

## 1. **Pick up** Name Folder

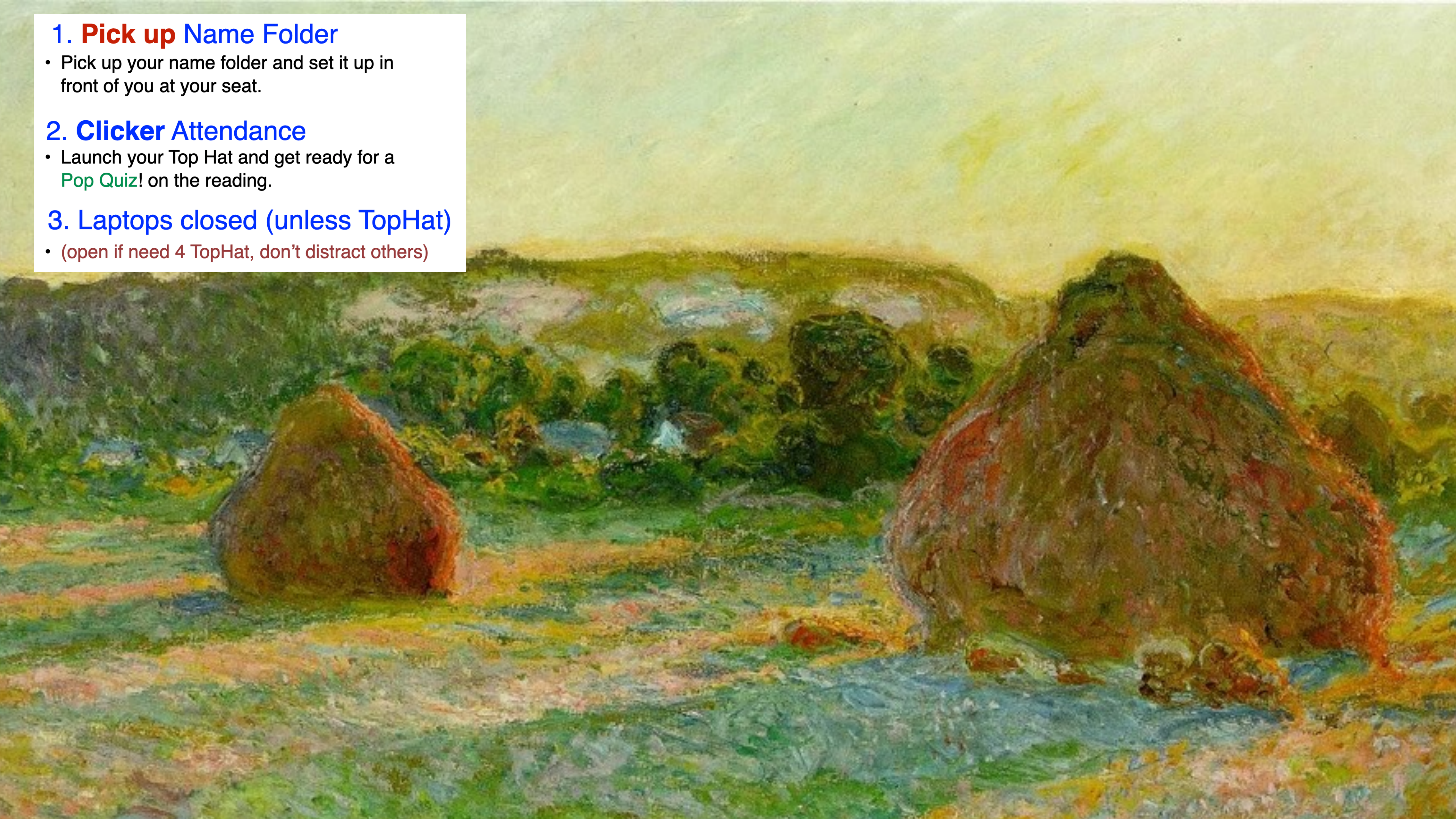
- Pick up your name folder and set it up in front of you at your seat.

## 2. **Clicker Attendance**

- Launch your Top Hat and get ready for a **Pop Quiz!** on the reading.

## 3. **Laptops closed (unless TopHat)**

- (open if need 4 TopHat, don't distract others)



# Announcements

1. **Advice: Remember Course pack for admission to lab today.** On Monday, show us your best work for the formal Proposal Talks (LIVE & recorded video).
2. **144 Contract (pink version):** signed and submitted by Friday 5pm
3. **Office Hours-** M/W 2-3pm, if there's a line, 10-minute limit.
4. **TopHat questions** gain points if answered correctly (but only need to get half of them correct, 50%, to earn 4.0 for attendance and participation)
5. **We will use a *University-level Grading System* this semester and scores will be grade levels, 4.0, 3.5, 3.0, 2.5, etc for human-graded assignments.** Everyone who earns same grade level on an assignment gets the exact same percentage score for it, e.g. all "3.5" grades ultimately become a 87.5% for everyone, all "4.0" grades become a 95% for everyone.

# What is a 4.0?

In the university grading system

*Quantity*

PERCENTAGE of mastery = PERCENTAGE grade

# What is a 4.0?

In the university grading system

*Quality*

Quality of work = Level of grade

# What is a 4.0?

In the university grading system

**If a student does mostly what was asked of them on an assignment and does a pretty good job, what's the grade supposed to be?**

- a. 4.0
- b. 3.5
- c. 3.0
- d. 2.5
- e. other

# What is a 4.0?

In the university grading system

- The “**4.0**” is **Outstanding** is the student blew you away with how much and how well they did the work. They taught you something you didn’t know.
- A “**3.5**” is **Most Excellent** every detail of their work was done extremely well and they found additional papers and evidence beyond what they were told/expected to do, to complete their work.
- A “**3.0**” is **Excellent** is impressive work, top of the class, and their work was done extremely well but nothing beyond what was expected.
- 2.0-2.5 "Pretty Good" the student mostly did the work required and a pretty good job, the average in the class.

# SpaceX launches Japanese lander, UAE rover to the moon

By [Mike Wall](#) published December 11, 2022

A tiny NASA moon probe that aims to hunt for lunar water ice went along for the ride as well.

[f](#) [t](#) [r](#) [p](#) [F](#) [e](#) [c](#) Comments (0)

[Click here for more Space.com videos...](#)



\*Timeline and contents subject to change.

# ispace

## Mission 1 Milestones

We have set 10 milestones, which we aim to achieve during the Mission 1. Each of the milestones has separate success criteria.

### ► Success 1 [ L - 2-3 Days ]

#### Completion of Launch Preparations

- Complete all development processes of the Series 1 lunar lander before flight operations.
- Contract and prepare launch vehicle, and complete integration of lunar lander into the launch vehicle.

### ► Success 2 [ L + 1 Hour ]

#### Completion of Launch and Deployment

- Complete successful separation of the lunar lander from the launch vehicle.
- Prove that the lander's structure is capable of withstanding the harsh conditions during launch, validating the design and gathering information towards future developments and missions.

### ► Success 3 [ L + 1.5 Hours ]

#### Establishment of a Steady Operation State

(\*Initial Critical Operation Status)

- Establish communication link between the lander and Mission Control Center, confirm a stable attitude, as well as start stable generation of electrical power in orbit. The completion of this step verifies the integrity of lander core systems and customer payloads.

### ► Success 4 [ L + 1-2 Days ]

#### Completion of first orbital control maneuver

- Complete the first orbital control maneuver, setting the lander on a course towards the Moon and verifying operation of the main propulsion system, as well as related guidance, control, and navigation system.

### ► Success 5 [ L + 1 Month ]

#### Completion of stable deep-space flight operations for one month

- Prove that the lander is capable of steady deep-space flight by completing a nominal cruise and orbital control maneuvers over a 1 month period.

### ► Success 6 [ L + 3-3.5 Months ]

#### Completion of all deep space orbital control maneuvers before LOI

- Complete all planned deep space orbital control maneuvers by utilizing gravity assist effects and successfully target the first lunar orbit insertion maneuver. This stage proves the ability of the lander's deep-space survivability, as well as the viability of ispace's orbital planning.

LOI = Lunar Orbit Insertion

### ► Success 10 [ L + 4.5 Months, 1.5 Hours ]

#### Establishment of a steady system state after lunar landing

- Establish a steady telecommunication and power supply on the lunar surface after landing to support customer payloads' surface operations.

### ► Success 9 [ L + 4.5 Months, 1 Hour ]

#### Completion of lunar landing

- Complete the landing sequence, verifying key landing abilities for future missions.

### ► Success 8 [ L + 4.5 Months ]

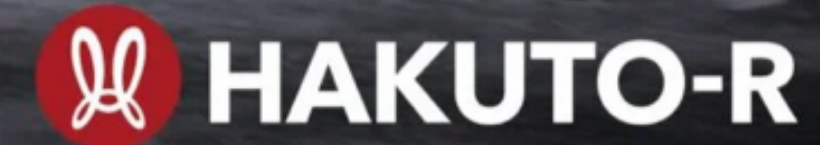
#### Completion of all orbit control maneuvers in lunar orbit

- Complete all planned lunar orbital control maneuvers before the landing sequence.
- Confirm the lander is ready to start the landing sequence.

### ► Success 7 [ L + 4 Months ]

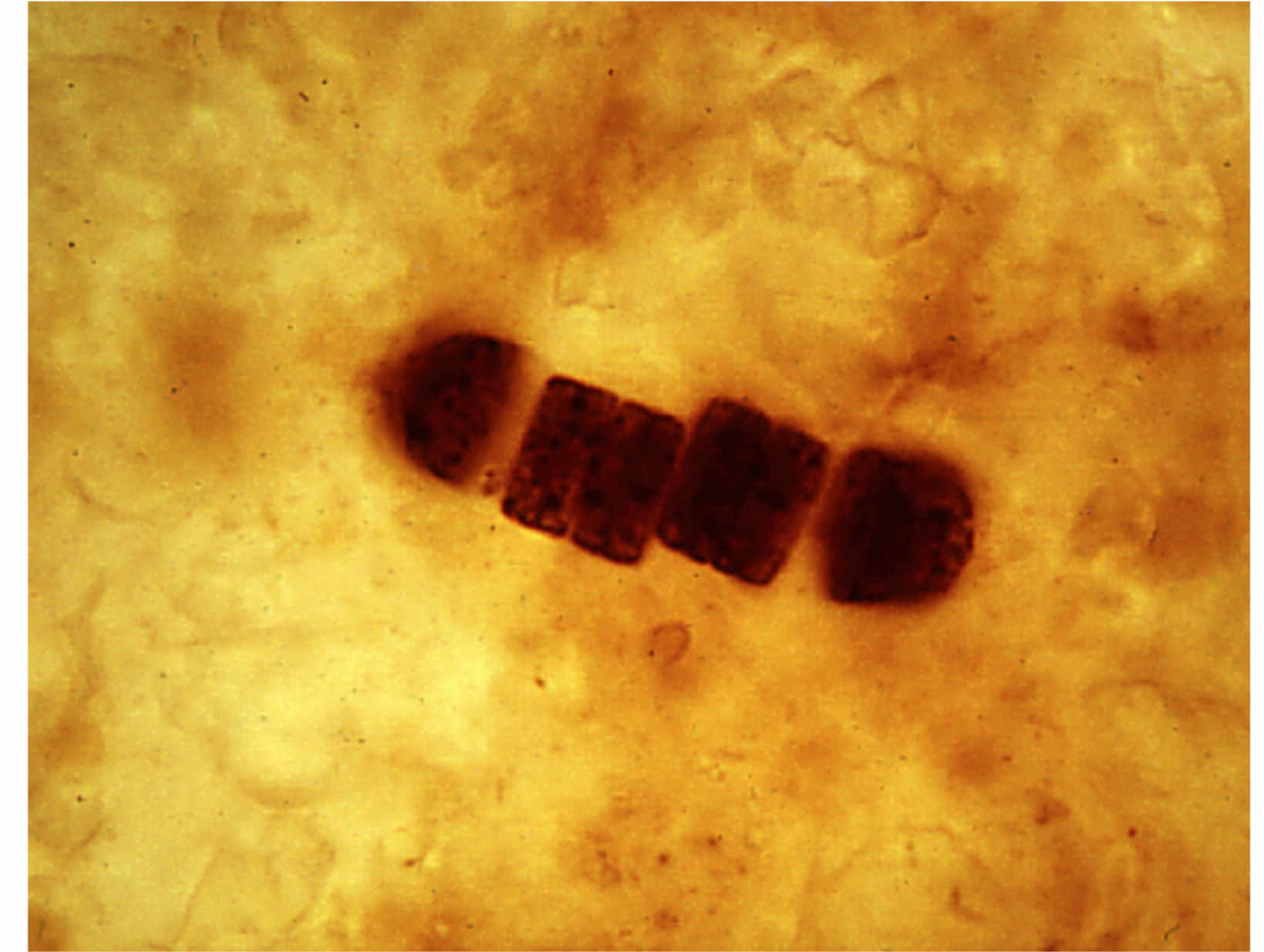
#### Reaching the lunar gravitational field / lunar orbit

- Complete the first lunar orbit insertion maneuver and confirm the lander is in a lunar orbit, verifying the ability of ispace to deliver spacecraft and payloads into stable lunar orbits.



## 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".

1/18/23 Evolution + Origin of cells

Section 4.2 Could abiotic molecules ... form life?

- Pink sheets  
- need Crock

L.O.s

- Use evidence to support life came from abiotic...
- Define four properties of life
- Describe how RNA molecules can be enzymes

Origin of life

- > long been a religious question, ELSI 4.1 clarified no fight between religion + science
- > could life come from non-life?
- > life made up of four molecules Nucleic Acids, CHOs, Lipids, Proteins "organic molecules"  
↳ intro to Lipids + phospholipids -> vesicles + micelle structures
- > Generally, atoms do not typically self-assemble spontaneously if mixed in tube
- > chicken vs. egg, all theory vs how first cell formed?

