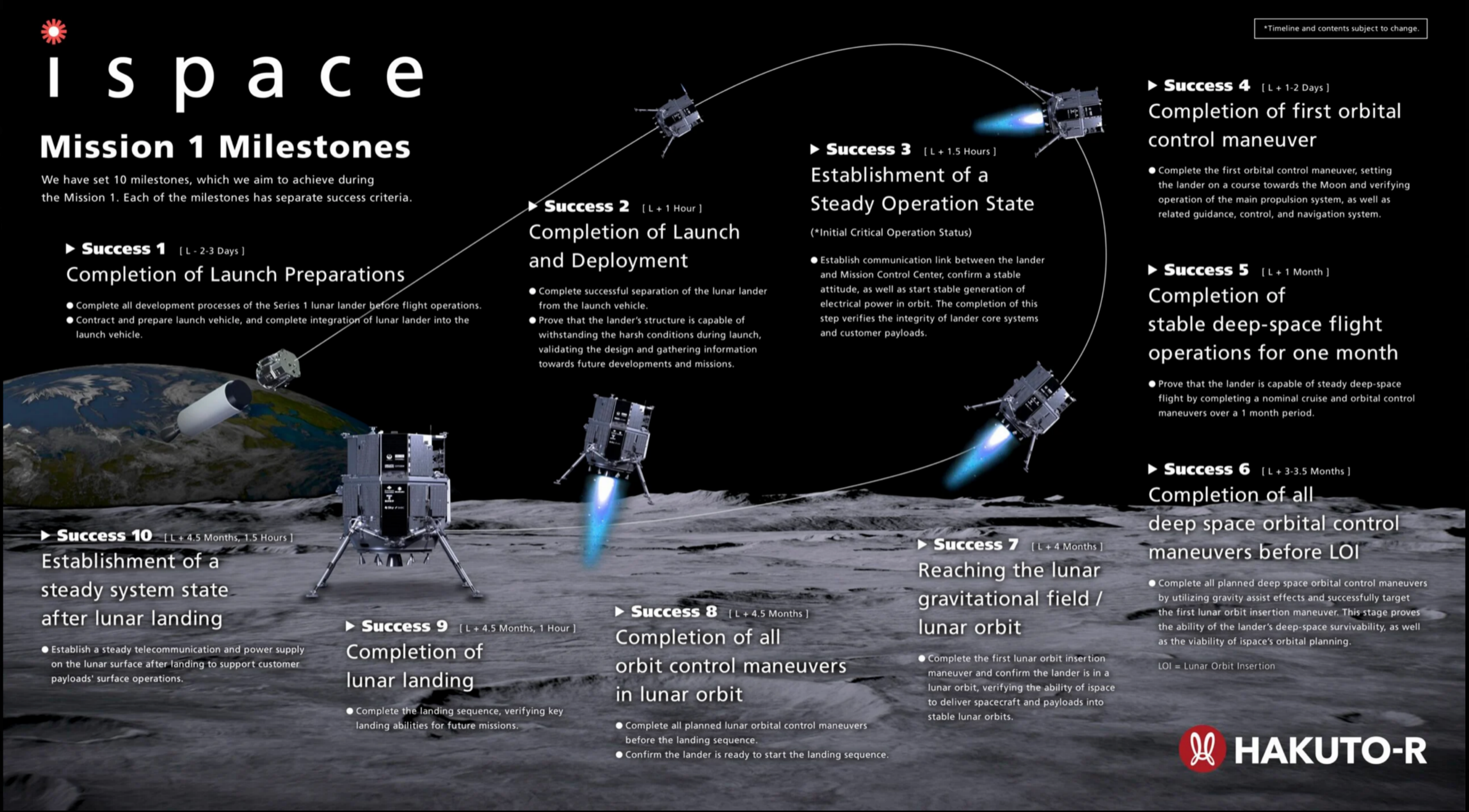


Image: ispace

Artistic impression of ispace's Hakuto-R Mission 1 lander.

Watch



ispace Hakuto-R Mission 1 profile and milestones.

What Constitutes Life?

(Take notes)

- First living entity was likely a self-replicating macromolecule that could:
  - Act as a template.
  - Catalyze reactions.
- First "living organism" was a type of enclosed environment, assisting replication.

