

Bacterial Metabolism

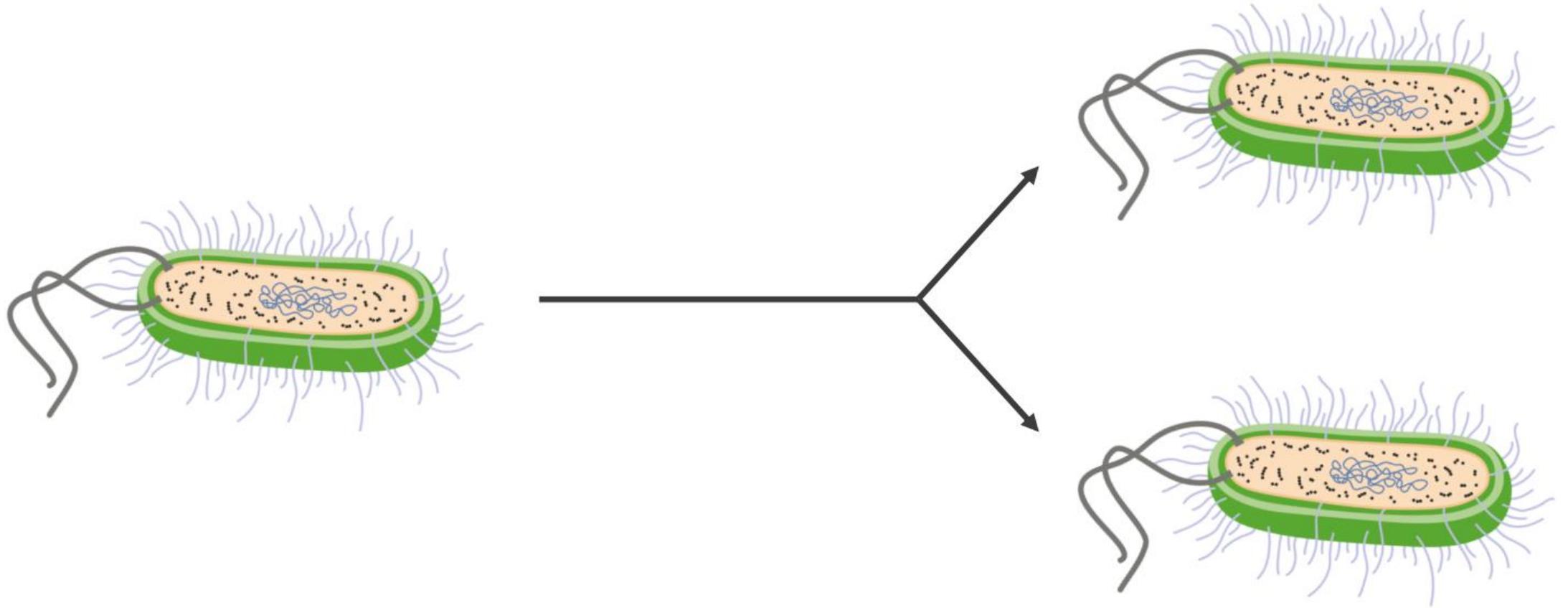
Dr. Hala Altarawneh



Outline

- Introduction to Bacterial Metabolism
- Making a Bacterial Cell
- ATP: The Energy Currency
- Three Pathways bacteria use to generate this ATP:
 - Glycolysis
 - Fermentation
 - Respiration

