A. VOCABULARY

WORD	MEANING
PHOSPHORYLATION	**Adding** a **PHOSPHATE** group This makes a molecule **more reactive** and **less stable**.
OXIDATION	**Removing HYDROGEN** **Removing ELECTRONS**
REDUCTION	**Adding HYDROGEN** **Adding ELECTRONS**
DECARBOXYLATION	**Removing CARBON DIOXIDE**
NADP	**A co-enzyme that can pick up and release HYDROGEN** **NADPH = reduced form (picked up H)** **NADP = oxidised form (released H)**

B. A CHLOROPLAST

Stroma

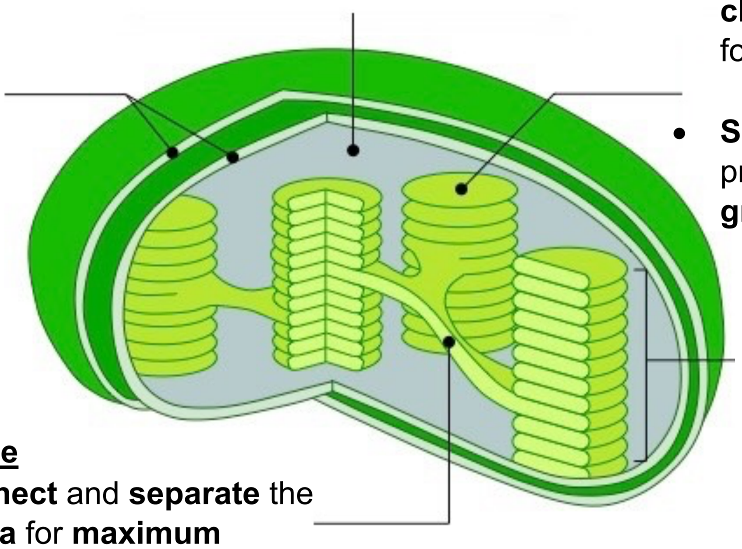
- Has an **optimum pH** and **enzymes** for the **Calvin cycle**

Thylakoid

- Contains **electron transport chain** and **ATP synthase** for **photophosphorylation**
- **Small internal volume** to provide a **steep proton gradient**

Double membrane

- Evidence for **endosymbiosis**



Grana

- **Flat membrane stacks** that are **highly folded** to give a **high SA:VOL** to **quickly accumulate protons**
- **Chlorophyll** arranged into **photosystems** for **maximum absorption** of **light energy**

Lamellae

- **Connect** and **separate** the **grana** for **maximum photosynthetic efficiency**

- Both chloroplasts and mitochondria have a **double membrane**, **70S ribosomes** and their own **DNA**.

C. THE POINT OF EACH STAGE

Stage	Where It Occurs	What Is Involved	The Point Of It
Light-dependent	**Thylakoids**	**LIGHT** **CHLOROPHYLL** **WATER**	To produce **NADPH** and **ATP** for the next stage. To produce **OXYGEN**.
Light-independent	**Stroma**	**CARBON DIOXIDE** **GLUCOSE**	To produce **GLUCOSE**.

D. PHOTOSYSTEMS

- Contain many **pigments** that absorb **photons** of **light**
- This causes **electrons** within them to become **excited**
- These **electrons** then pass along **electron carriers**