IQs: 1. molecule structure + hydrophilic/phobic NOPS 2. Look at structures, fatty acid amino acids

1953 -> Univ. of Chicago Stanley Miller

-> tried to replicate primitive earth conditions, see if can make complex molecules

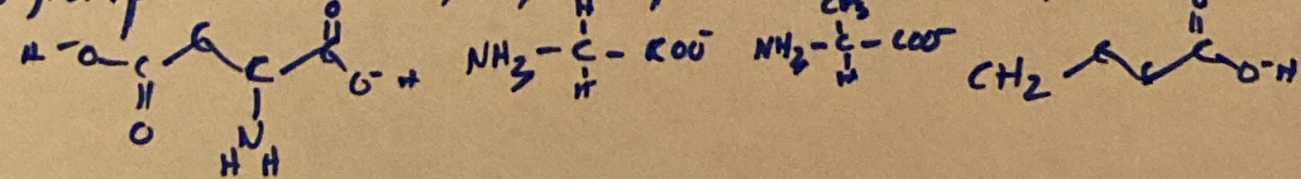
Figure 4.5

Purpose -> test if abiotic -> biotic in early earth conditions

Methods -> glassware, heat, spark, coolant, vacuum, H<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub> gas ran for entire week student WOB illustrate + explain? used spray stain to visualize

Findings - observed water -> pink -> red (cloudy), pulled out, liquid dried used 2D TLC to separate + visualize molecules to ID them to concentrate

ID'd: (aa's): aspartic acid, glycine, α-Alanine, butyric acid (fat)



-> Since 1953 others have found more lipids + nucleic acids

-> NASA also found lipids in meteorite (landed in Australia 1969) then 2001

-> NASA chemists replicated outer space synthesis of lipids via UV light on inorganic

-> Interstellar ice has same four gases as in NASA experiment + UV is abundant too these lipids form vesicles 3D + can carry cargo.

Fig 4.6 - lipids + vesicles + structure illustration of vesicles

IQ 3. Outcome of Miller's experiment? New Qs? Meteorite? 4. 2008 Pabbed paper

(section 4.2 cont.)

2008 Science paper by Johnson et al - re examined Miller's samples disassembled his volcanic apparatus vs classic one. -> Found aa's, lipids ∴ proteins, fats, nucleic acids

\*So, if found complex organic materials can be generated from abiotic they turned to question, could one create a cell?

Life's properties: Change, Replication, energy + existence as 3D + cargo  
↳ who can copy themselves?

Self-organizing + replicating molecules

Membranes... RNA molecules... not alive, life emerges...  
ribosomes are self-organizing, (lipids are too.)

1985 -> RNA-world hypothesis - earliest genomes were RNA (+ enzymes)

• result of discovery of ribozymes = Nobel Prize

-> bizarre little organism Tetrahymena RNA could self-splice its intron cut + ligate! 186nts

Ribozyme can do this CpU + GpN + ribozyme (chemistry)

-> CpUpN + G + ribozyme

glue tag DNA polymerase

Figure 4.8 | Been + Cech 1988 Science

"Net Elongation of an RNA Primer catalyzed by the Tetrahymena Ribozyme" - PCR knowledge help you translate title to human language?

Purpose: test RNA world hypothesis or test if ribozyme can elongate primer

Methods: Controls -> negative -> absence of free nucleotides (dinucleotides specific)

"Starter RNA" pCs is 5-base long Primer of just C<sub>5</sub>C<sub>4</sub>C<sub>3</sub>C<sub>2</sub>C<sub>1</sub>

In four separate tubes had different free nucleotides (A, G, C, U)

Analysis by gel electrophoresis, gel separates, radioactivity GpA, GpG, GpC, GpU

X-ray film exposed to radioactivity turned black. visualizes 32P \* radioactive

MW ladders included 3 to 11 bases in length + radioactive

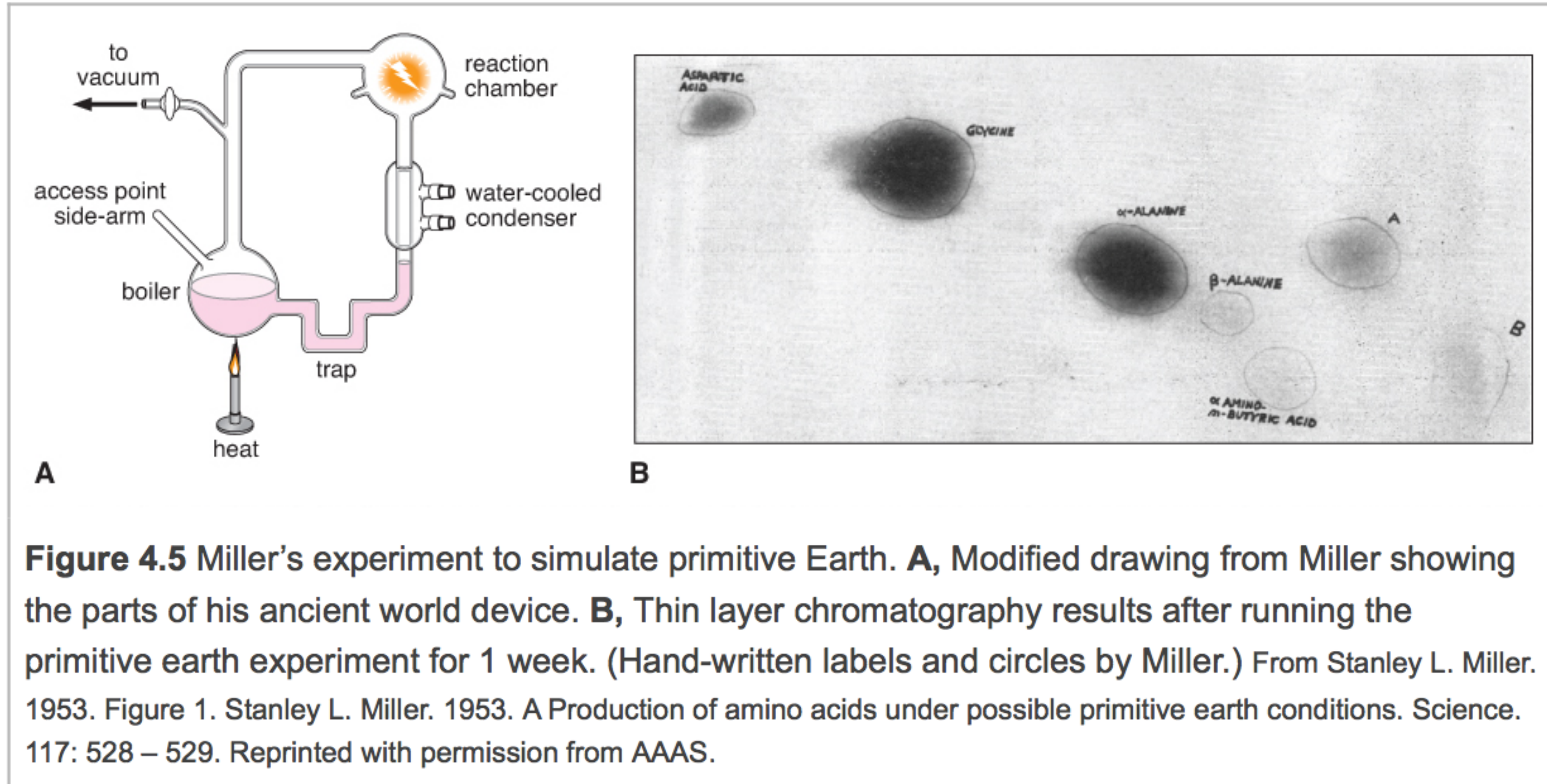
IQs: 5. which base worked best? (why, what evidence) 6. significance of experiment? replication is possible that ribozyme could not add "G"!? \*

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

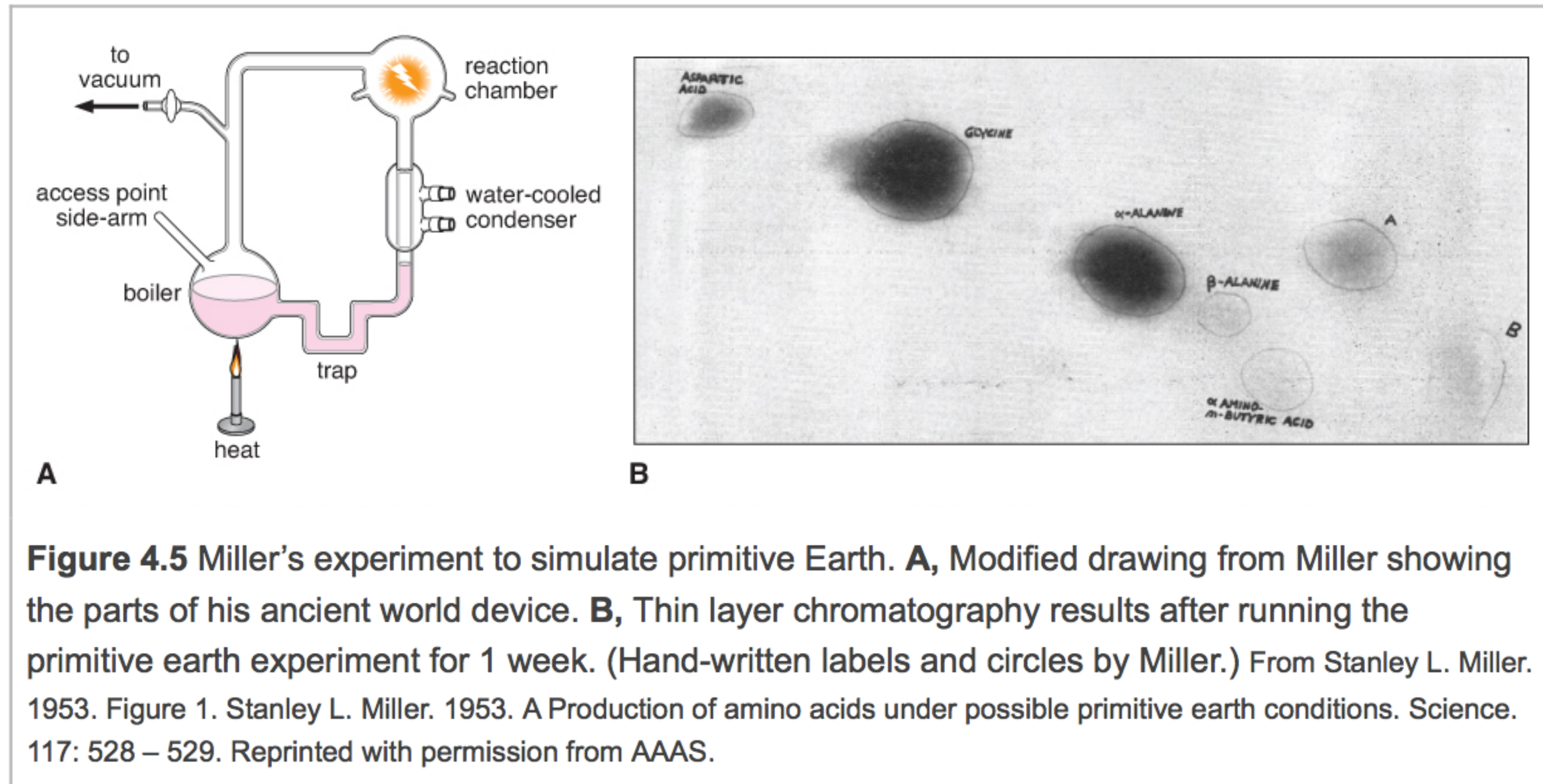
### **Biology Learning Objectives**

- 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.

# (Trifecta)



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



# Miller Separated Products by TLC

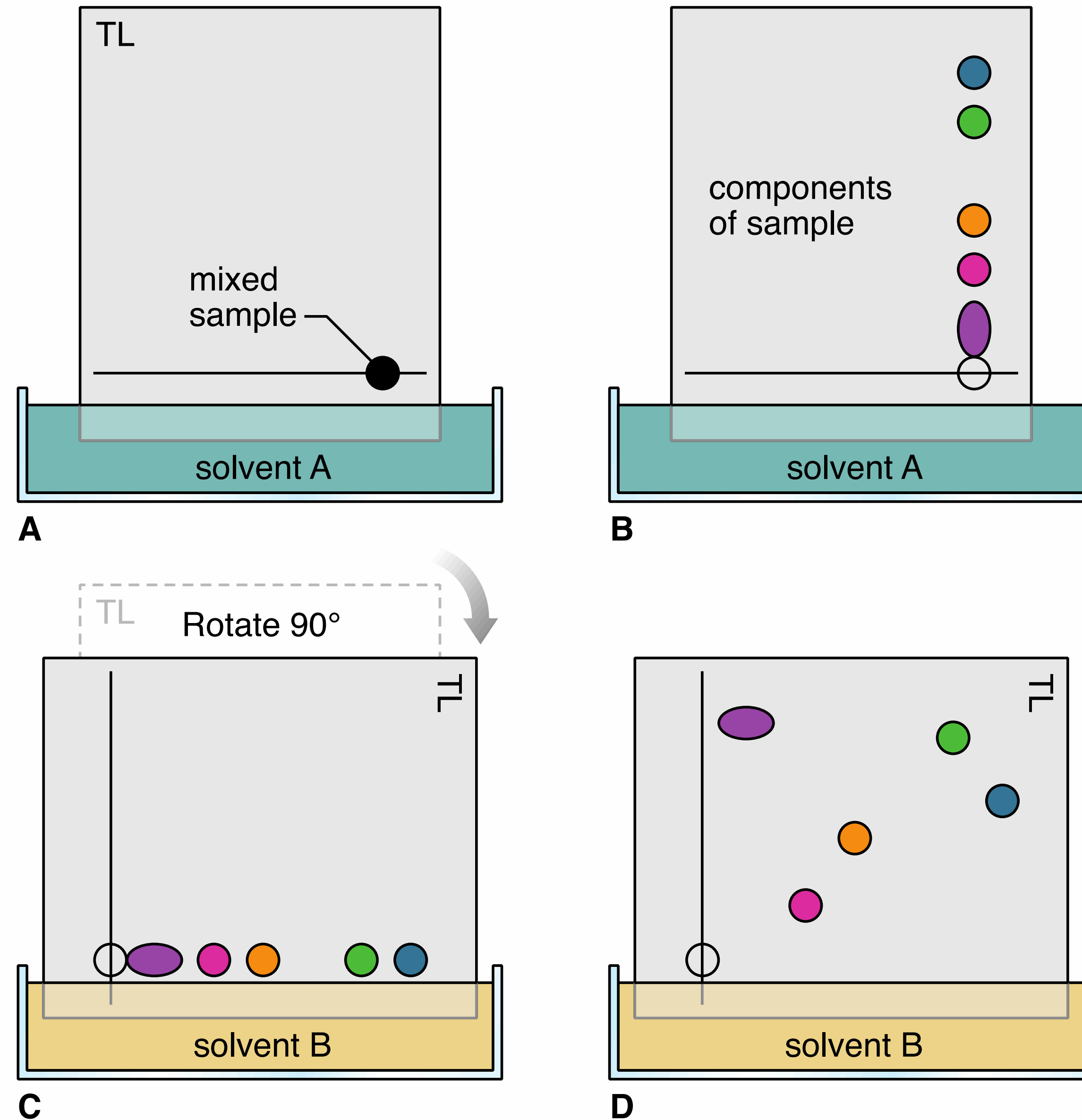


Fig. 1.19

# The Miller Volcanic Spark Discharge Experiment

Adam P. Johnson,<sup>1</sup> H. James Cleaves,<sup>2</sup> Jason P. Dworkin,<sup>3</sup> Daniel P. Glavin,<sup>3</sup> Antonio Lazcano,<sup>4</sup> Jeffrey L. Bada<sup>5\*</sup>