Making a Bacterial Cell



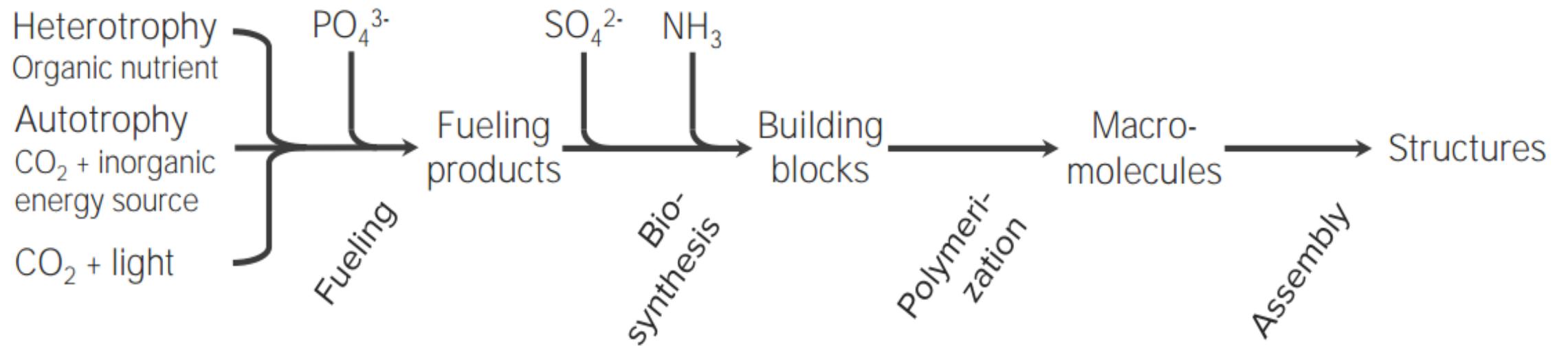
Making a Bacterial Cell: Definitions

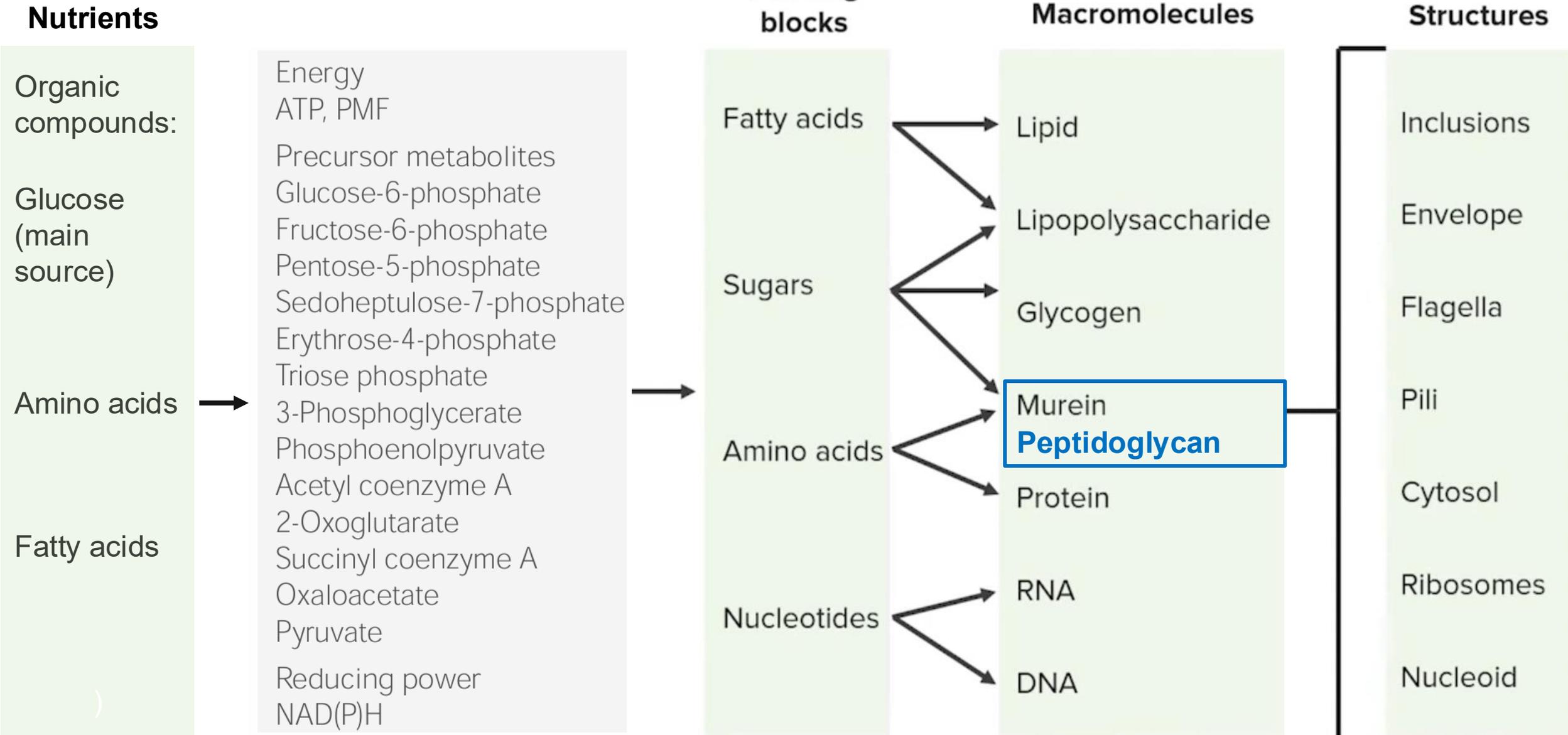
- Microorganisms are divided into two main groups based on their carbon source:
- Autotrophs, which get carbon from inorganic sources like carbon dioxide,
- Heterotrophy
 - Carbon source: Organic nutrients (glucose, amino acids, fatty acids)
 - Energy source: Breaking down these same organic compounds
 - Most human pathogens are heterotrophs, which is why they need to invade our bodies