Unicellular Tetrahymena

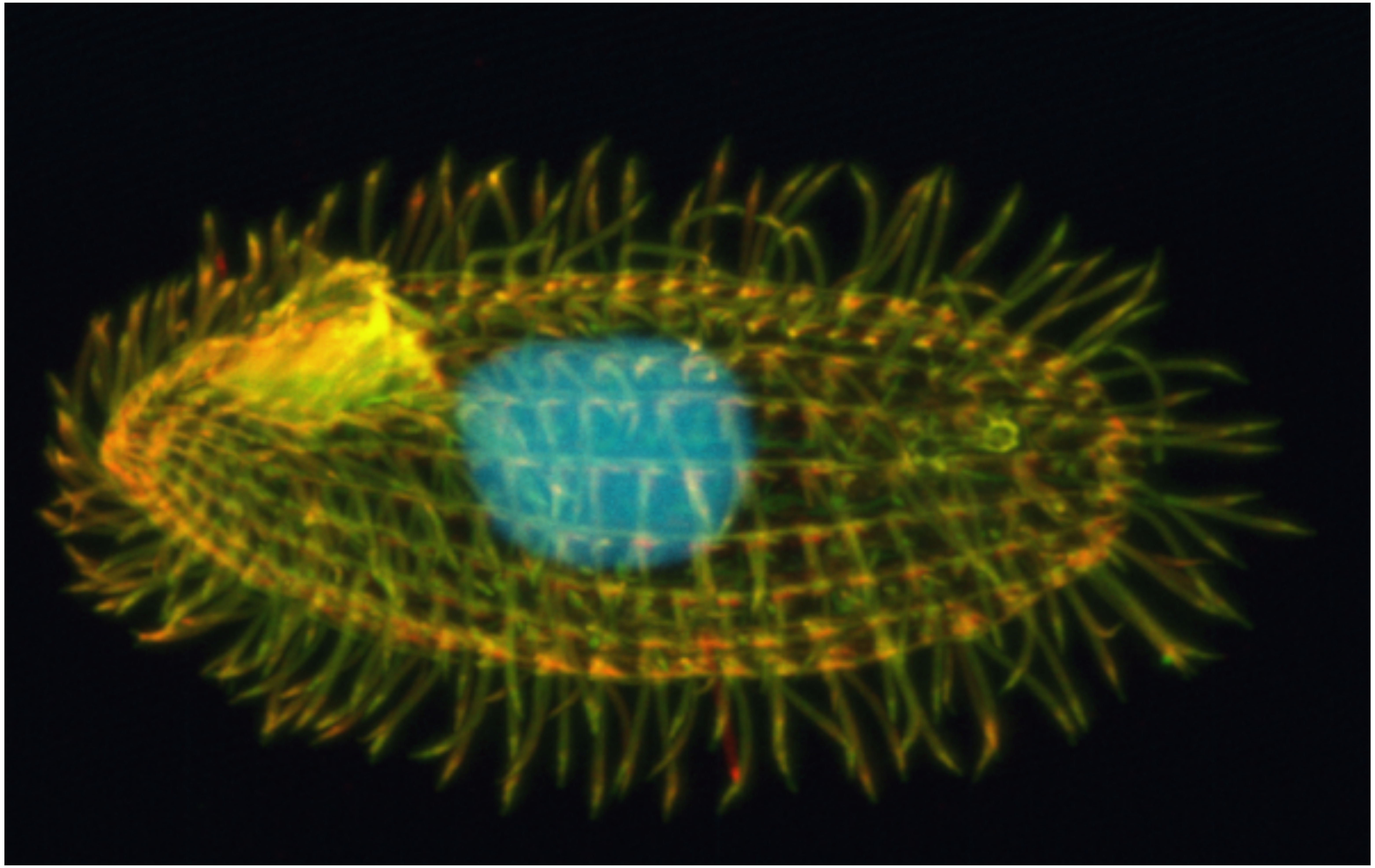
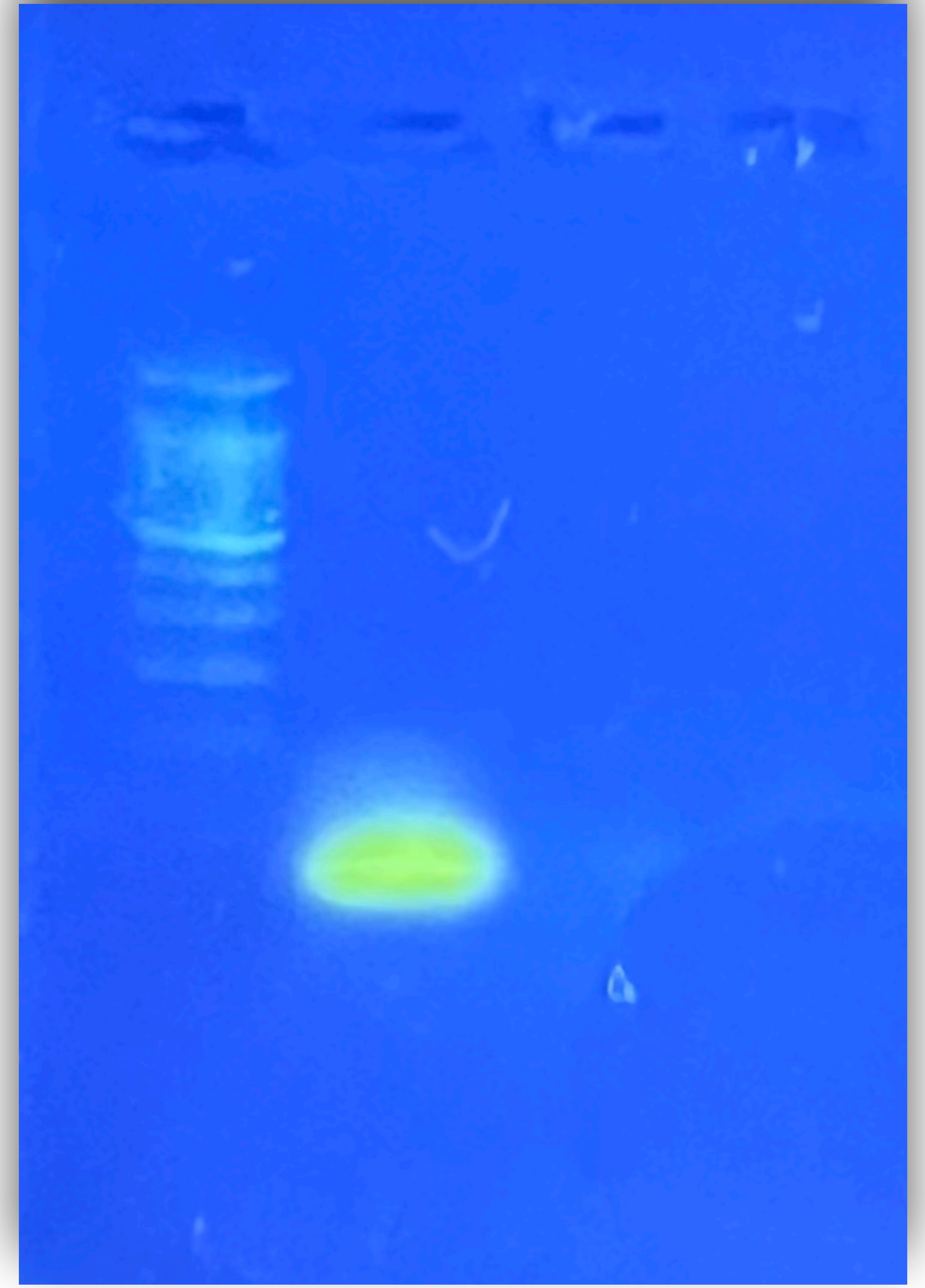
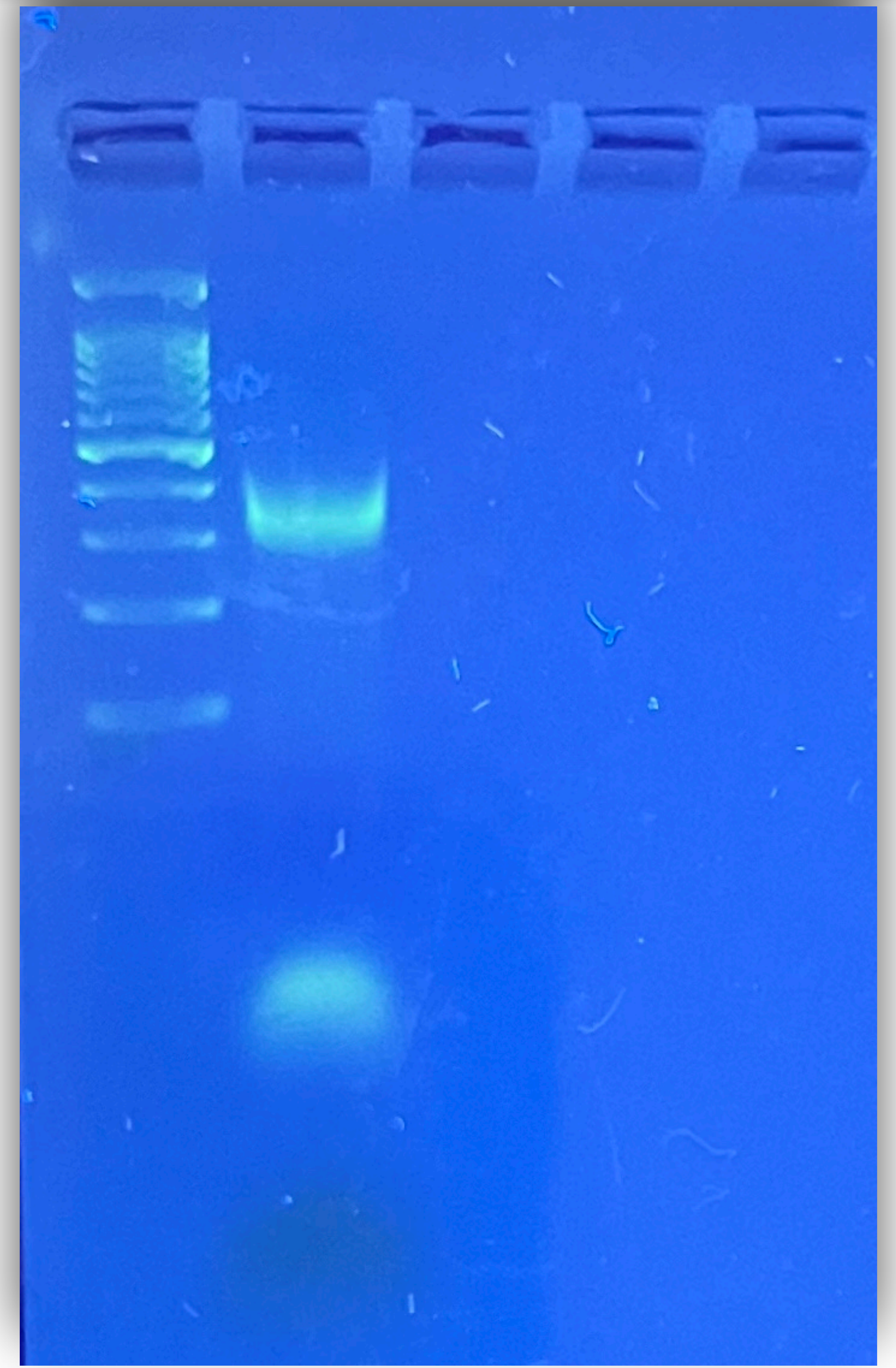