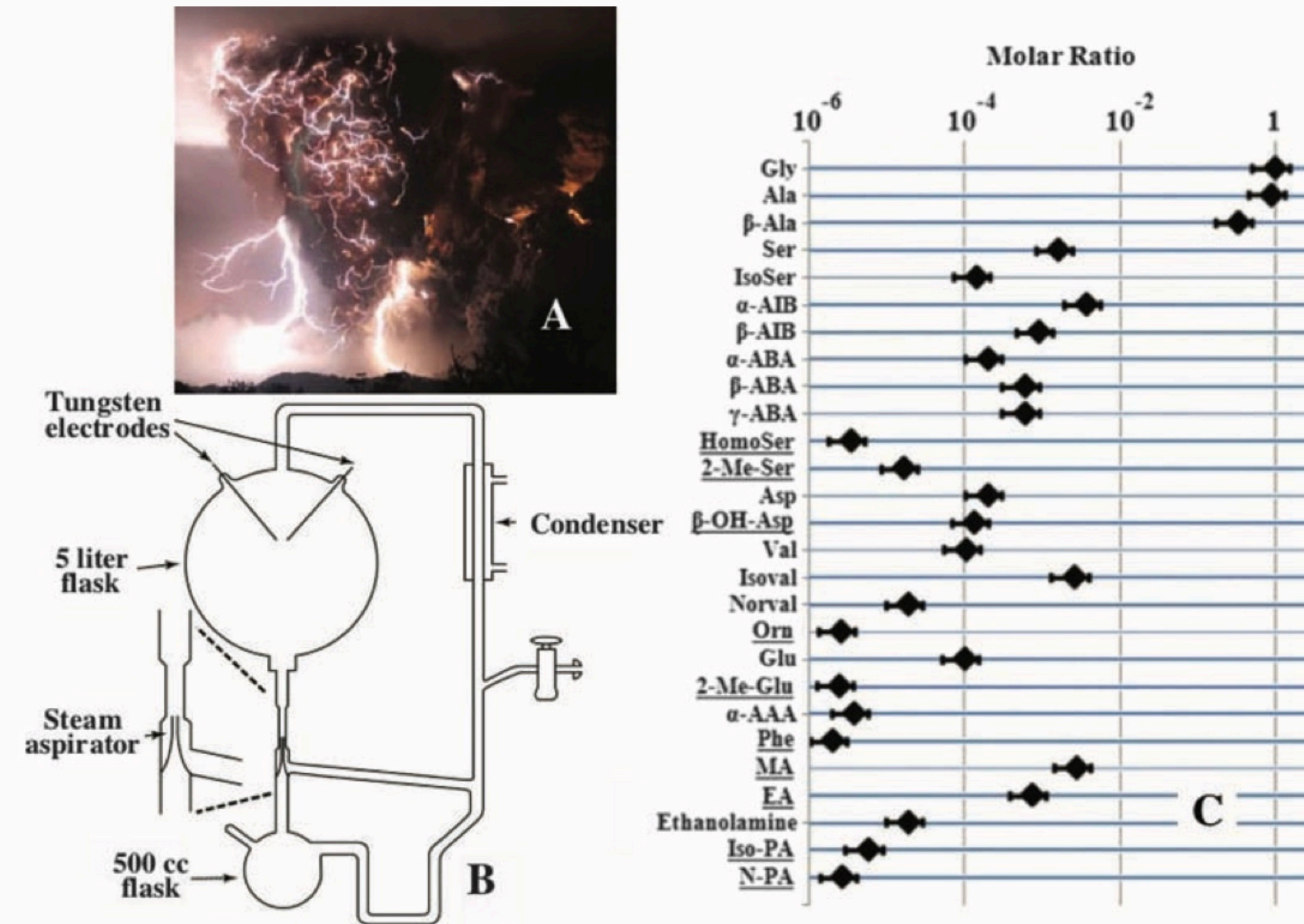
In 1953, Miller (1) published a short paper describing the spark discharge synthesis of amino acids from a reducing gas mixture thought to represent the atmosphere of the early Earth. This exper-

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

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<sub>4</sub>, 200 torr of NH<sub>3</sub>, and 100 torr of H<sub>2</sub> [these would have dissolved in the water according to their solubilities (2)]. Water was added to the 500-cm<sup>3</sup> (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.

iment 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

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.

## 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

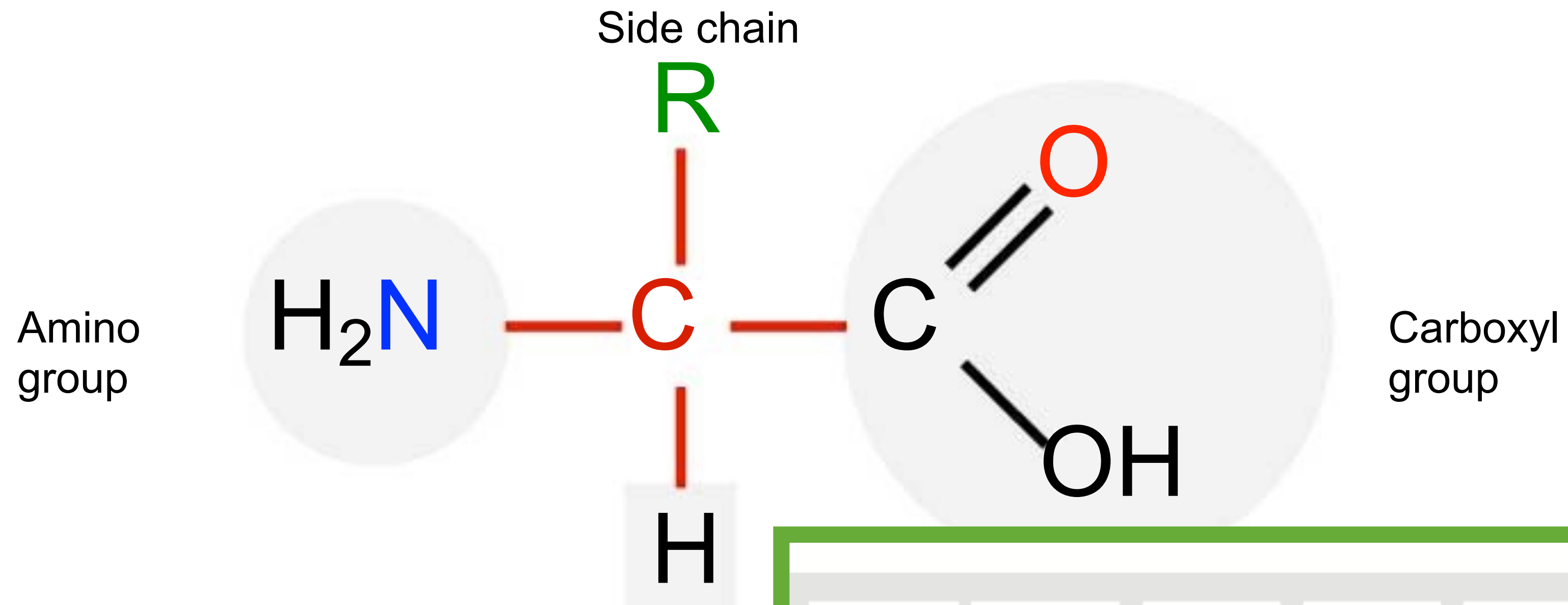
## References and Notes

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. Yechezkel, 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).

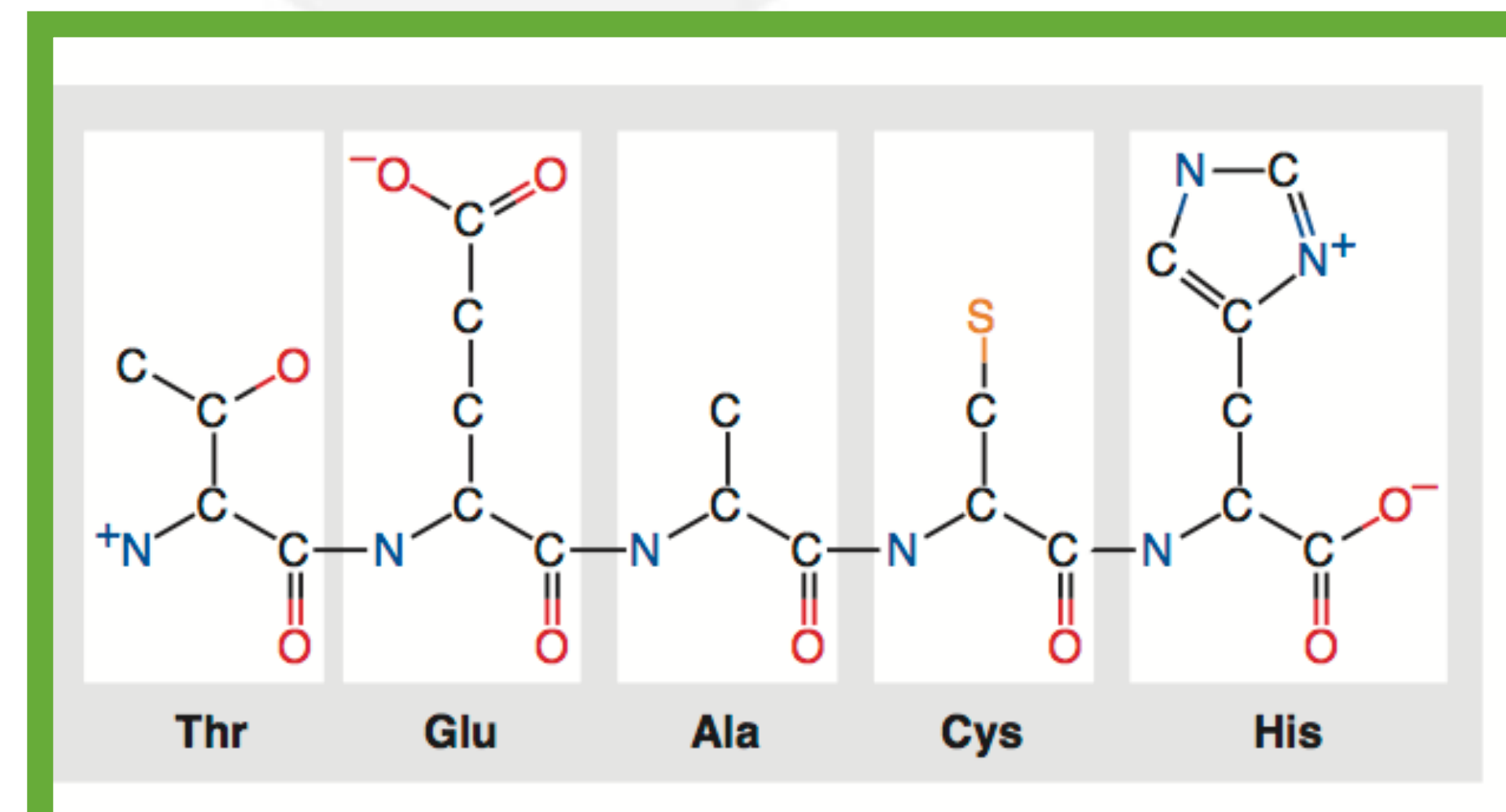
# Molecules of the Prebiotic Soup

- 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



# Miller's Primitive Earth Experiment

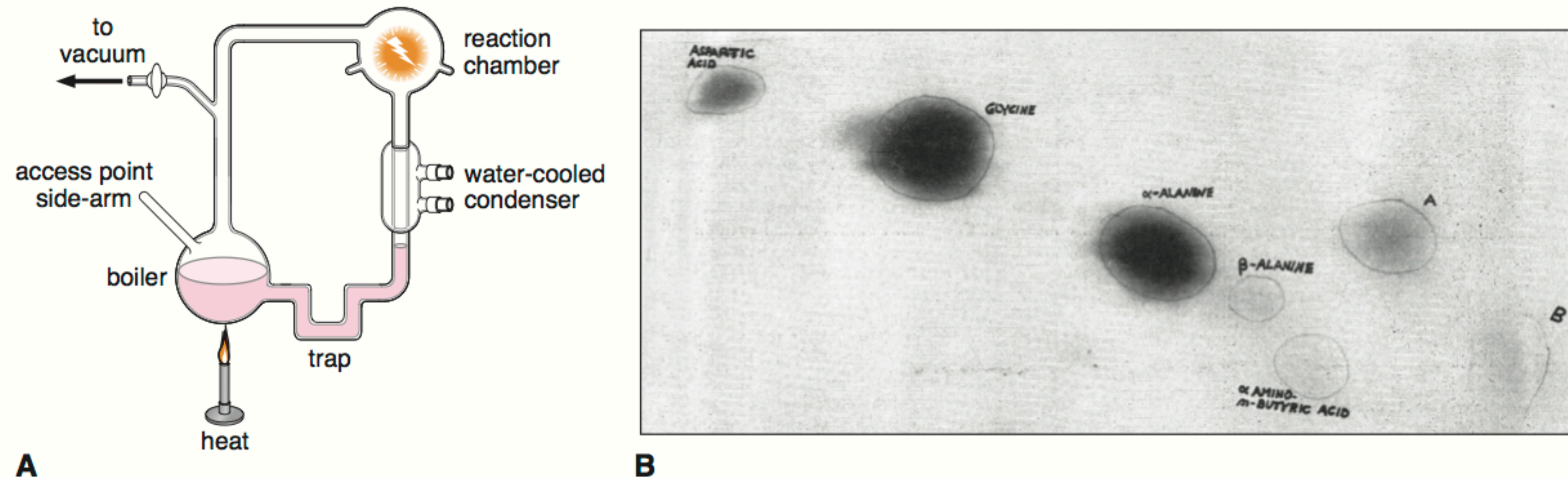


Fig. 4.5

modified from Stanley L. Miller. 1953

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# Miller's Primitive Earth Apparatus