Making a Bacterial Cell: Definitions

- **Metabolism = ALL the chemical reactions bacteria use to:**
 - **Generate energy** (catabolism - breaking down nutrients → ATP)
 - **Build cellular components** (anabolism - synthesizing DNA, proteins, cell wall)
- **The Two Sides of Metabolism:**
 - **Catabolism:** Breaking down glucose, fats, proteins → releases energy (ATP)
 - **Anabolism:** Using that ATP to build new structures

Making a Bacterial Cell





Making a Bacterial Cell

- The nutrients enter the central metabolic simultaneously produce:
 - ✓ ATP (Energy) → Used for biosynthesis, movement, transport
 - ✓ 12 Precursor Molecules → Made as intermediates (byproducts) → Starting points for ALL biosynthesis → Modified to create **building blocks**
- **Building blocks:**
 - ✓ Amino acid
 - ✓ Sugar
 - ✓ Fatty acid
 - ✓ Nucleotides

Making a Bacterial Cell

Polymerization (Linking):

Building blocks → Macromolecules (uses ATP)

- Amino acids → PROTEINS (enzymes, toxins, structural)
- Nucleotides → DNA & RNA (genetic material)
- Sugars → PEPTIDOGLYCAN (cell wall)
- Fatty acids → LIPIDS (membranes)
- Sugars + lipids → LPS (Gram-negative envelope)

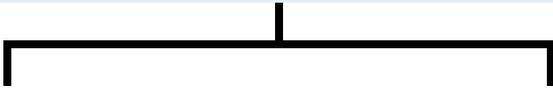
Cell Division:

Complete cell → TWO daughter cells

GLUCOSE
(from host)



GLYCOLYSIS & KREBS CYCLE
(Central Metabolic Pathways)