Fig. 6.7

A: courtesy Esther Zhuang and Kalju Kahn; B public domain

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





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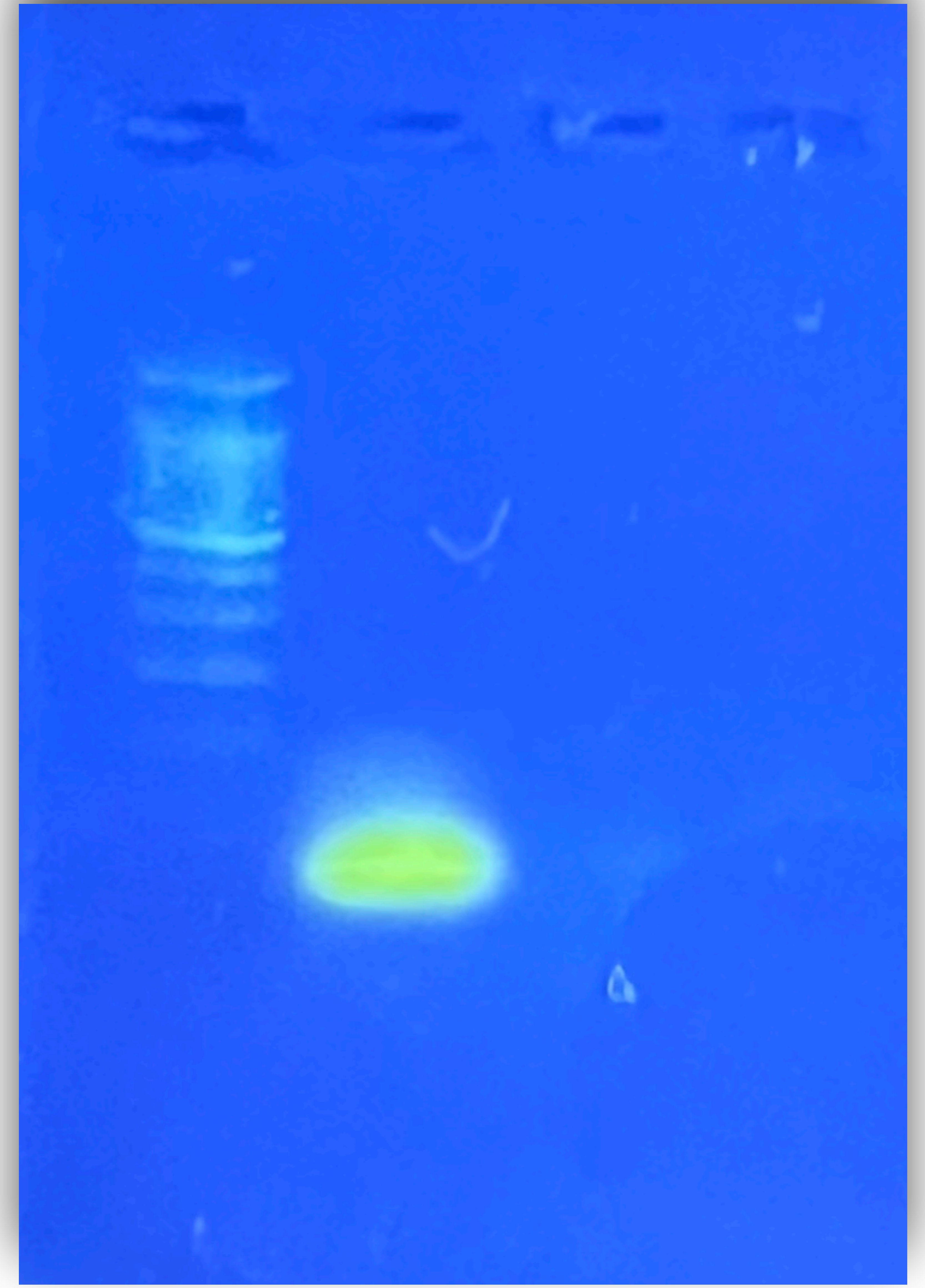
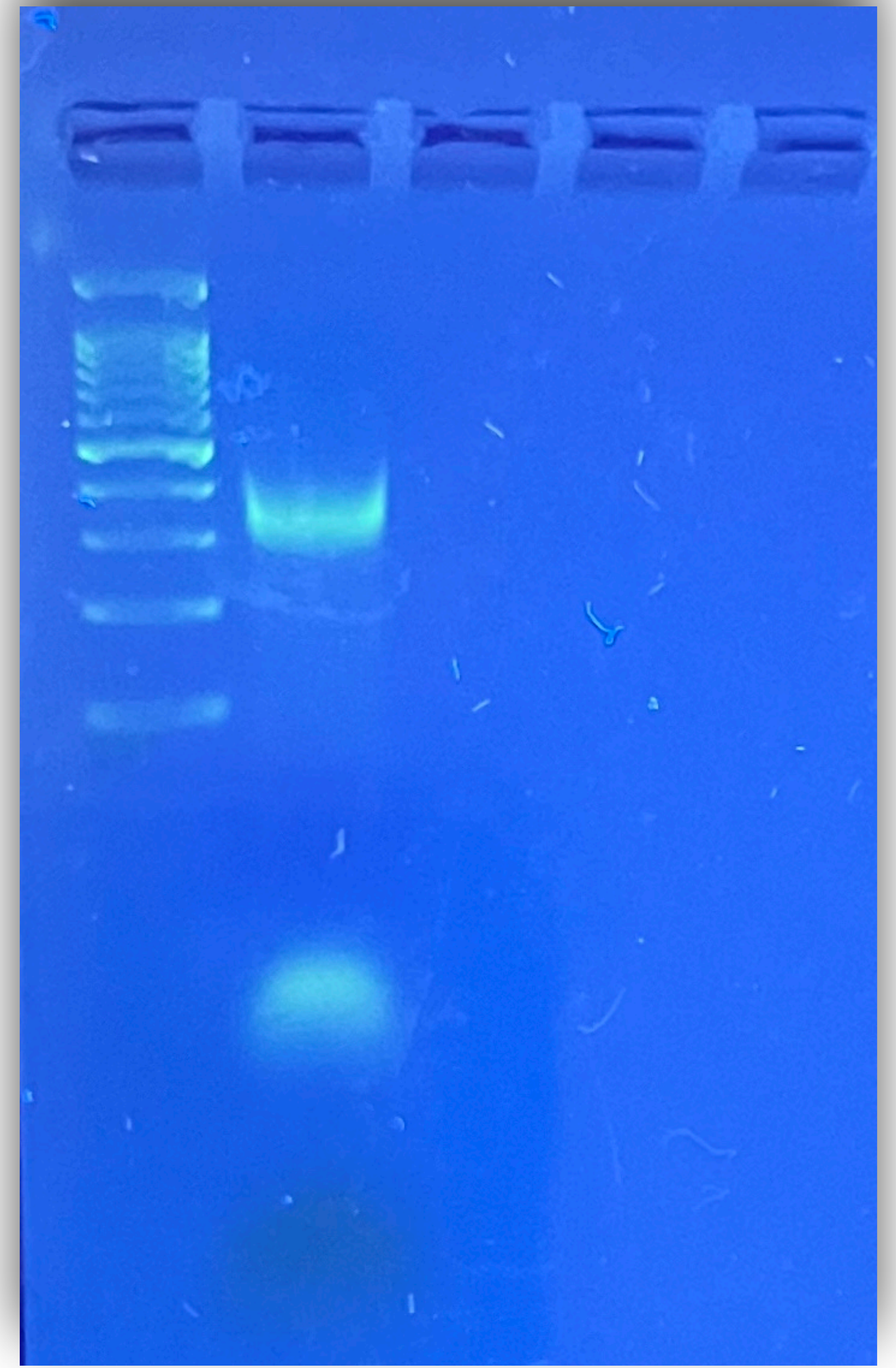