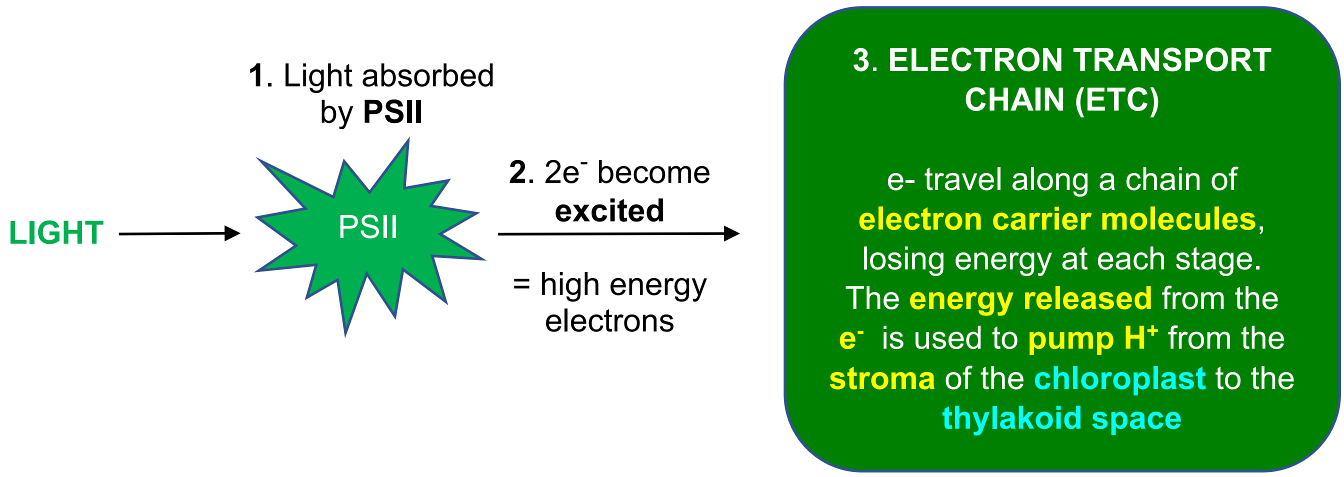
Photosystem	Part of the thylakoid membrane it is found in	Involved
I	Parts exposed to the **stroma**	In producing **NADPH**
II	Parts stacked inside the **grana**	In producing: - an **H+ concentration gradient** - **ATP**

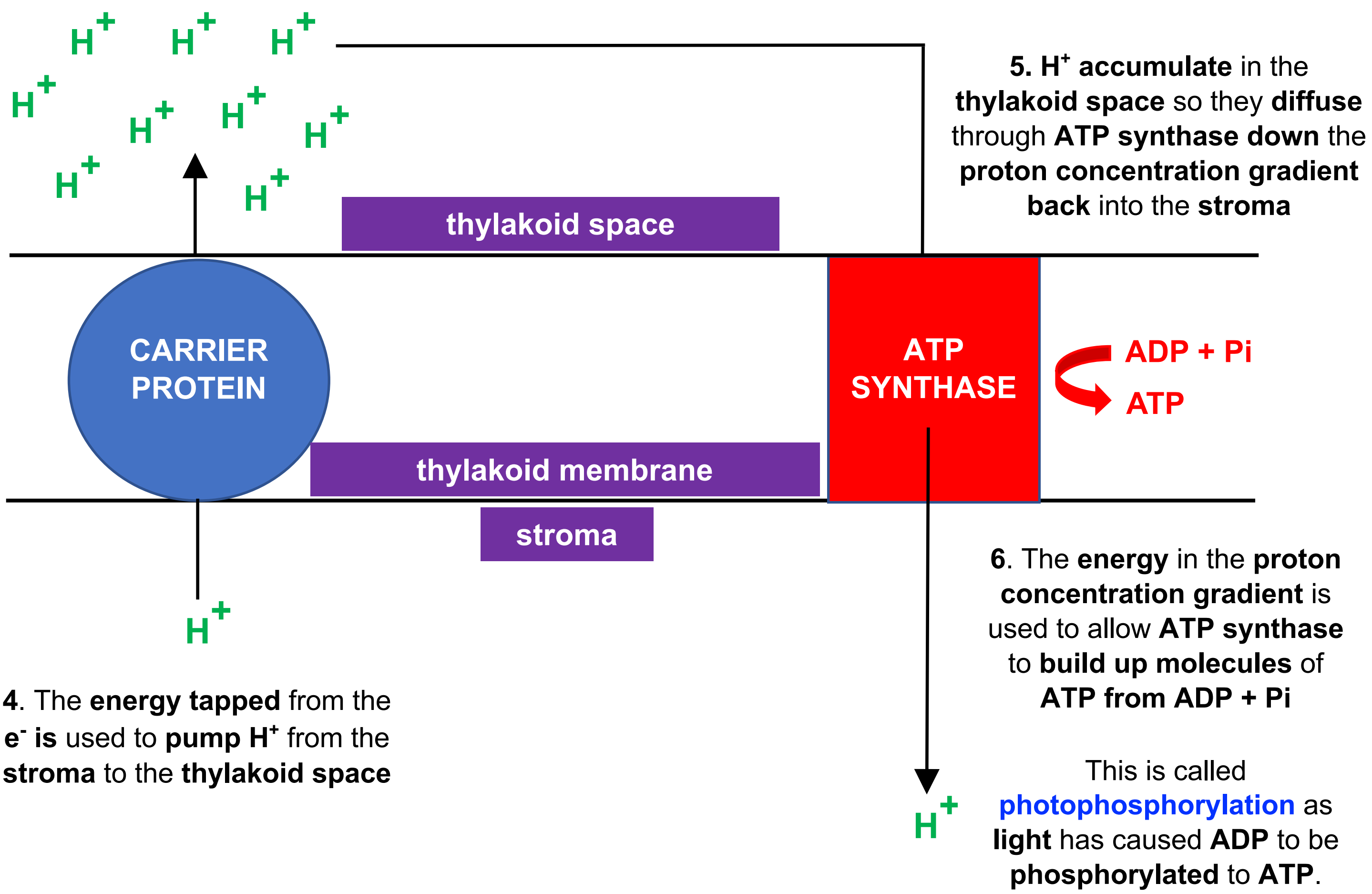
- **NADPH** and **ATP** are **made** in the **light-dependent** reactions (Stage 1) as they are **needed** for the **light-independent** reactions (Calvin cycle: Stage 2).