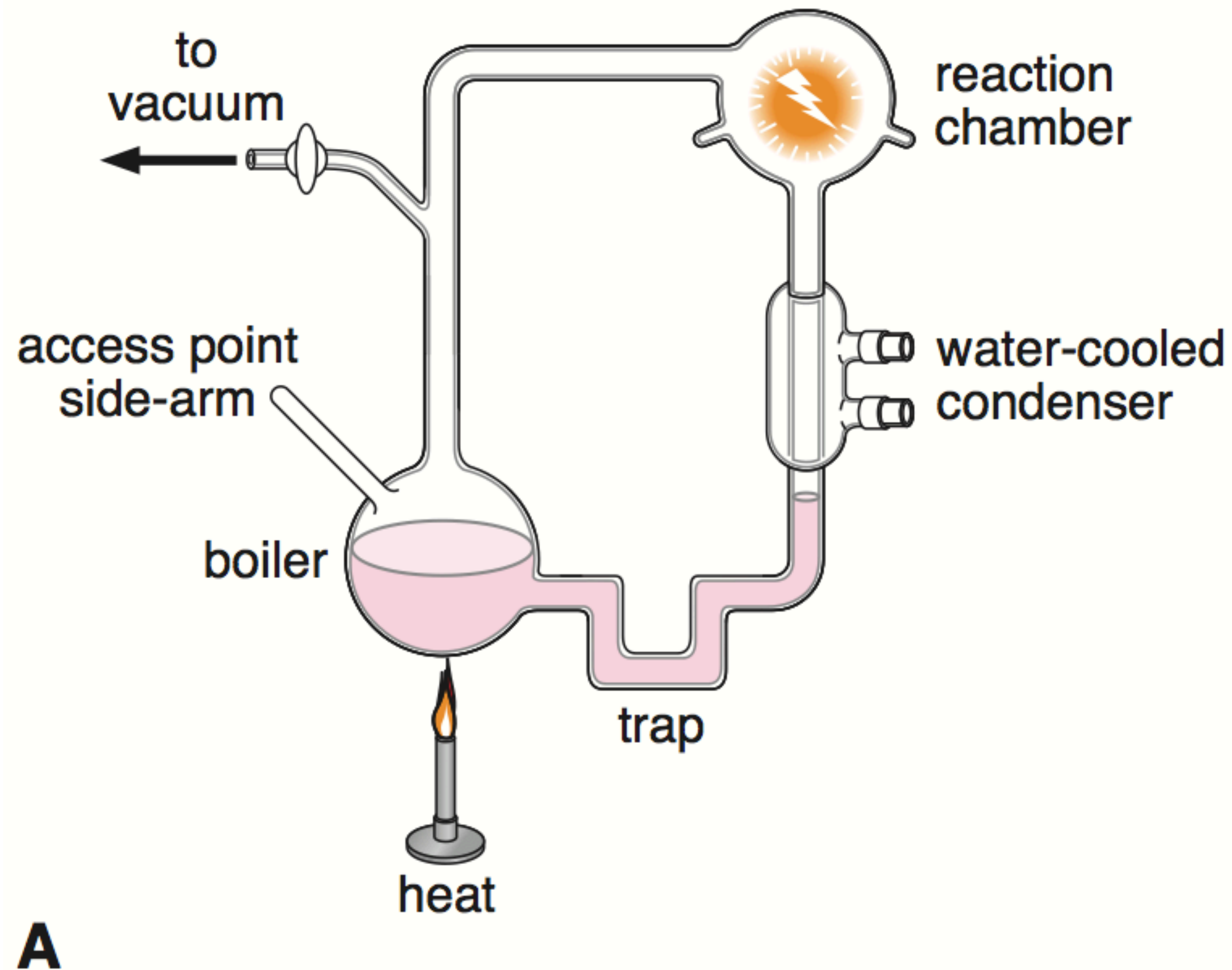


Fig. 4.5

modified from Stanley L. Miller. 1953

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# Miller's Primitive Earth Apparatus

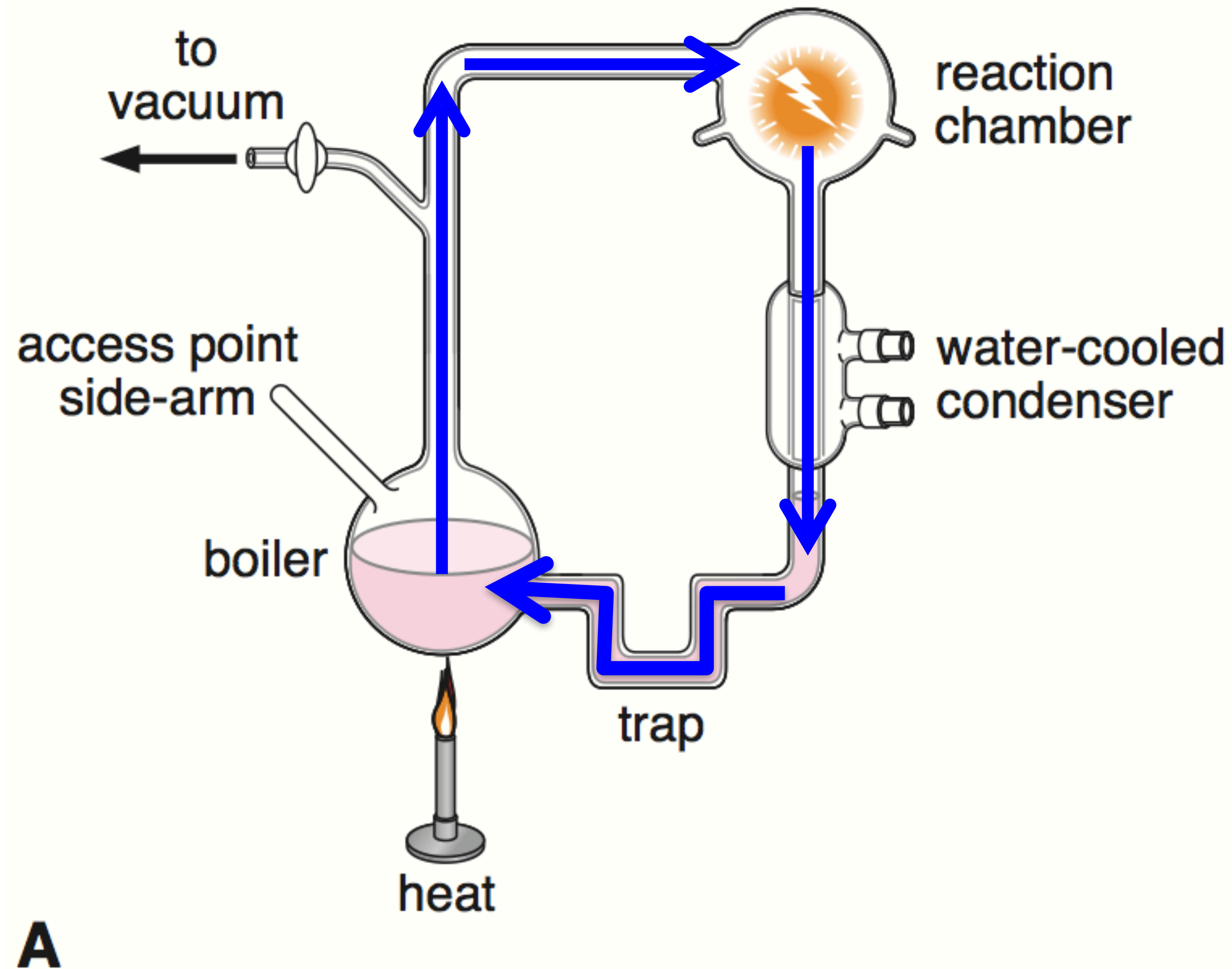
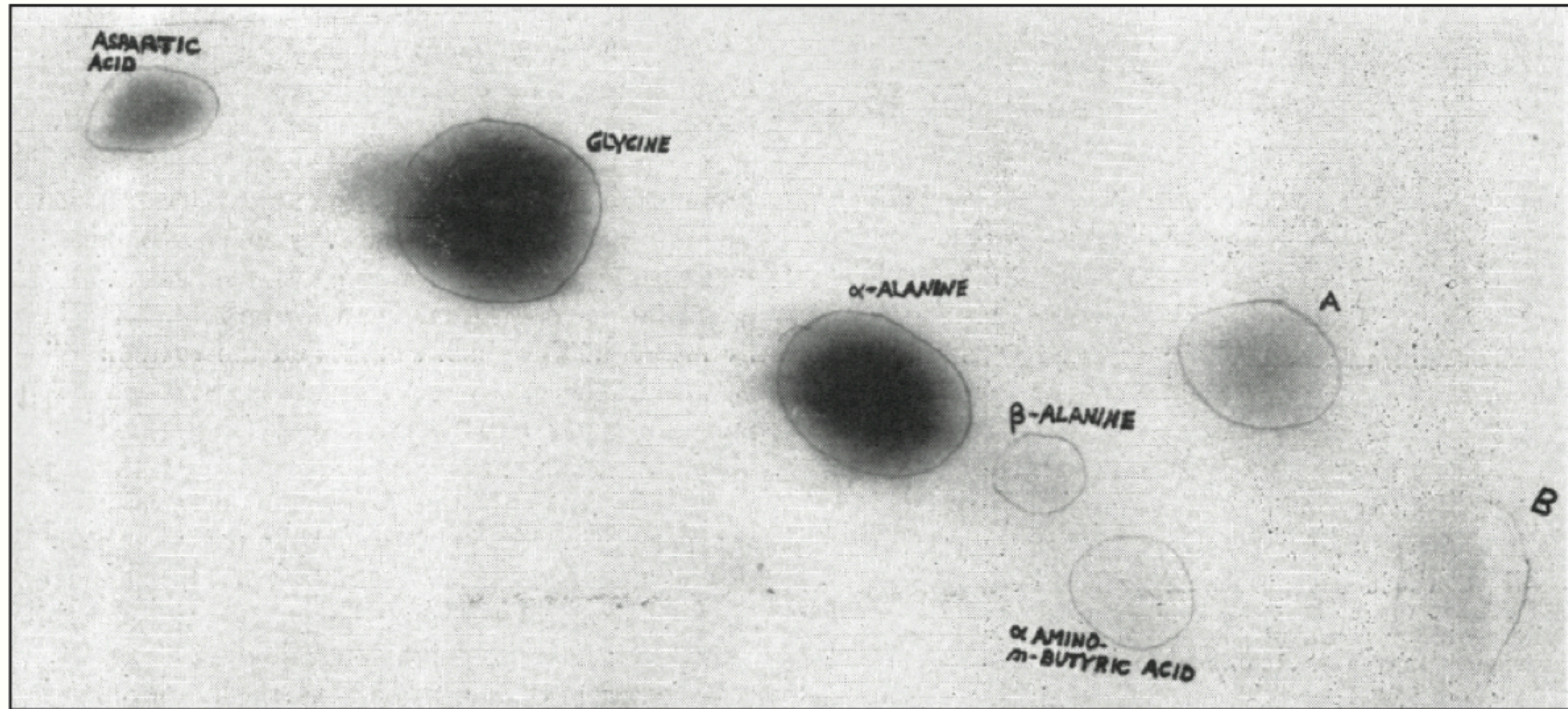


Fig. 4.5

modified from Stanley L. Miller. 1953

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# Products from Miller's Experiment