1. How do they visualize the molecules of interest?
2. How do they separate them in an orderly fashion?

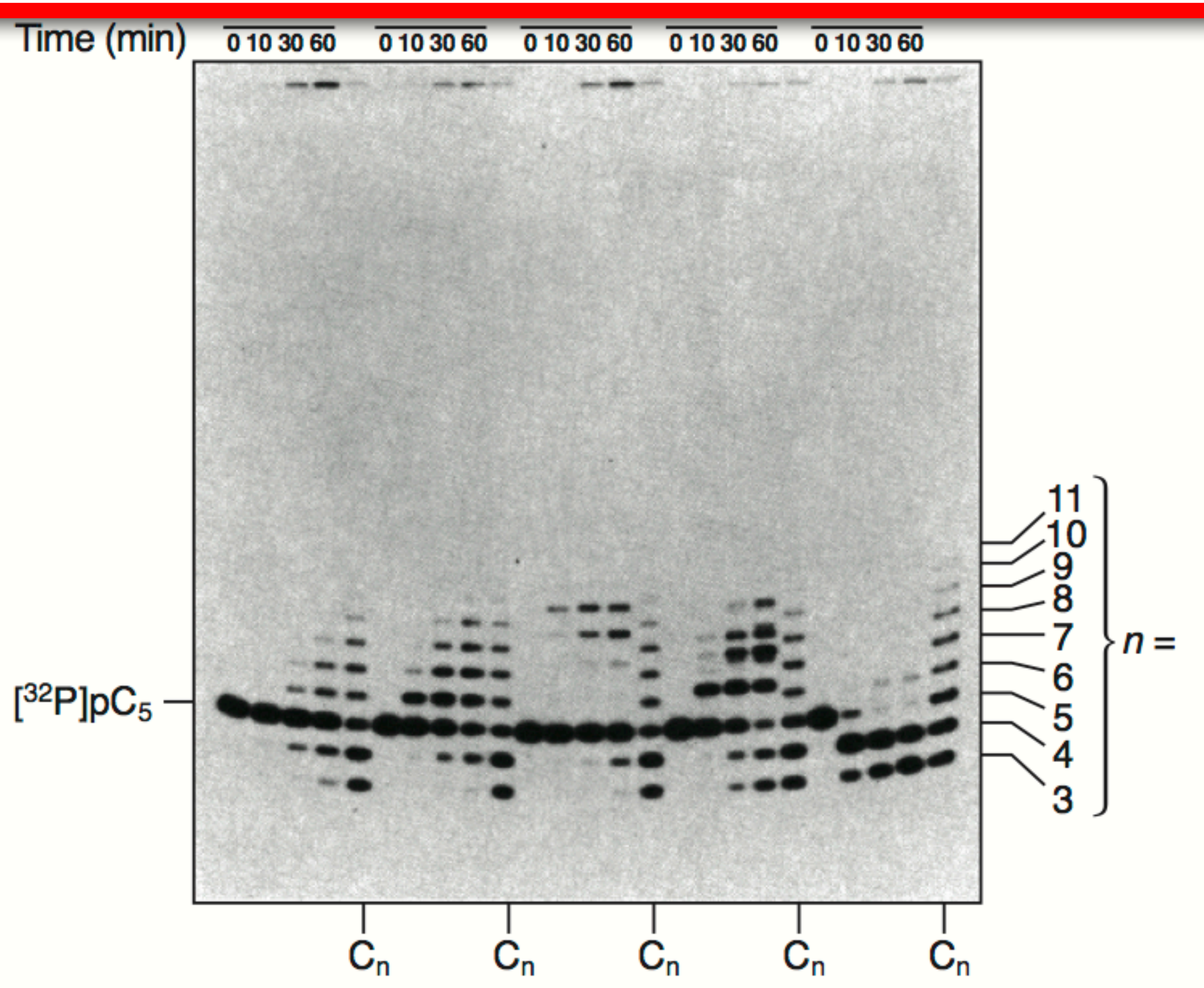


Figure 4.8 RNA polymerizes more RNA. Results are from gel electrophoresis of RNA molecules separated by size. RNA molecular size is indicated on the right side by

Modified from Been and Cech. 1998

Fig. 4.8

(Trifecta)

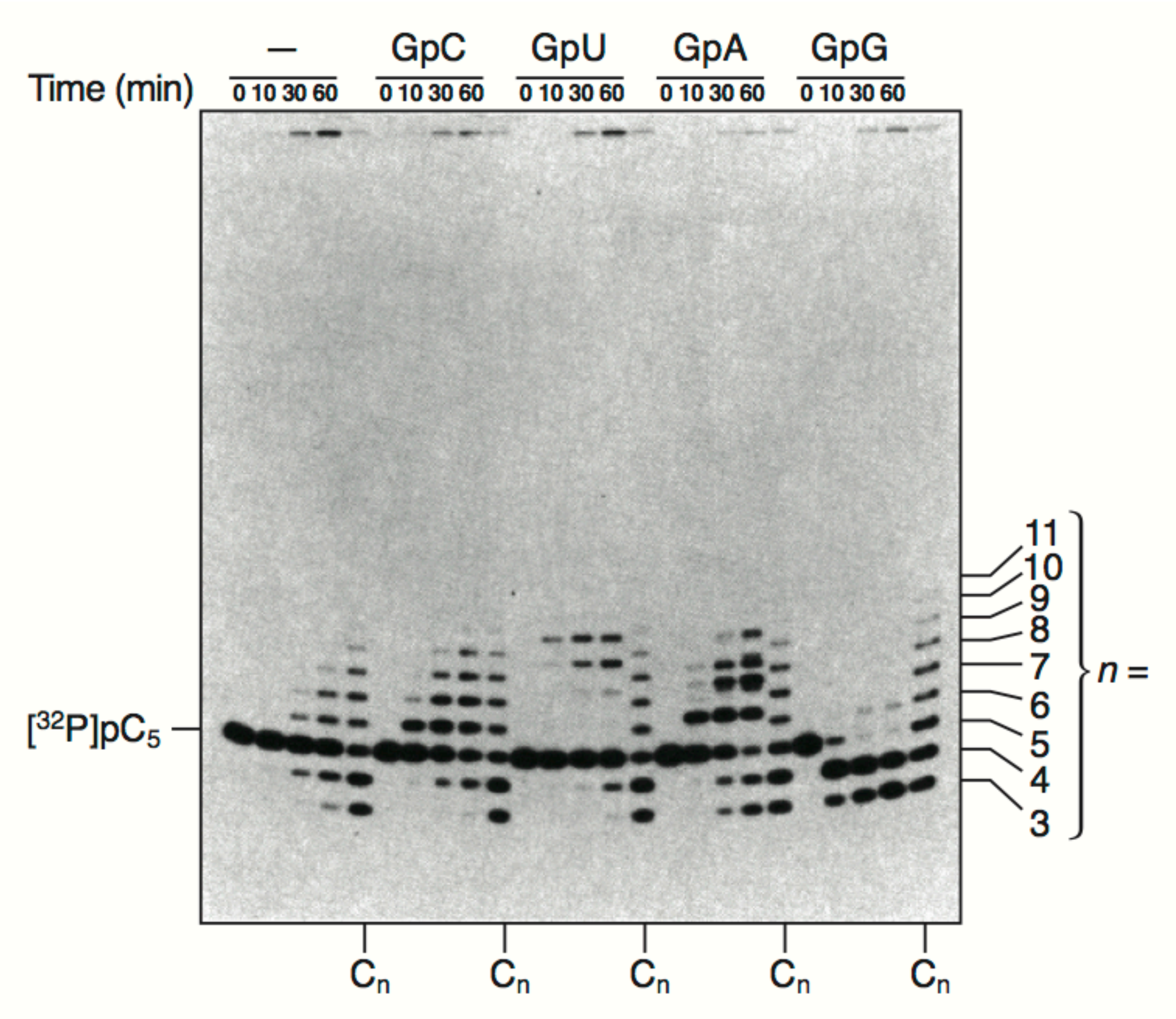


Figure 4.8 RNA polymerizes more RNA. Results are from gel electrophoresis of RNA molecules separated by size. RNA molecular size is indicated on the right side by