E. PHOTOSYNTHESIS

Stage 1: Light-dependent reactions (Thylakoids)

- Occur in the **thylakoids**
- Needed: **light; chlorophyll; water**
- Produced: **NADPH; ATP; oxygen**





ATP is produced by CHEMIOSMOSIS – its production is coupled to the movement of electrons and H⁺ across a membrane

PROBLEM!

NADPH STILL NEEDS TO BE **MADE**

PSII **CANNOT ABSORB MORE LIGHT** UNLESS THE **2E$^-$** THAT IT HAS **LOST** ARE **REPLACED**

How NADPH is made

LIGHT

absorbed

2e- from previous electron carriers pass to **PSI** → PSI

2e- become **excited** = high energy electrons →

3. ELECTRON TRANSPORT CHAIN (ETC)

e- travel along a chain of **electron carrier molecules**, losing energy at each stage. The **energy released** from the **e$^-$** is used to **reduce NADP** to **NADPH**

How the process is completed

in the thylakoid space

$H_2O \xrightarrow{\textbf{photolysis}}$ 2e- + $2H^+$ + ½ O_2 **(is excreted)**

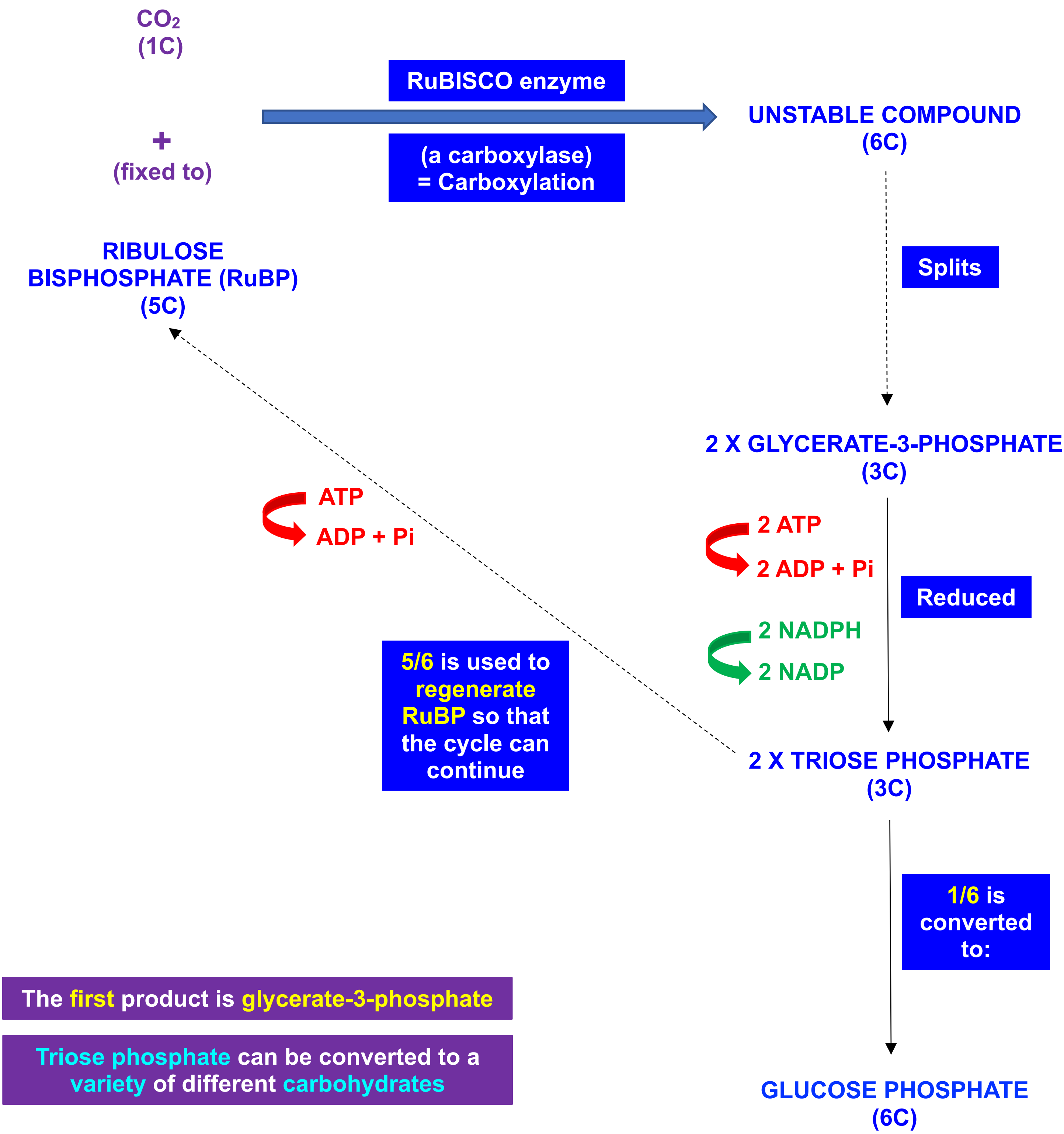
(splitting water using light)