**B**

Fig. 4.5

modified from Stanley L. Miller. 1953

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# Separated by 2D TLC

thin layer chromatography results



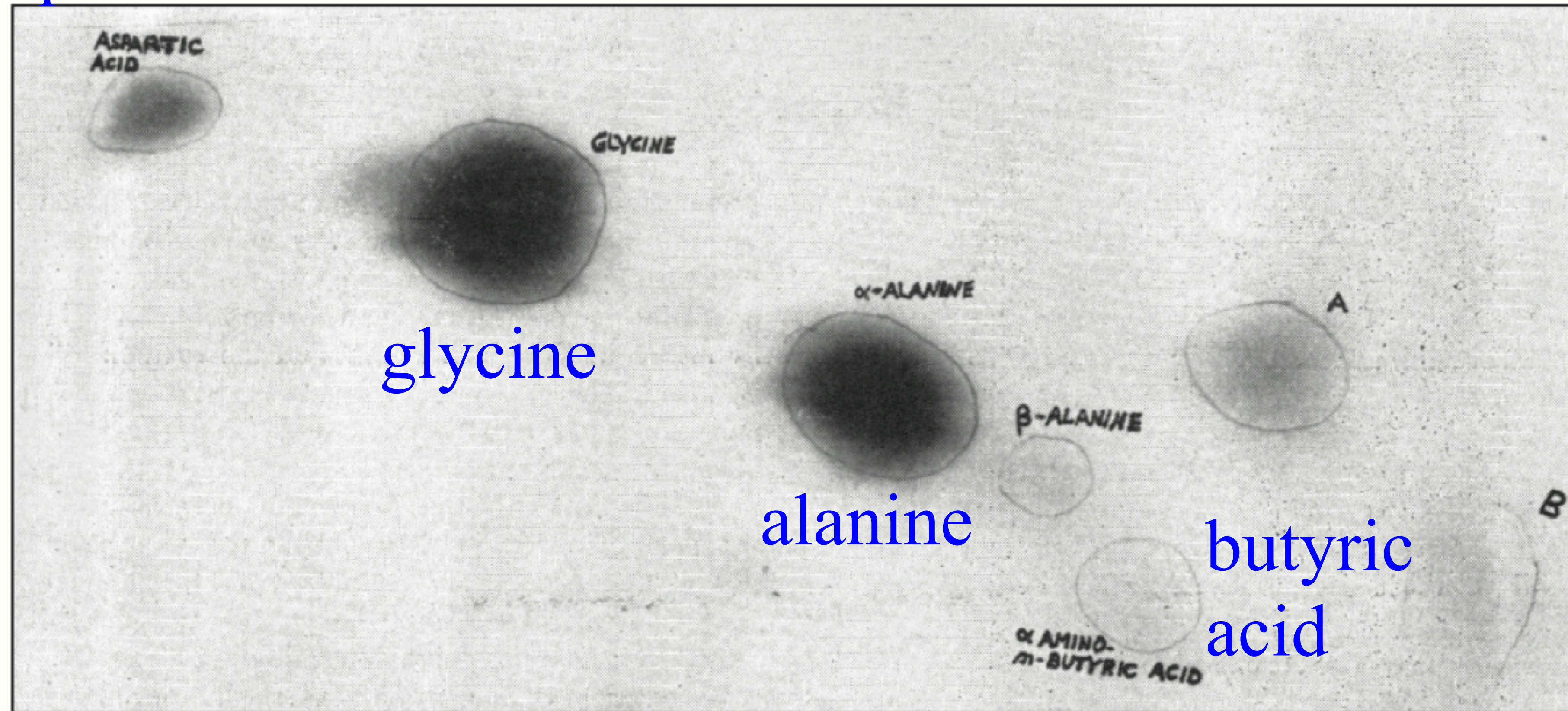
Fig. 4.5

modified from Stanley L. Miller. 1953

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# Separated by 2D TLC

aspartic acid



**B**

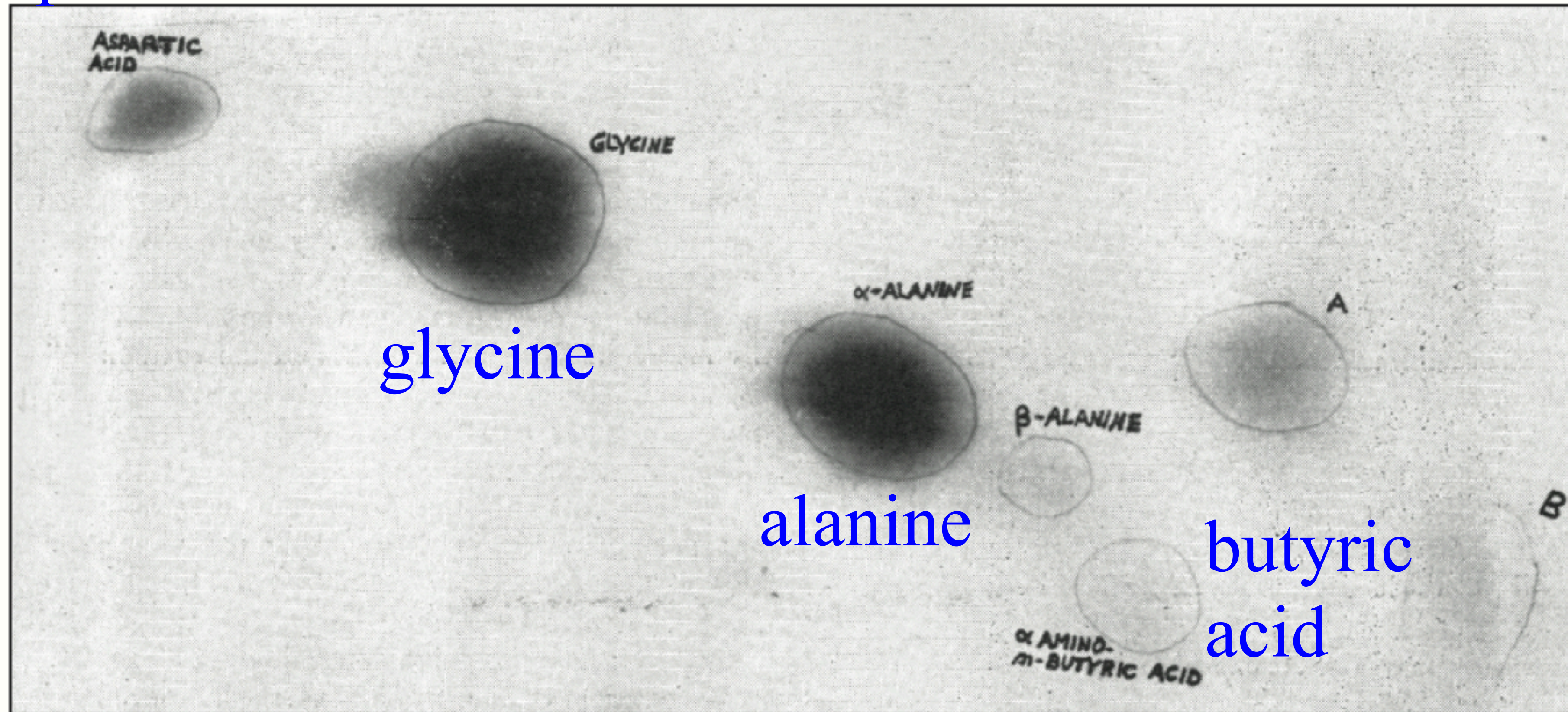
Fig. 4.5

modified from Stanley L. Miller. 1953

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# Separated by 2D TLC

aspartic acid



**B** amino acids and fatty acids produced abiotically

Fig. 4.5

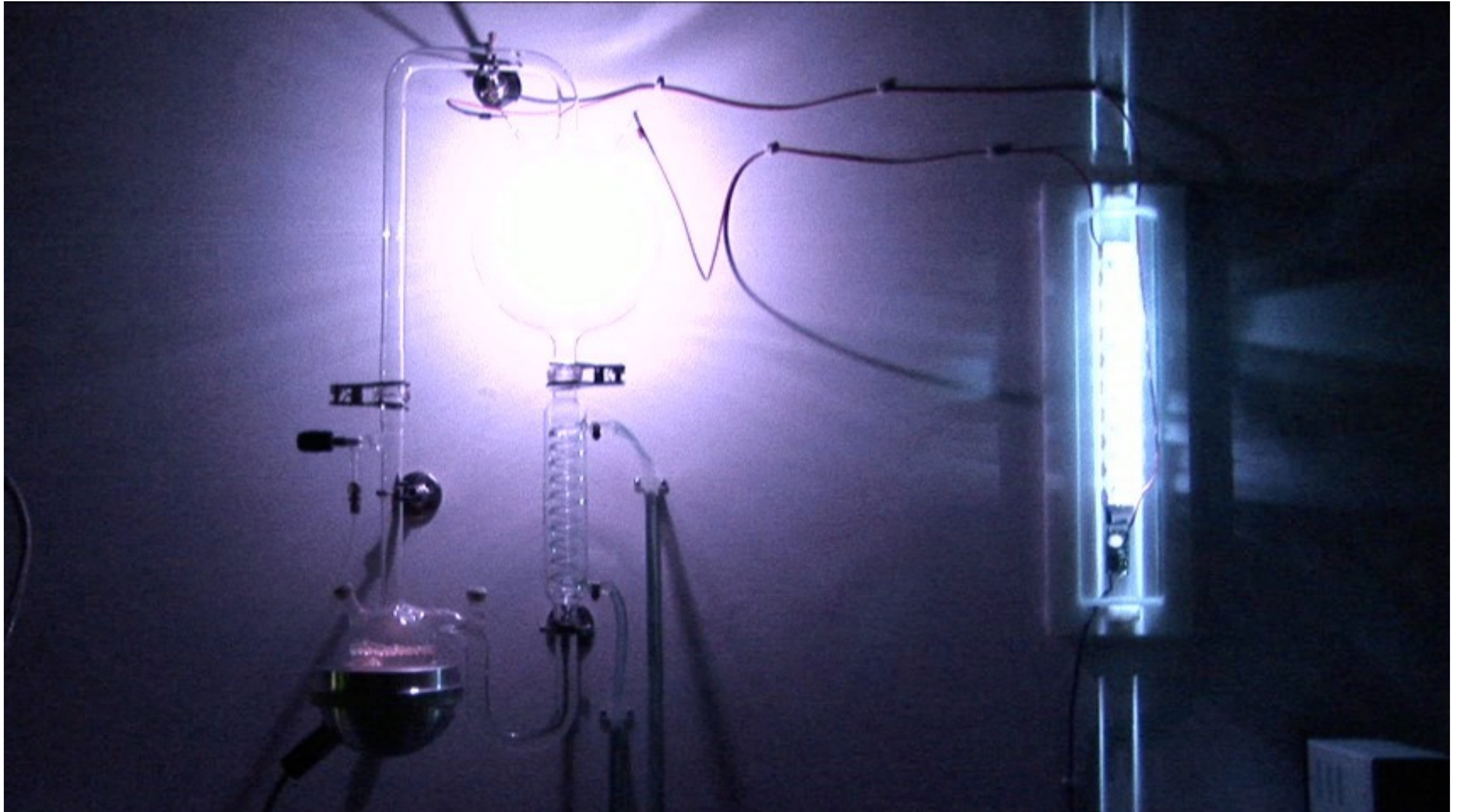
modified from Stanley L. Miller. 1953

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# Stanley Miller experiment @ MSU

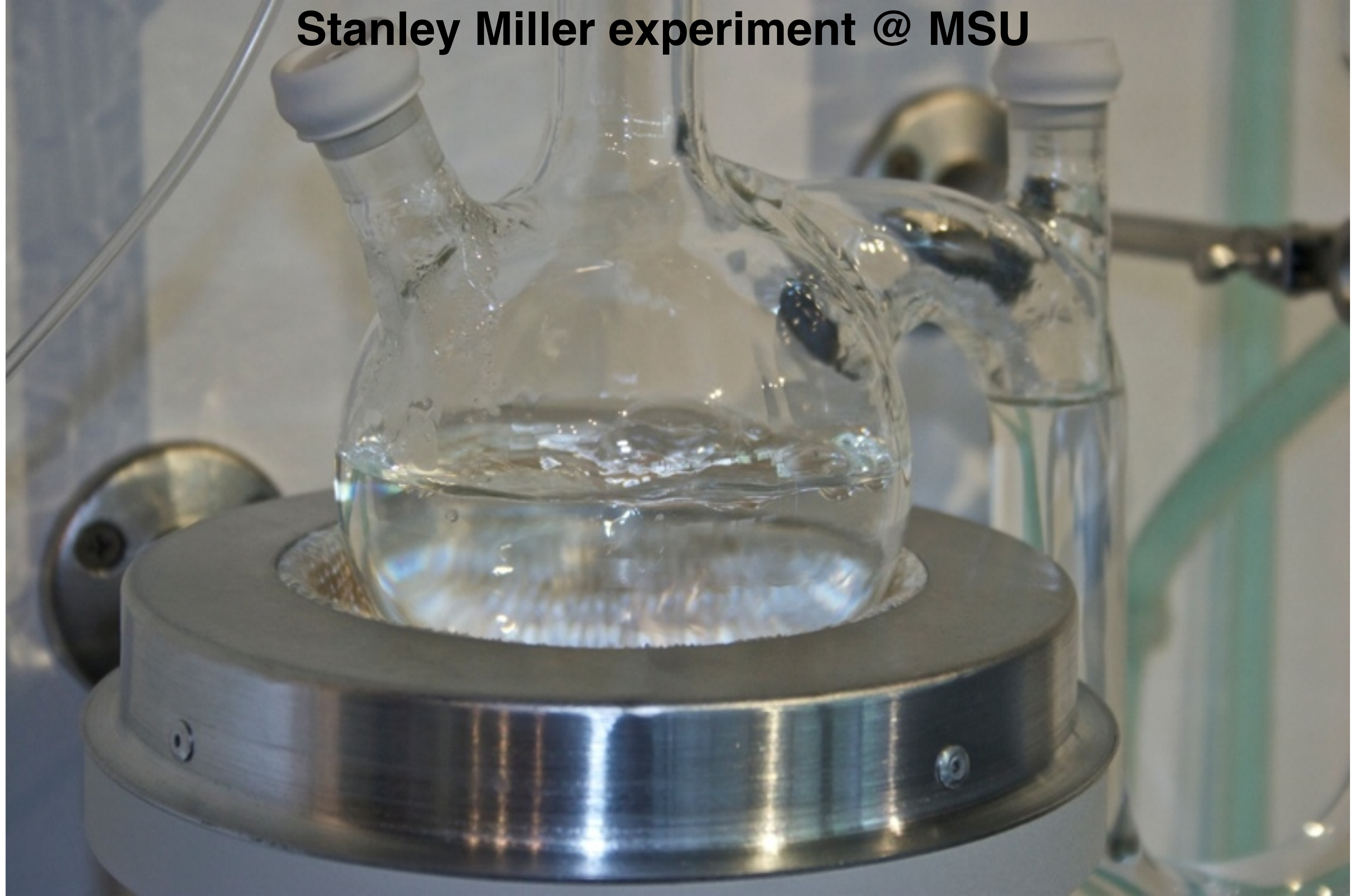


# Stanley Miller experiment @ MSU

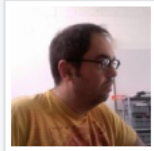
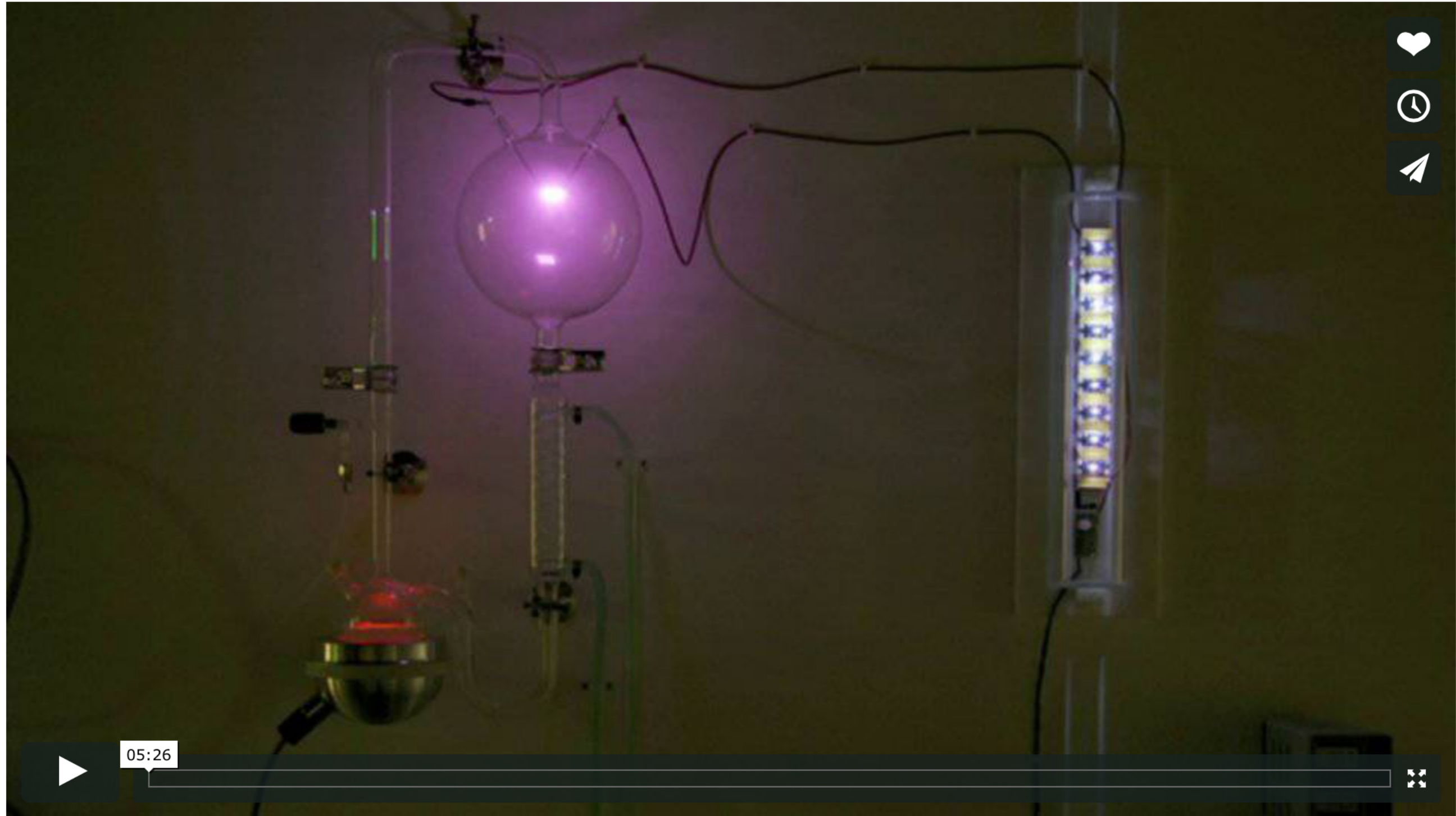