Fig. 4.8

Modified from Been and Cech. 1998

RNA World: RNA (ribozyme) can polymerize nucleotides

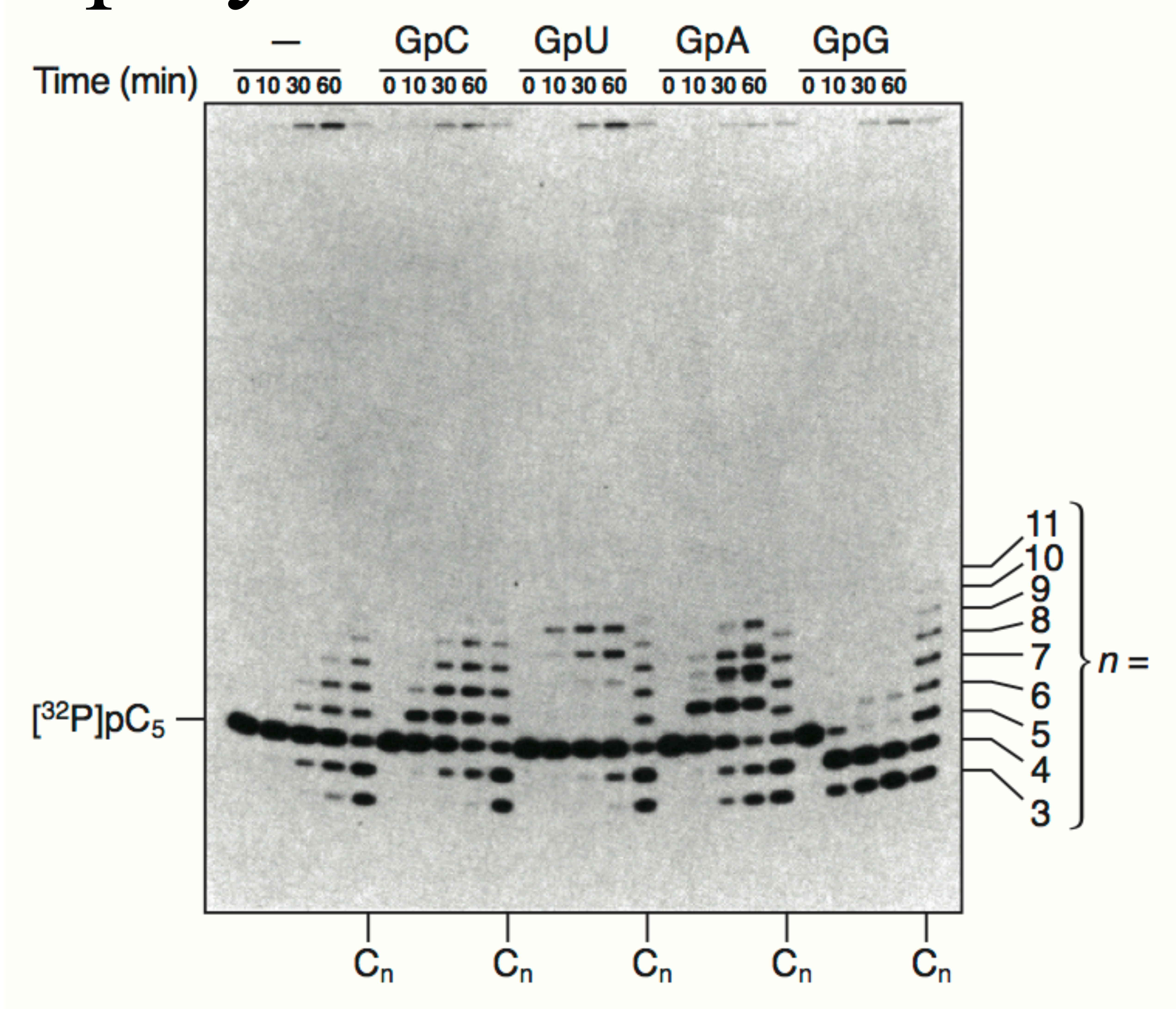


Fig. 4.8

Figure 4.8 RNA polymerizes more RNA. Results are

modified from Been and Cech. 1998

Functional Ribozyme

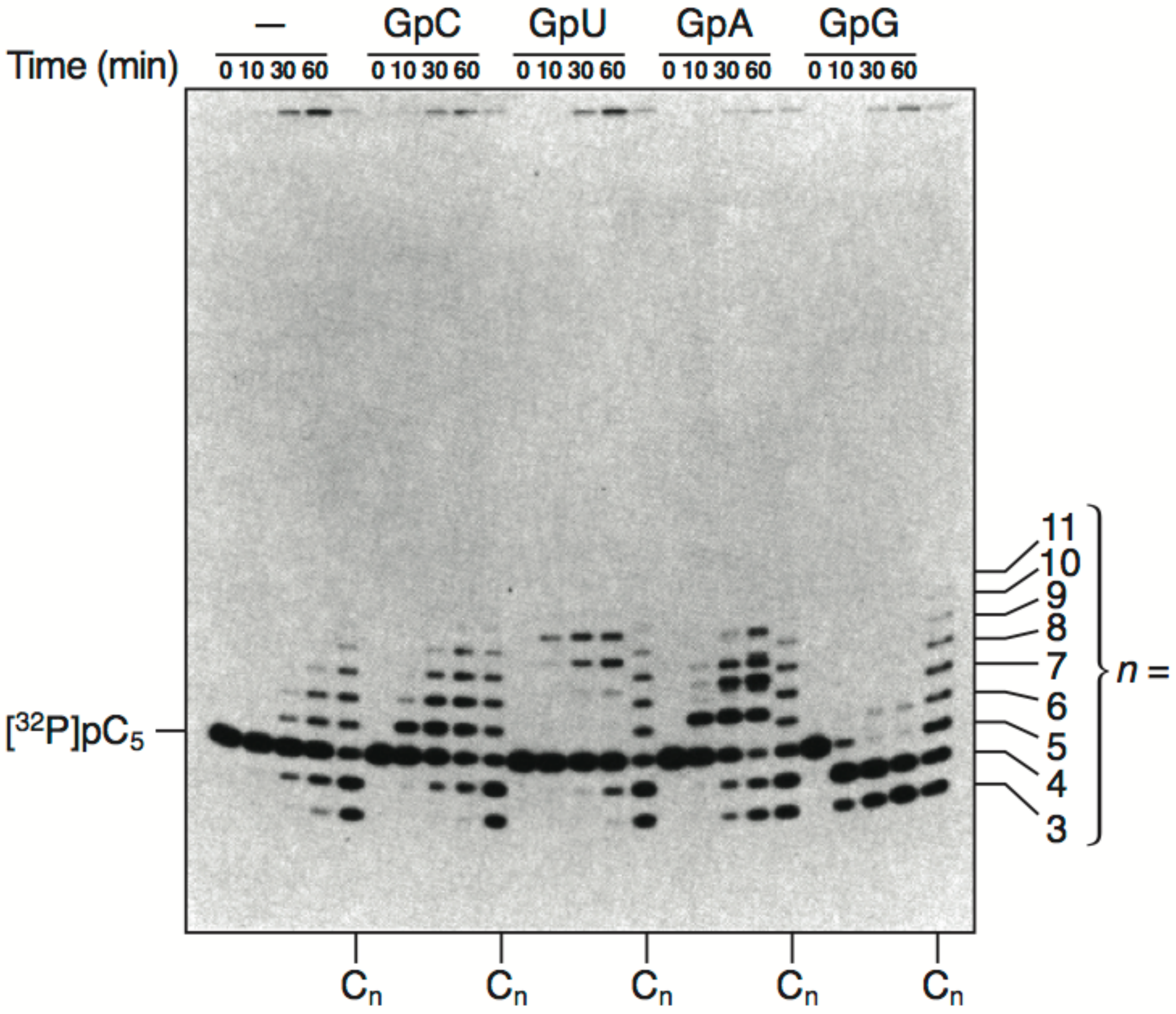
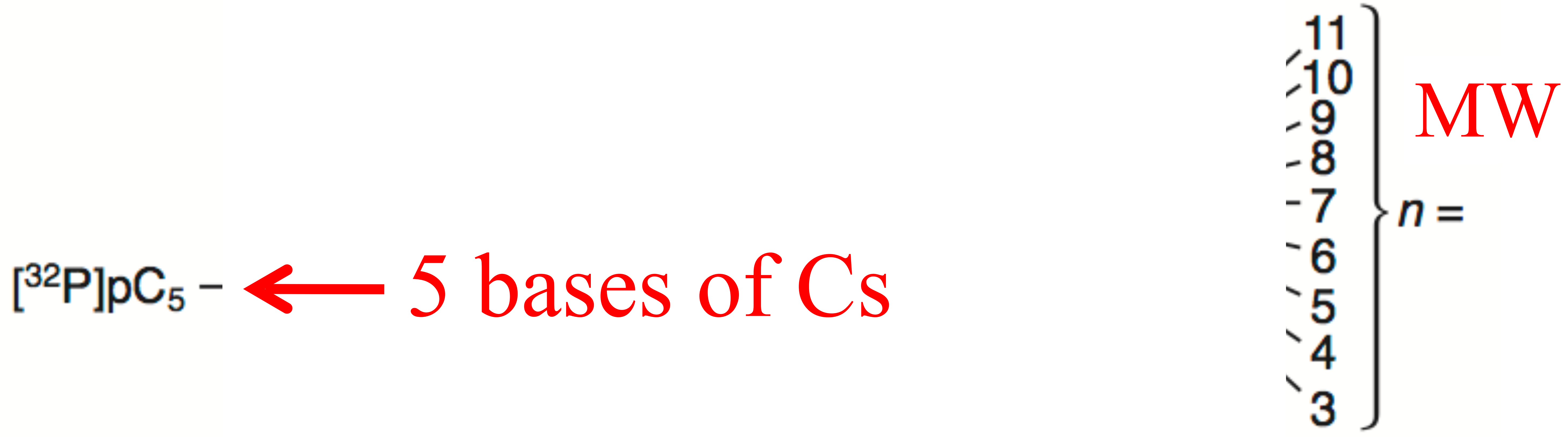