2e- → **replace** the **2e$^-$ lost** from **PSII**

$2H^+$ → **reused** in the **H^+ concentration gradient**

Stage 2: Light-independent reactions = The Calvin Cycle (Stroma)

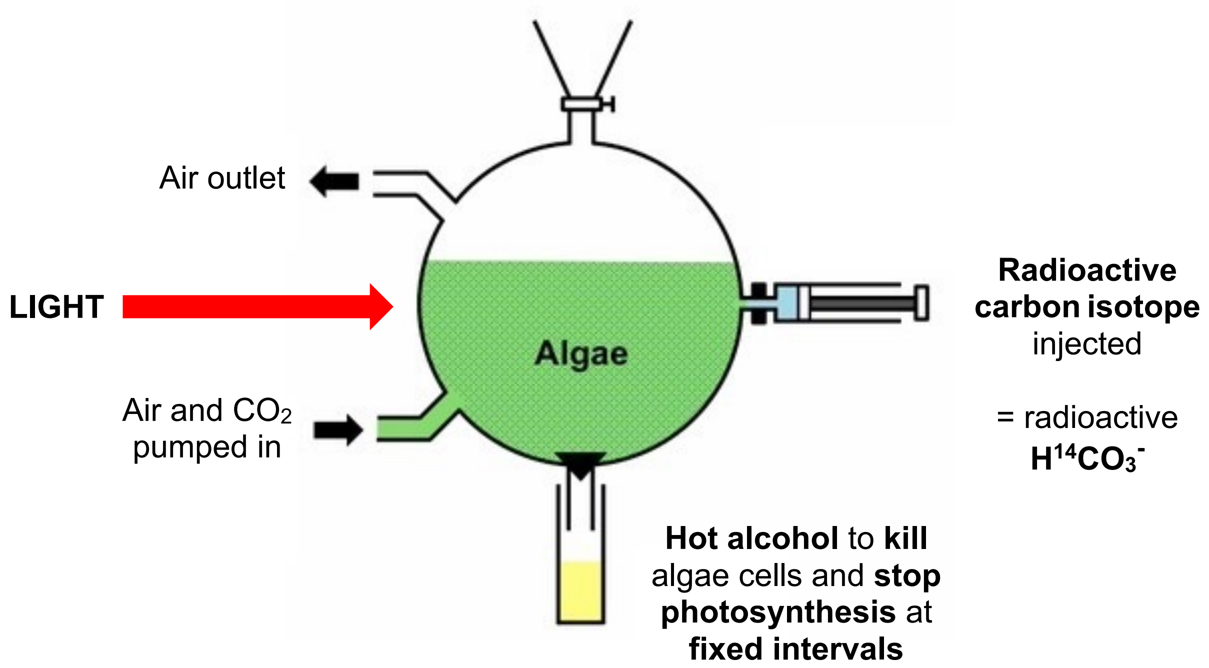
- Occur in the **stroma**
- Needed: **CO_2; NADPH; ATP**
- Produced: **glucose (phosphate)**
- **ATP** and **NADPH** from the **light-dependent reactions** are used here
- **Ribulose bisphosphate** is simply a **CO_2 acceptor** molecule – it **fixes** (combines with) **CO_2**.