# Stanley Miller experiment @ MSU





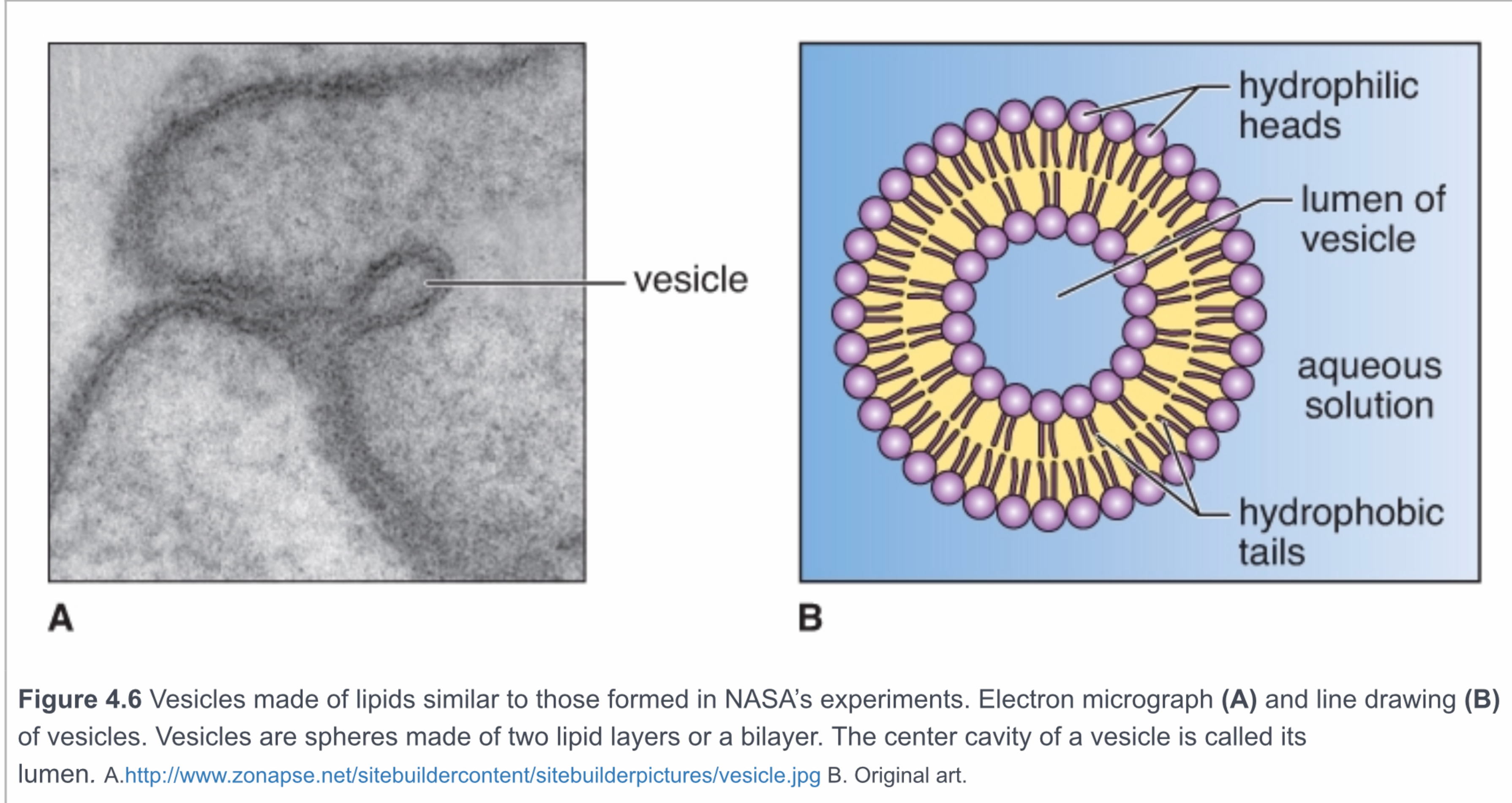


# Origins of Life: Experiment #1.x

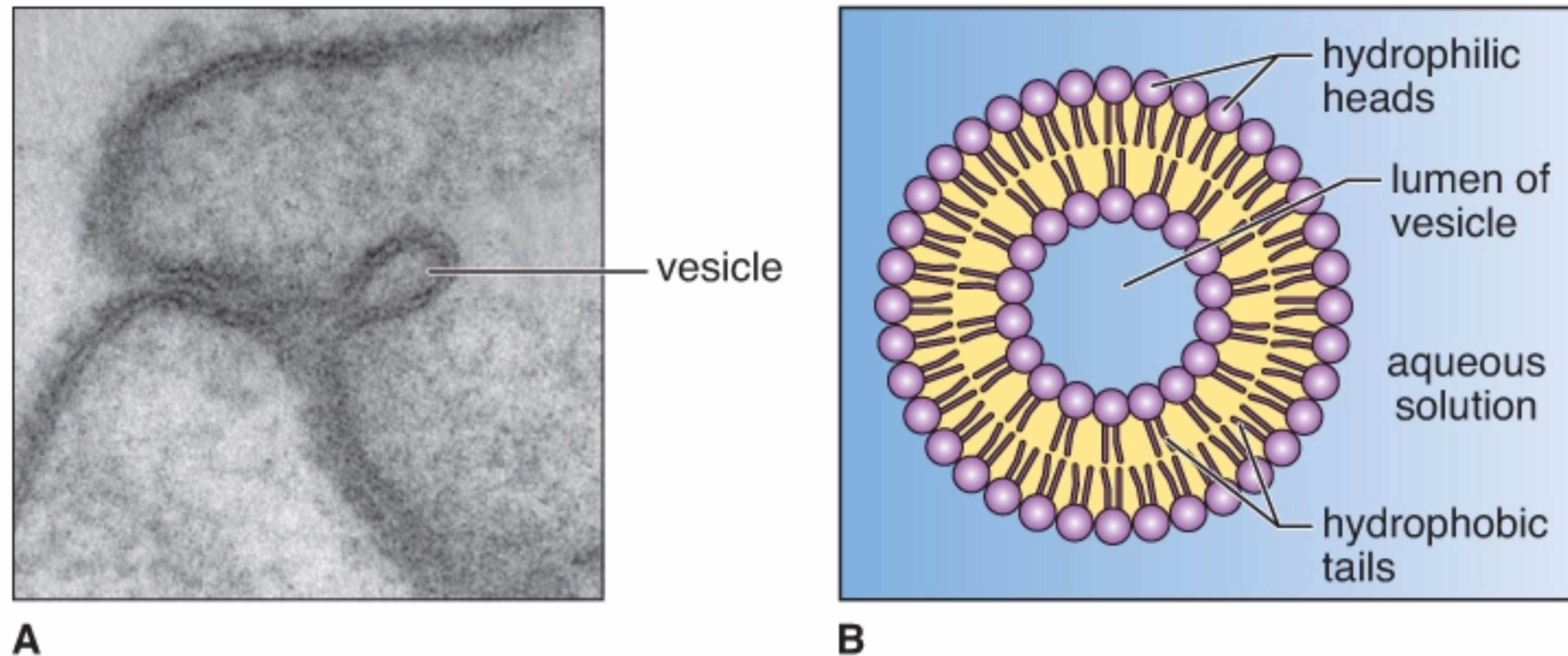
from Adam W. Brown 2 years ago NOT YET RATED

<http://vimeo.com/32106116>

# (Trifecta)



# NASA: UV light helps form lipids and vesicles



**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.

# 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

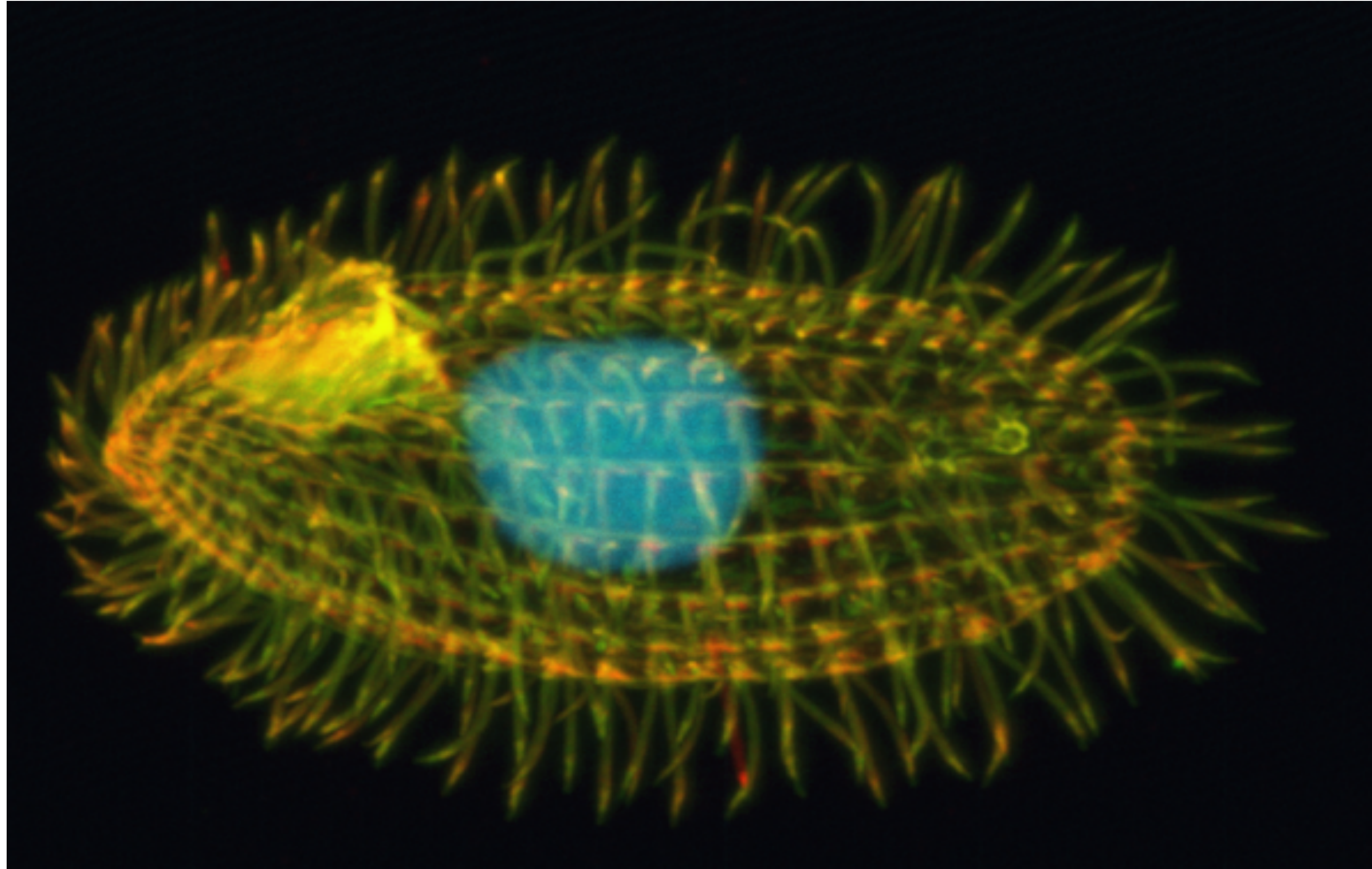


Fig. 6.7

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



# RNA as an RNA Polymerase: Net Elongation of an RNA Primer Catalyzed by the *Tetrahymena* Ribozyme

MICHAEL D. BEEN AND THOMAS R. CECH [Authors Info & Affiliations](#)

SCIENCE • 18 Mar 1988 • Vol 239, Issue 4846 • pp. 1412-1416 • DOI: 10.1126/science.2450400