Fig. 6.8

modified from Been and Cech. 1998

Functional Ribozyme

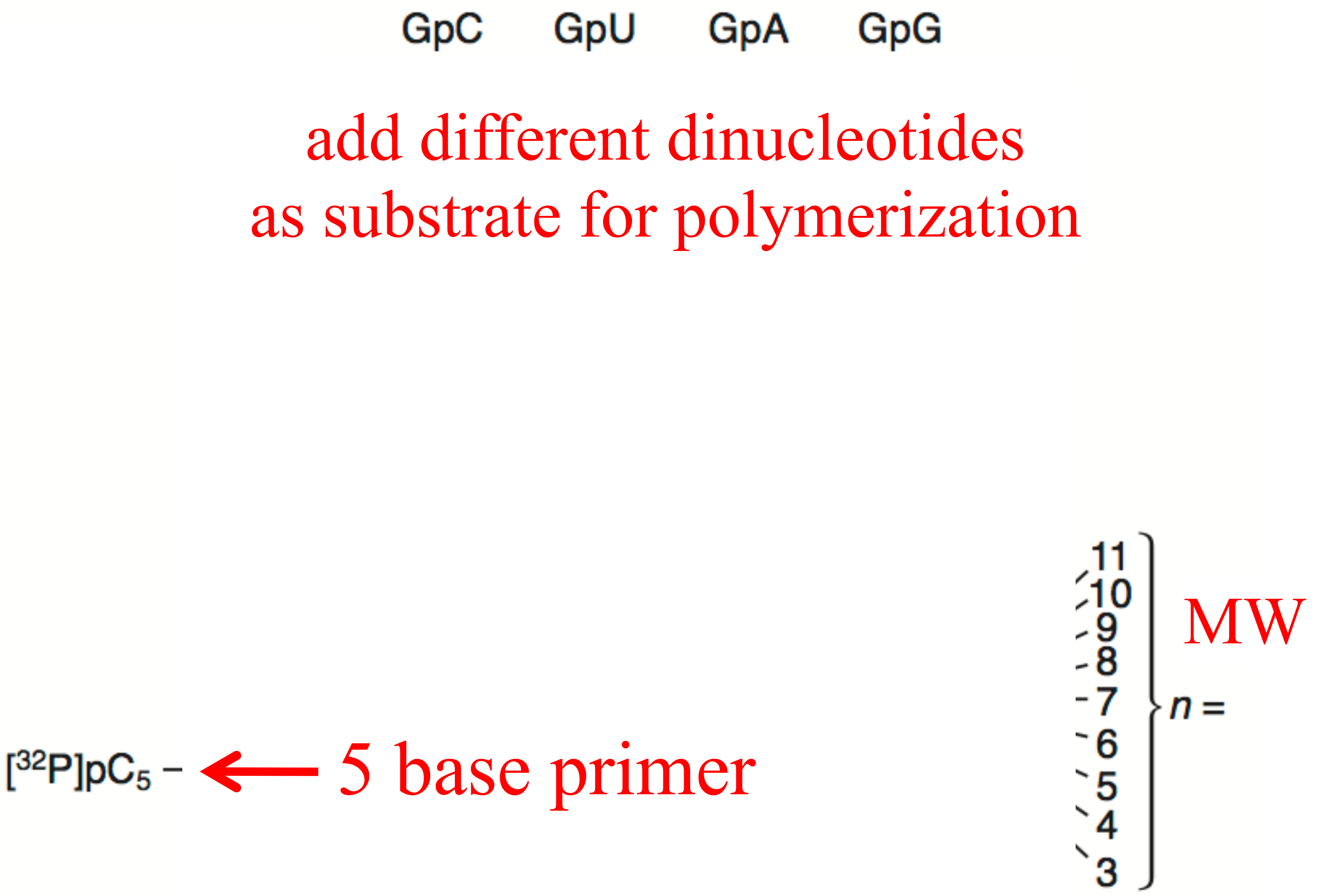
CpU + GpN + ribozyme → CpUpN + G + ribozyme.