F. MELVIN CALVIN'S LOLLIPOP EXPERIMENT

- He worked out the **order** that **different compounds are produced** in the **light-independent** reactions (**Calvin cycle**).

What Calvin did



- Algae (***Chlorella***) are placed in a **thin glass** container of a **large surface area** for **maximum light absorption**.

- Algae are given **plenty** of **light** and **CO_2.**

- At the **start**, algae are supplied with **radioactive carbon** (**$H^{14}CO_3^-$**)

- Algae will **use** this in **photosynthesis** to produce **compounds** in the **Calvin cycle**.

- All compounds produced would **contain ^{14}C** and be **radioactive**.

- At **fixed time** intervals, algae cells were **killed** with **hot alcohol** to **stop photosynthesis**.

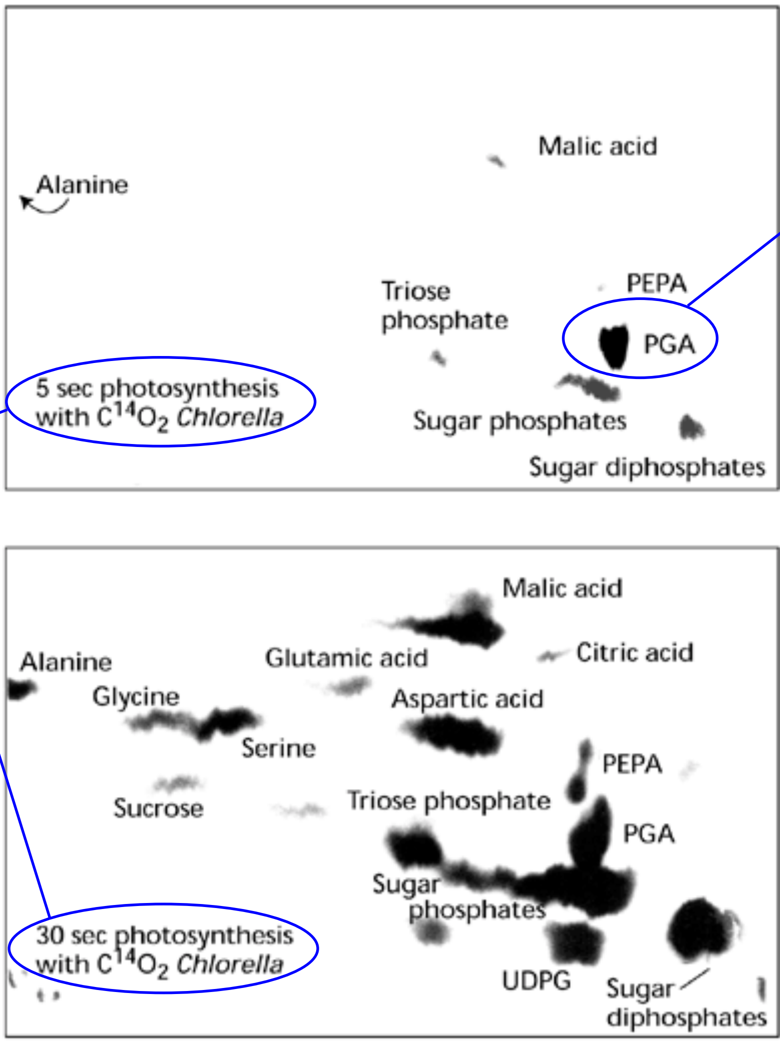
- **2-D chromatography** was then used to **separate** the different compounds produced.