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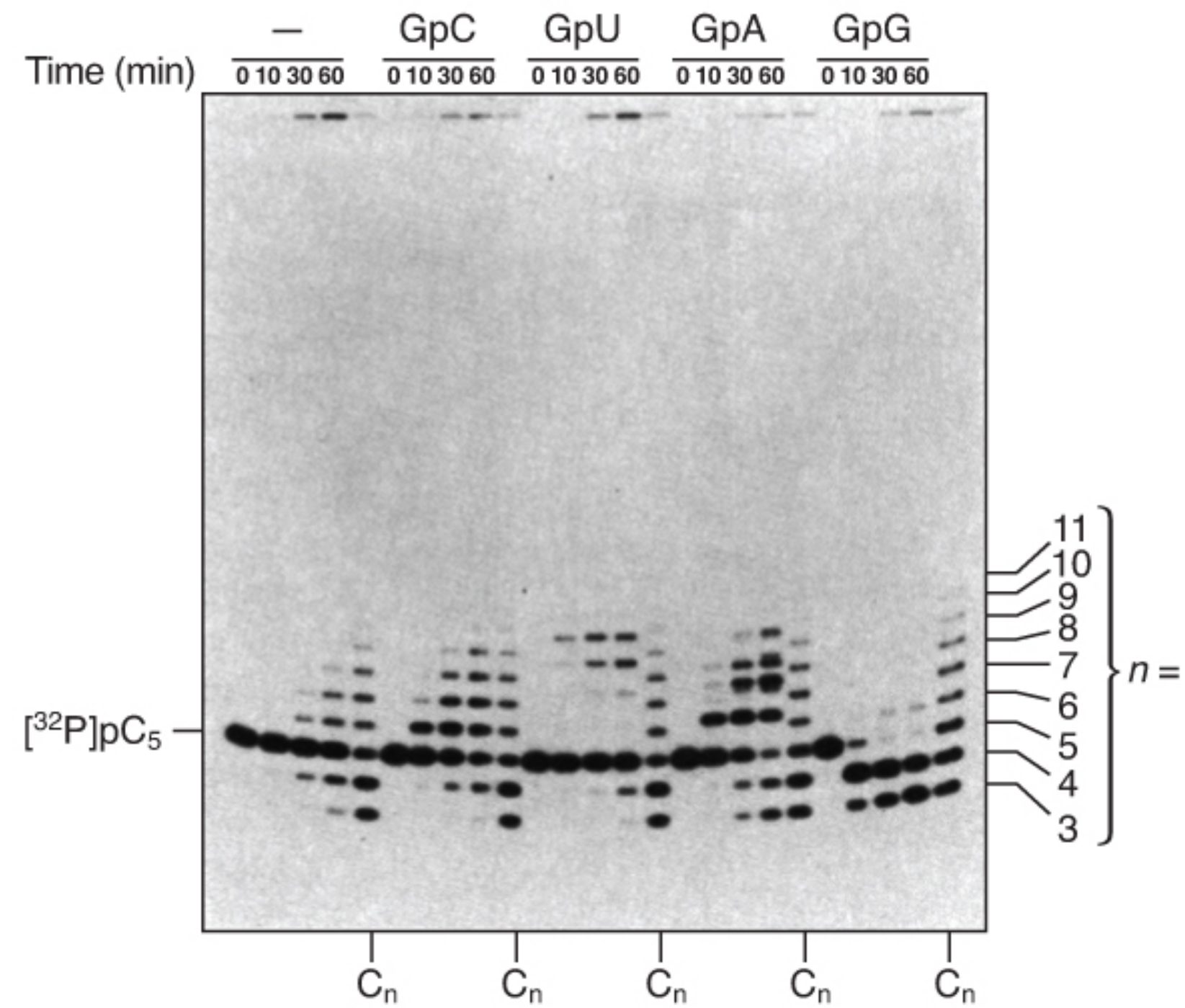
CHECK ACCESS

## Abstract

A catalytic RNA (ribozyme) derived from an intervening sequence (IVS) RNA of *Tetrahymena thermophila* will catalyze an RNA polymerization reaction in which pentacytidylic acid (C<sub>5</sub>) is extended by the successive addition of mononucleotides derived from a guanylyl-(3',5')-nucleotide (GpN). Cytidines or uridines are added to C<sub>5</sub> to generate chain lengths of 10 to 11 nucleotides, with longer products being generated at greatly reduced efficiency. The reaction is analogous to that catalyzed by a replicase with C<sub>5</sub> acting as the primer, GpNs as the nucleoside triphosphates, and a sequence in the ribozyme providing a template. The demonstration that an RNA enzyme can catalyze net elongation of an RNA primer supports theories of prebiotic RNA self-replication.



(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 the number of bases, and the original  $\text{pC}_5$  molecular size is marked on the left. Negative control and four experimental dinucleotides are grouped by the incubation times indicated at the top. Columns labeled  $C_n$  are molecular weight markers 3 to 9 bases. From Been and Cech. 1998. Figure 1. Michael D. Been, and Thomas R. Cech. 1998. RNA as an RNA Polymerase: Net Elongation of an RNA Primer Catalyzed by the Tetrahymena Ribozyme. *Science*. 239: 1412 – 1416. Reprinted with permission from AAAS.

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

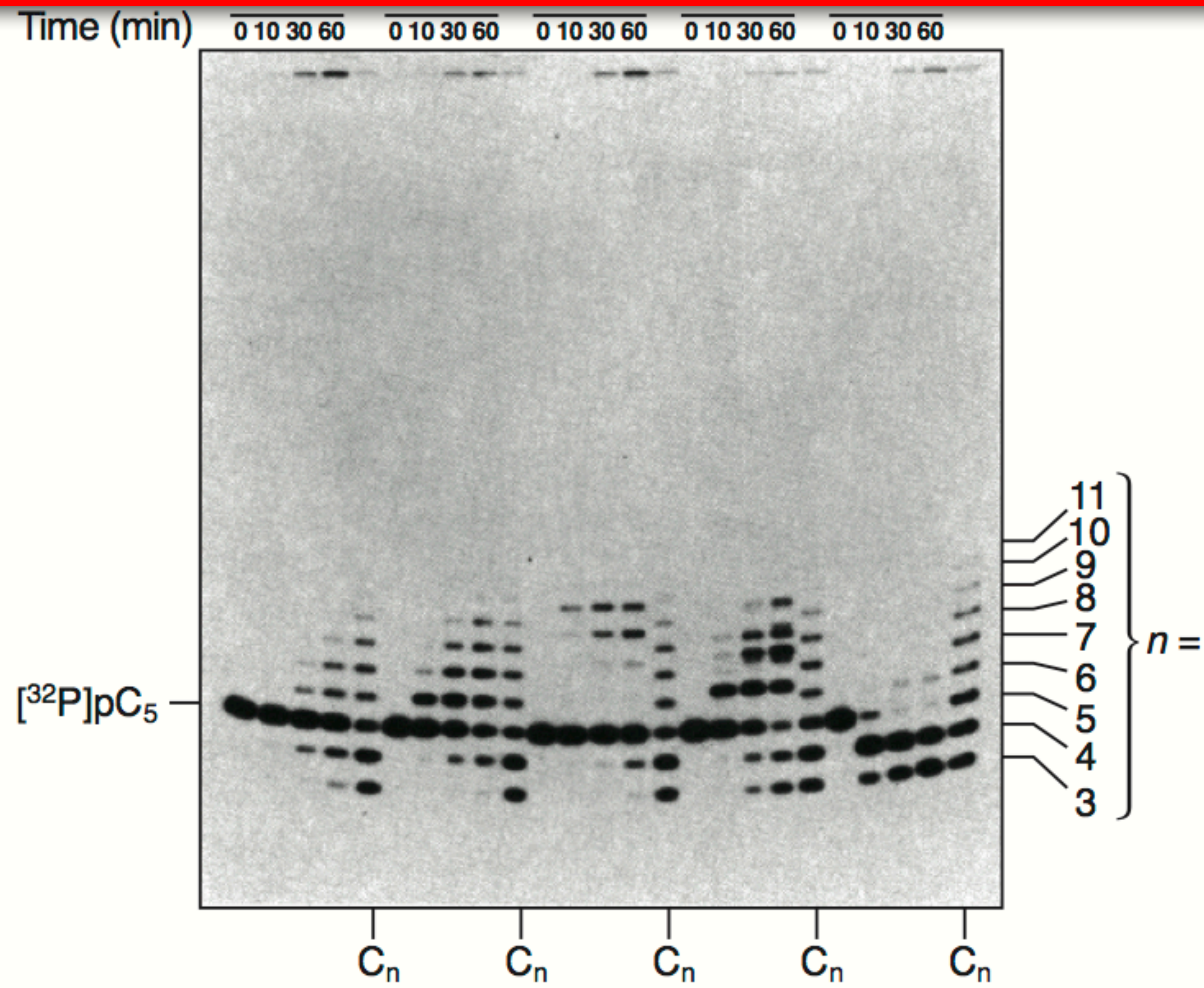


Fig. 4.8

**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

# RNA World: RNA (ribozyme) can polymerize nucleotides

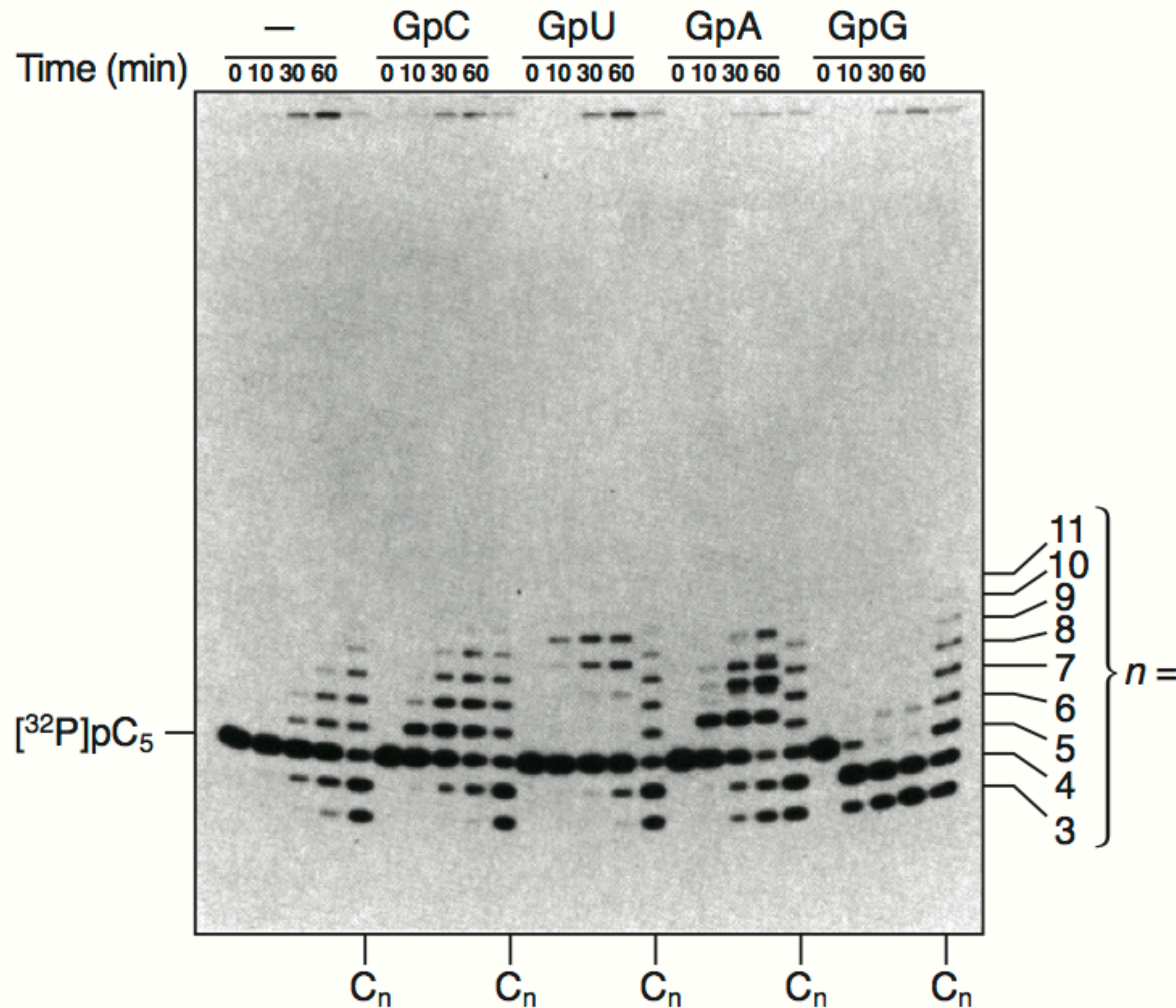


Fig. 4.8

Figure 4.8 RNA polymerizes more RNA. Results are modified from Been and Cech. 1998

# Functional Ribozyme



$[\text{}^{32}\text{P}]\text{pC}_5$  ← 5 bases of Cs

11  
10  
9  
8  
7  
6  
5  
4  
3 } MW  
n =

# Functional Ribozyme

GpC GpU GpA GpG

add different dinucleotides  
as substrate for polymerization

$[^{32}\text{P}]\text{pC}_5 - \leftarrow$  5 base primer

11  
10  
9  
8  
7  
6  
5  
4  
3 } MW  
n =

# Functional Ribozyme

	—	GpC	GpU	GpA	GpG
Time (min)	<u>0 10 30 60</u>	<u>0 10 30 60</u>	<u>0 10 30 60</u>	<u>0 10 30 60</u>	<u>0 10 30 60</u>