modified from Been and Cech. 1998

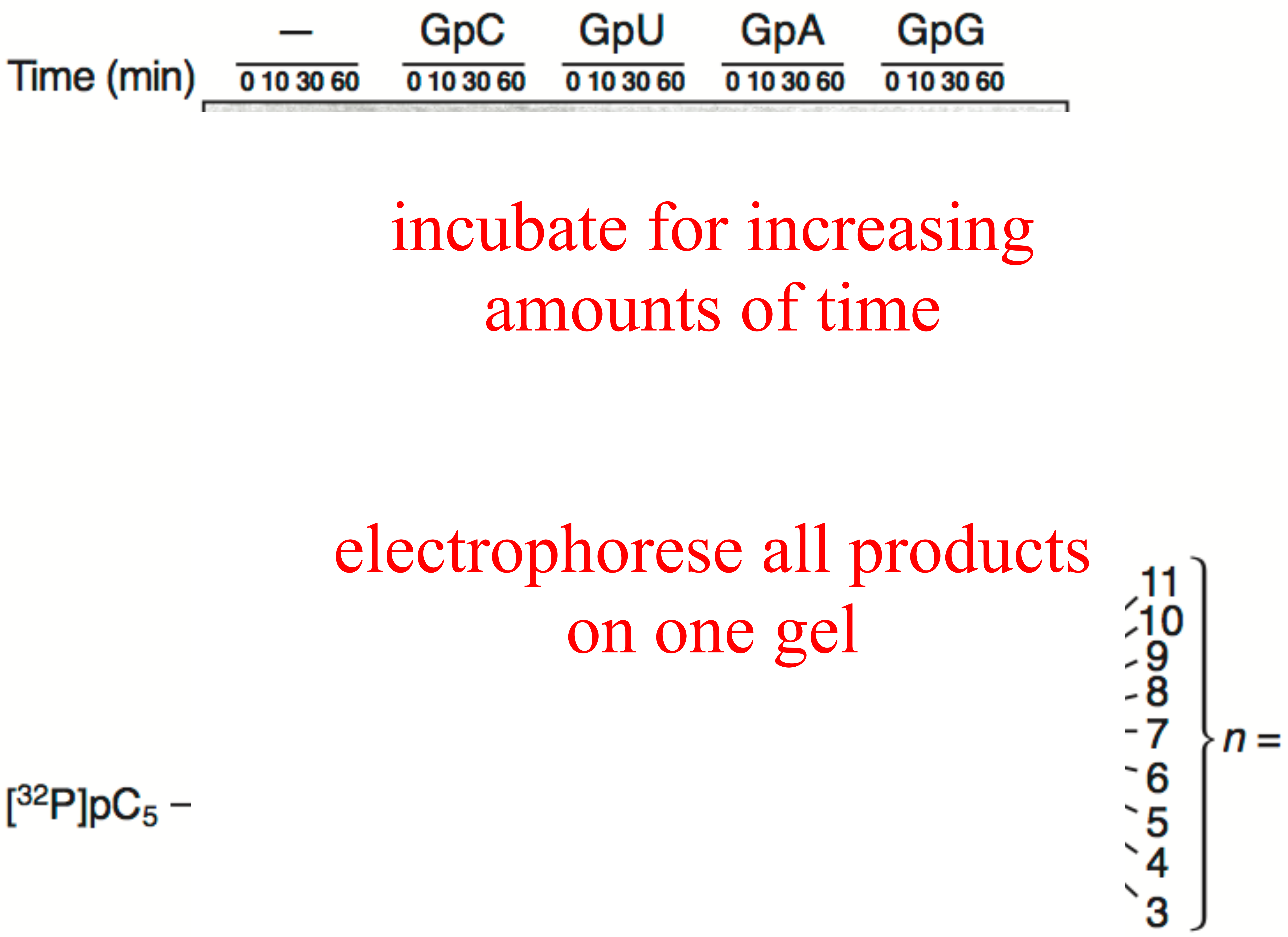
Functional Ribozyme

add different dinucleotides
as substrate for polymerization



modified from Been and Cech. 1998

Functional Ribozyme

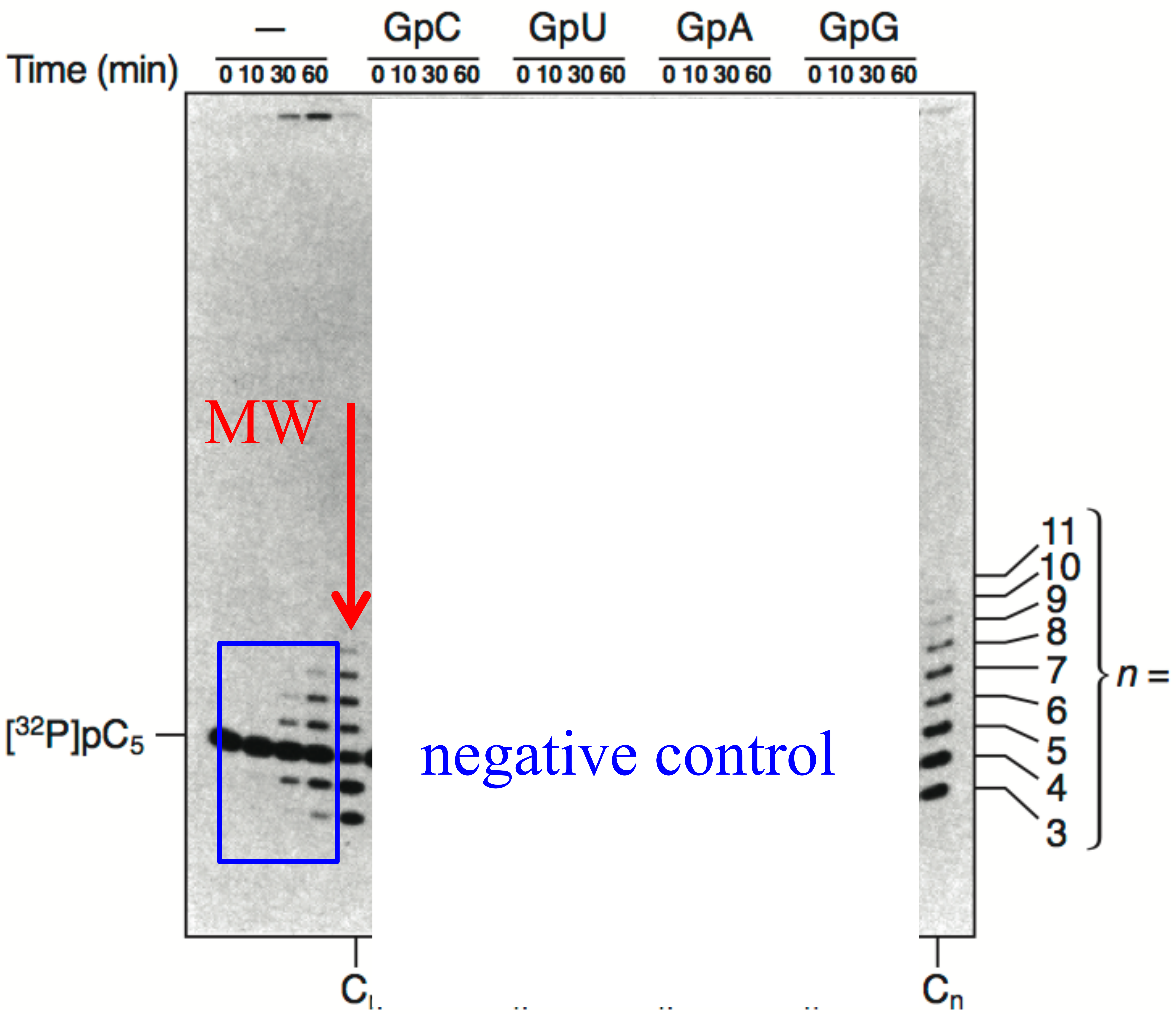


incubate for increasing amounts of time

electrophorese all products on one gel

modified from Been and Cech. 1998

Functional Ribozyme



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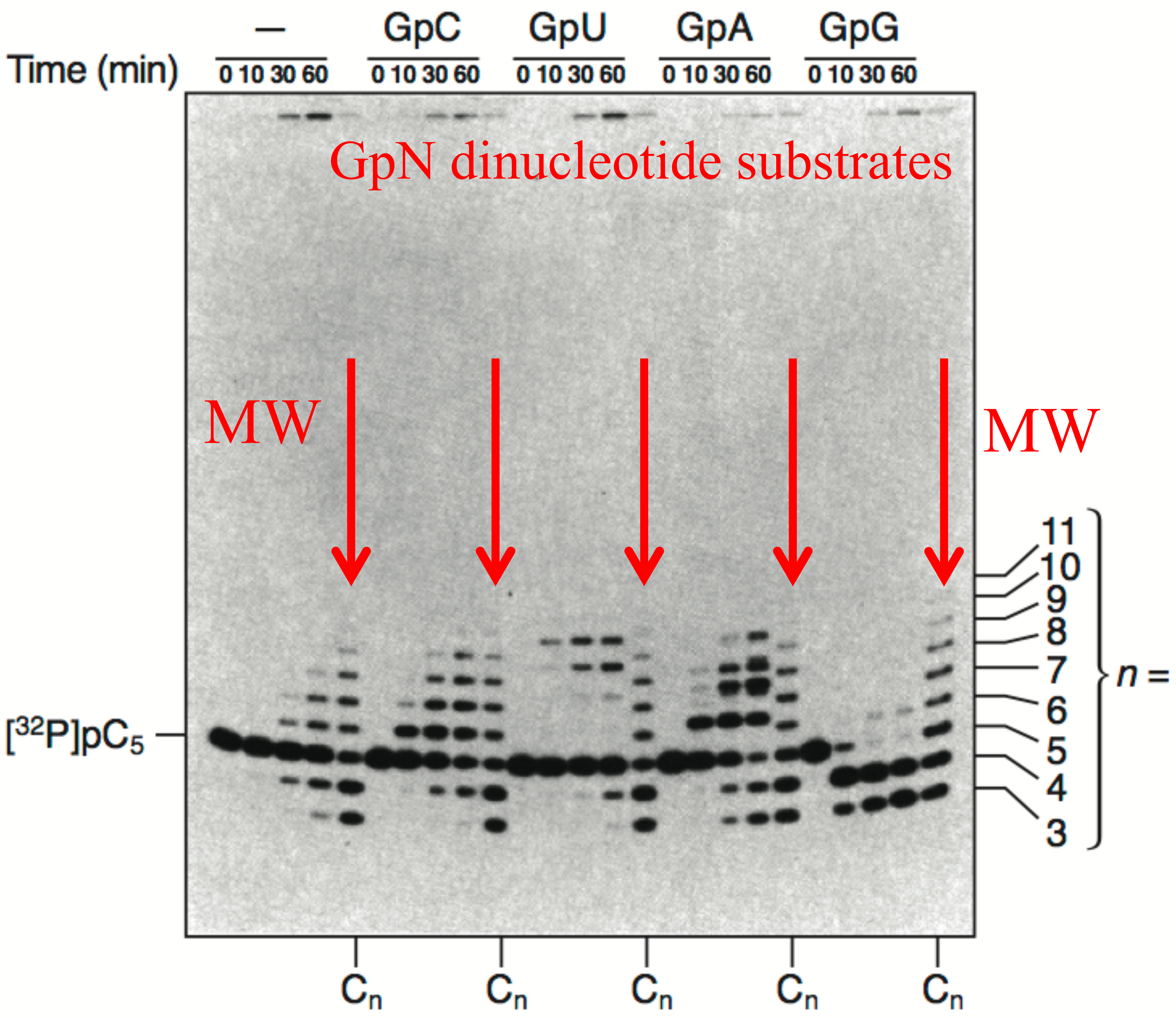
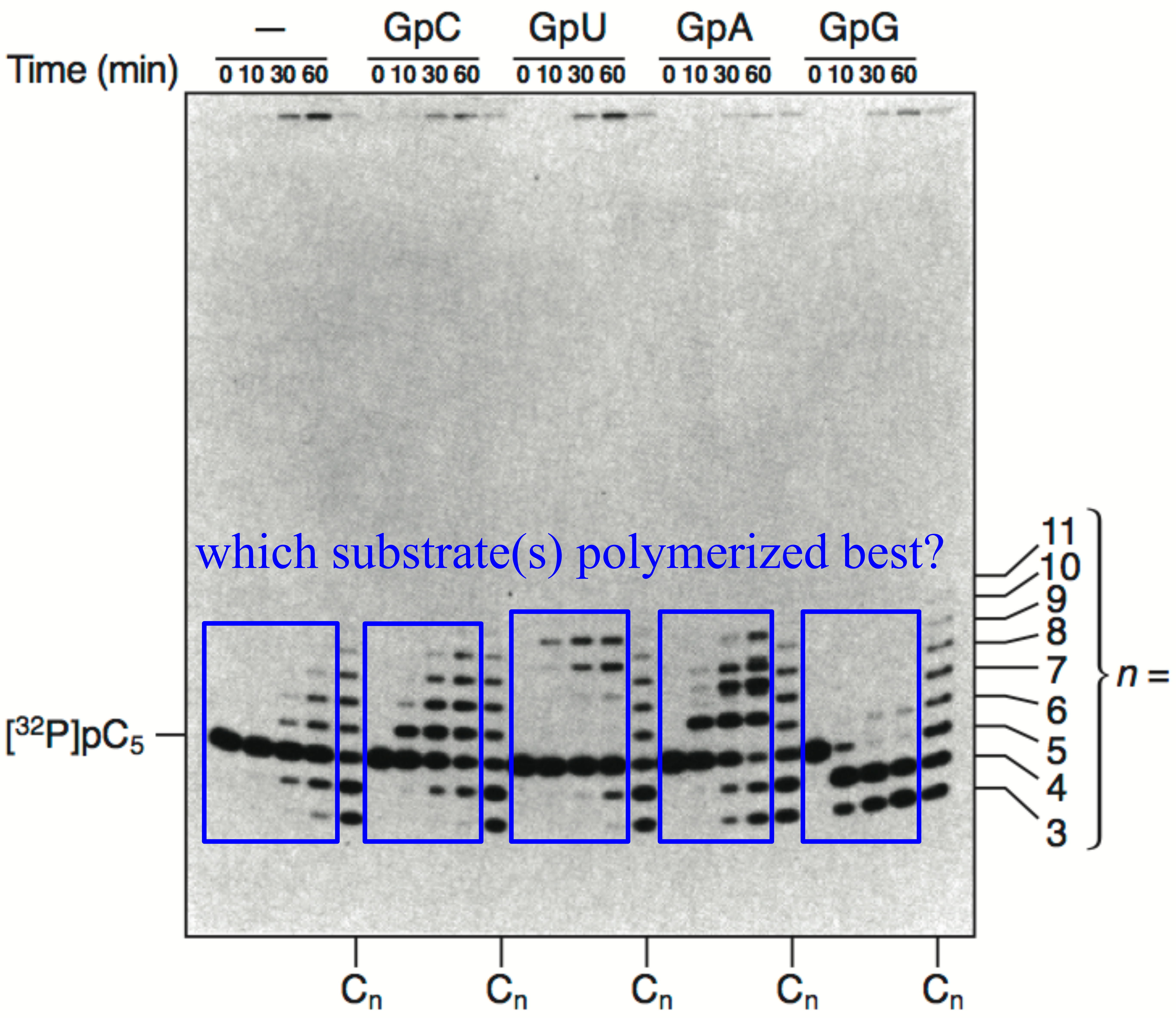
Functional Ribozyme