- **Autoradiography** was then used to **detect** and **identify** the **radioactive** compounds produced.

- These compounds would appear **black** on an **X-ray** film.

Calvin's results

Samples were **killed** and **analysed** at **different time intervals** after exposure to **$^{14}CO_2$**



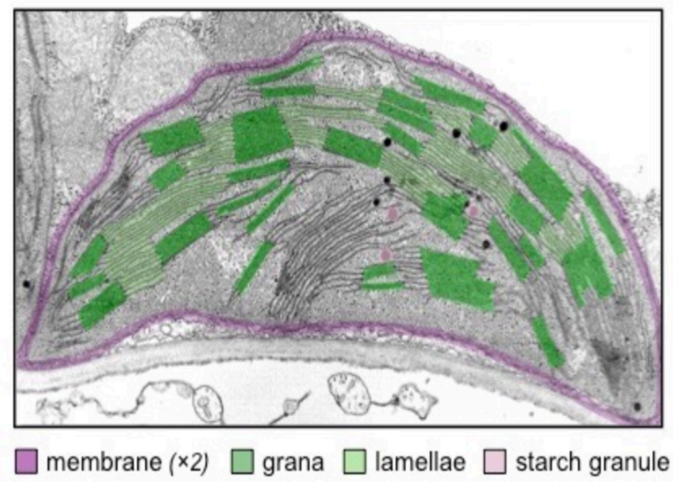
There is **more** labelled PGA = **glycerate-3-phosphate** than any other compound after **5 secs** so this must be the **first compound produced**

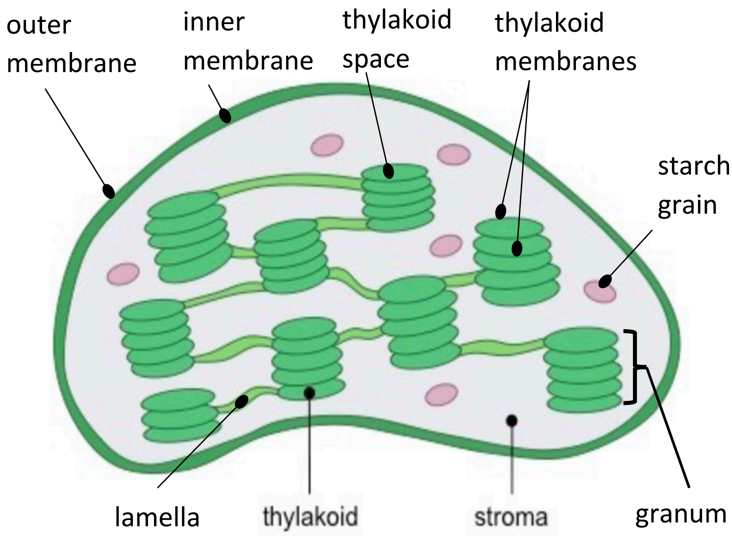
What Calvin Showed

- After **5 seconds**, there is **more glycerate-3-phosphate** than any other compound
- (So) **glycerate-3-phosphate** is the **first** stable **product**
- The **next** compound to be detected was **triose phosphate**
- A **wide range** of **carbon compounds** was **quickly** made in **sequence** from this
- A **cycle** of **reactions** was used to **regenerate RuBP**

G. STRUCTURE & FUNCTION OF A CHLOROPLAST

ELECTRON MICROGRAPH	DIAGRAM





- Feel free to also add many **70S ribosomes** and **circular DNA** to the diagram.

STRUCTURE	ADAPTATION
Thylakoid Space	**Very small volume so:** a **steep H^+ concentration gradient** can be created
Thylakoid Membranes	**Large total surface area so:** **maximum light absorption** by **PSI** and **PSII** Provide a site for **electron flow**, creation of an **H^+ concentration gradient** and **chemiosmosis**
Starch Grains	For **storage** of **carbohydrate** until it is **exported** from the chloroplast
Granum	A **stack** of **thylakoids so:** **maximum absorption** of photons of **light** **Highly folded** provides a large **SA:VOL so:** **H^+** can be **quickly accumulated**
Stroma	**Contains**: • All **enzymes** needed for the **Calvin cycle** (e.g. **Rubisco**) • Naked **DNA** • **70S Ribosomes** for **protein synthesis**