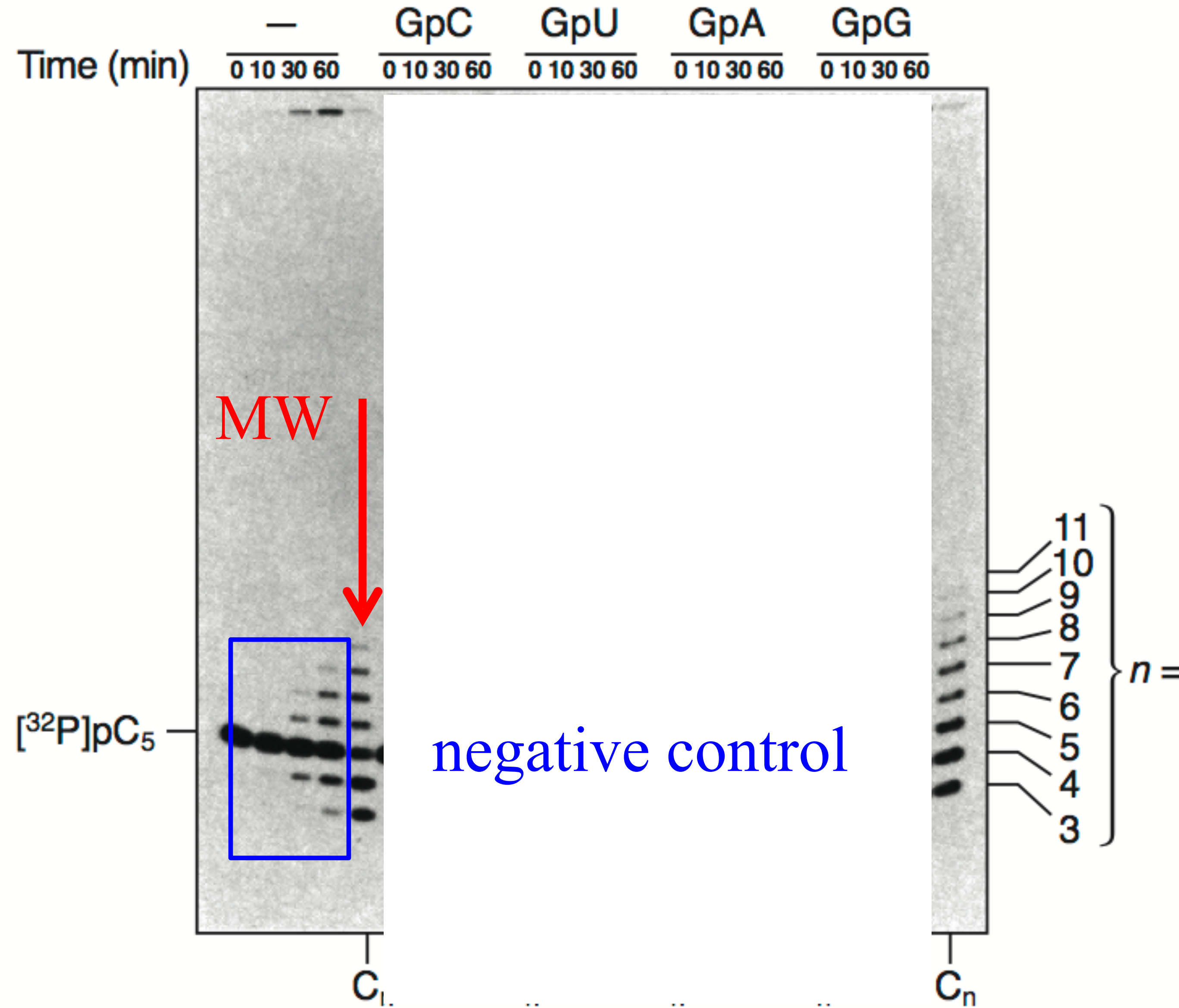
incubate for increasing amounts of time

electrophorese all products on one gel

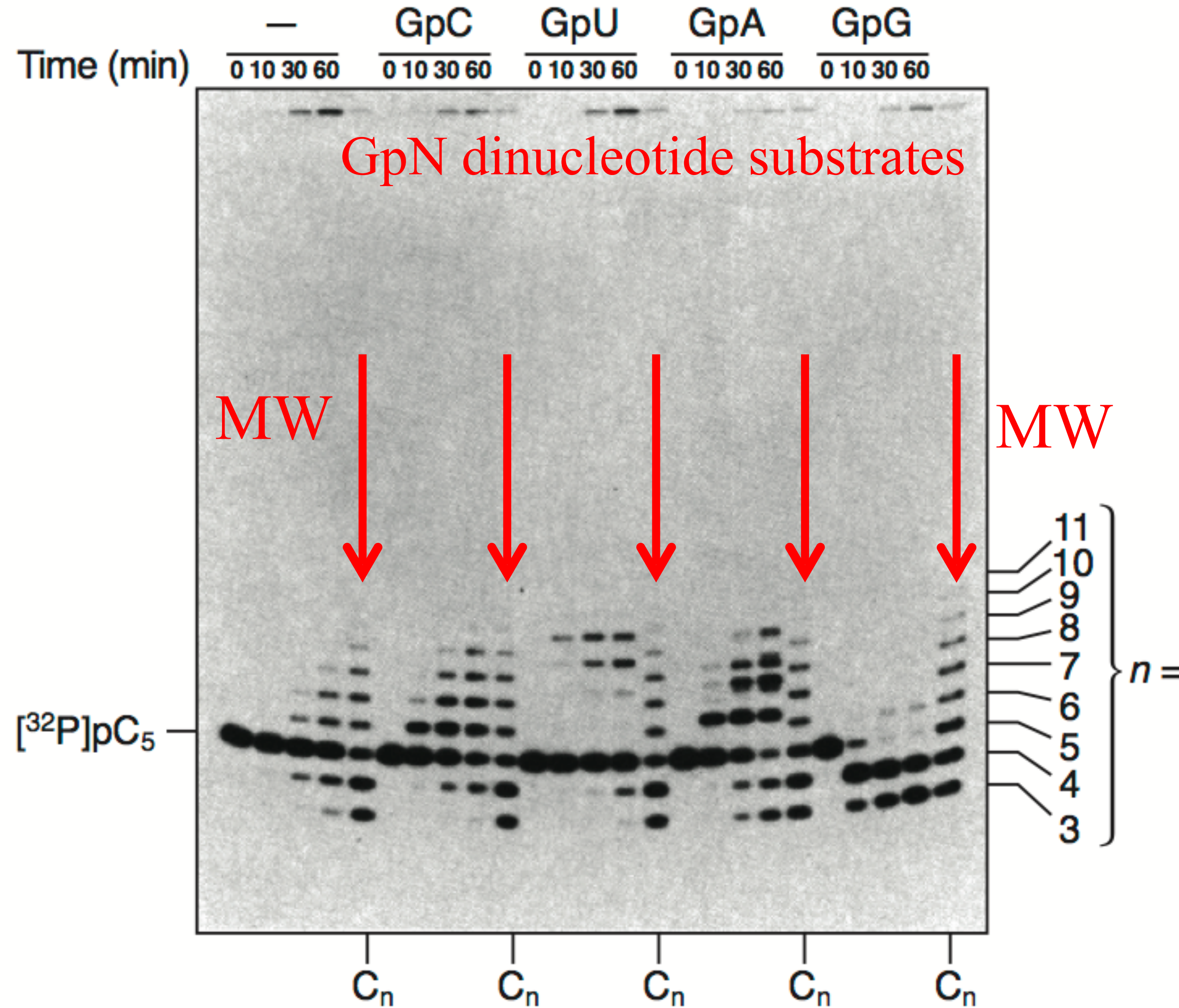
[<sup>32</sup>P]pC<sub>5</sub> -

11  
10  
9  
8  
7  
6  
5  
4  
3 } n =

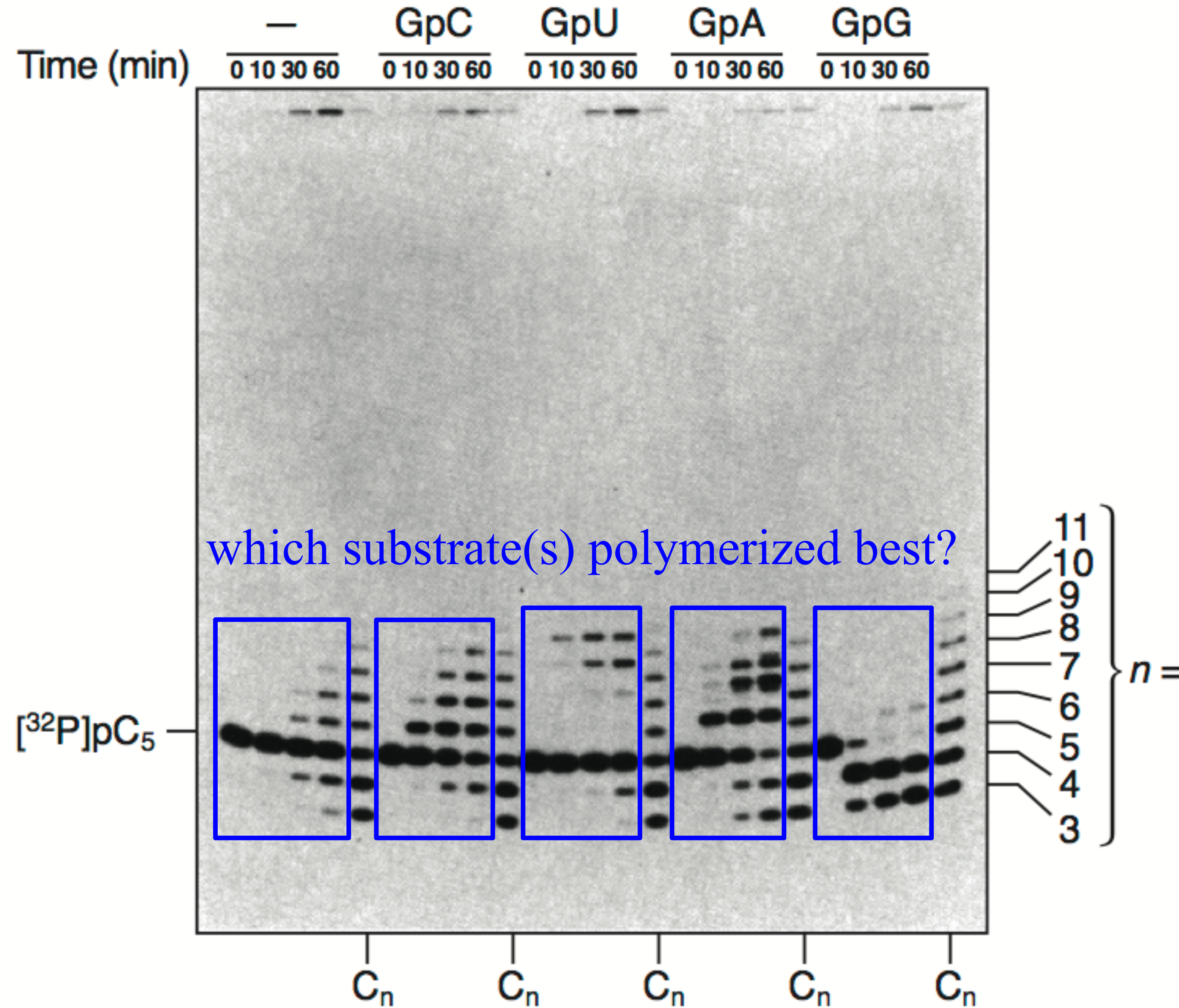
# Functional Ribozyme



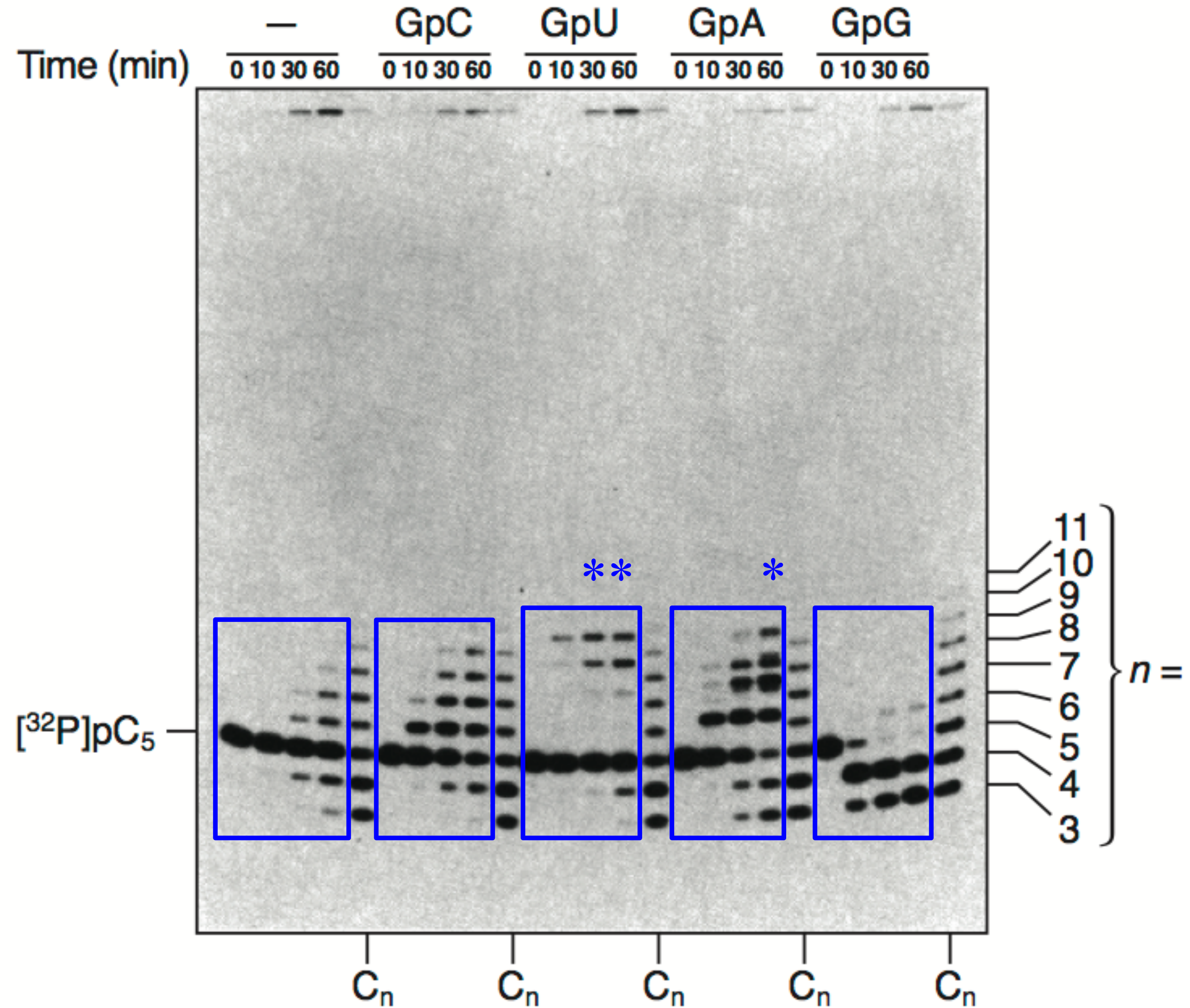
# Functional Ribozyme



# Functional Ribozyme



# Functional Ribozyme



# Molecules of the Prebiotic Soup

- Sugar monomers together make nucleotides.
  - hexoses and pentoses form readily in **Miller exp.**
  - **Ribose Question:** did ribose dominate, i.e., RNA?
- Nucleotide monomers together make nucleic acids.
  - Only **purines** have been synthesized in experiments simulating early earth conditions, not pyrimidines.