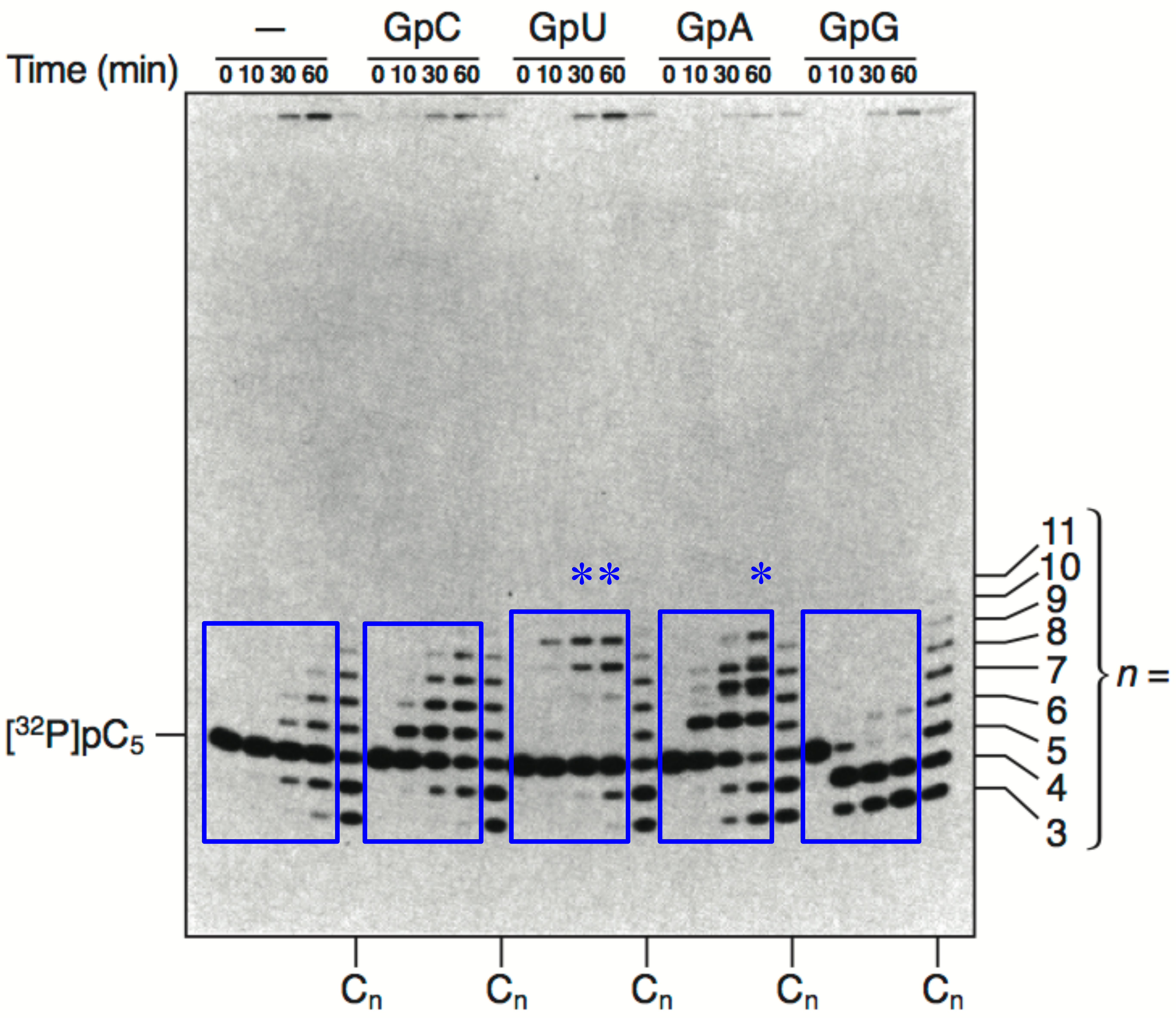
modified from Been and Cech. 1998

Functional Ribozyme



modified from Been and Cech. 1998

Functional Ribozyme



modified from Been and Cech. 1998

Announcements

- **Prof Interviews** (Luckie busy OHs, but still can make appts)

  Reminder: you voted for:

- Final exam **#1(alternate)** is Wednesday of week 15 (12:40pm)

VOTED: To cover material after Exam II (**VOTE NOW too?**)

  Final exam #2 (optional) is Tuesday of Final's Week 16, 12:45pm

- Final paper is due Thursday week 14 (tomorrow) 5pm
- Final lab period was Tuesday week 14 (yesterday)

Final Exam topics

W10	M, 31	***EXAM II***	*LIVE in-person (in classroom)*	
	W, 2 **Nov.**	Cellular	Lect. 17, Ch2 (2.1 RNA types)	*LIVE in-person (Luckie & LAs)*
W11	online	Cellular	Lect. 18, Ch2 (2.3 Translation)	Online videos (Malcolm Campbell)
	W, 9	Cellular	Lect. 19, Ch2 (Slides e.g. Translation)	*in-person (Luckie & LAs)*
W12	online	Molecular	Lect. 20, Ch1 (1.1, 1.2 Griffith)	Online videos (Luckie & LAs)
	W, 16	Molecular	Lect. 21, Ch1 (1.4 DNA struct)	*LIVE in-person (Luckie & LAs)*
W13	online	Molecular	Lect. 22, Ch1 (1.5 epigenetics)	Online videos (Malcolm Campbell)
	W, 23	Molecular	Journal Club (6.5 race-medicine)	*IVE in-person (Luckie & LAs)*

Thanksgiving Break, Nov. 24-27

W14	online	Molecular	Lect. 23, Ch4 (4.1 Evolution)	Online videos (Malcolm Campbell)
	W, 30	Molecular	Lect. 24, Ch4 (4.2 Miller)	*LIVE in-person (Luckie & LAs)*

TBA see official schedule (tentative time/date) **FINAL EXAM** finals week 2022