ATP
(Energy)
2-38 molecules

Powers this! →

PRECURSORS
(Building Materials)
12 molecules

+ NH₃
+ PO₄³⁻
+ SO₄²⁻



BUILDING BLOCKS
• Amino acids • Nucleotides
• Sugars • Fatty acids



MACROMOLECULES
• Proteins • DNARN
• Peptidoglycan • Membranes



 **NEW BACTERIAL CELL** 
Ready to divide!

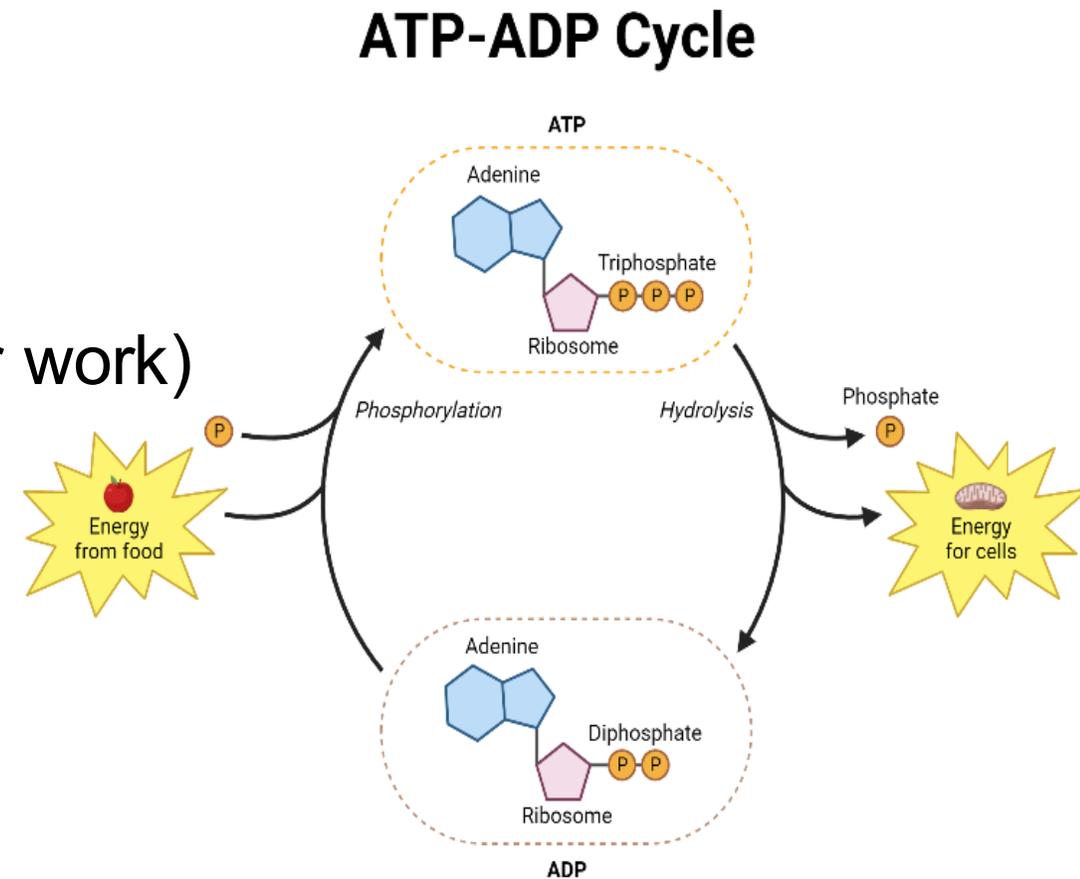
What is ATP?

- **ATP: THE ENERGY CURRENCY**
 - ATP = Adenosine Triphosphate
 - Universal energy carrier in all living cells
 - Molecular currency" of energy

- When needed:

$ATP \rightarrow ADP + P_i + \text{ENERGY (for cellular work)}$

- That energy powers:
 - DNA replication
 - Protein synthesis
 - Active transport
 - Flagellar movement
 - Biosynthesis of cell components



How do bacteria make ATP?

Bacteria make **ATP** through THREE main ways:

- Glycolysis
- Respiration
- Fermentation

How do bacteria make ATP? Glycolysis

All bacteria **start here:**

Glucose → GLYCOLYSIS → 2 Pyruvate + **2 ATP** + **2 NADH**

- Occurs in ALL bacteria (and ALL living cells!)
- Does NOT require oxygen

How do bacteria make ATP? Glycolysis

Why important?

- Provides energy for growth and survival
- Supplies building blocks for other pathways (fermentation or respiration)

Clinical link:

- Many pathogens rely on glycolysis inside the host
- Lab tests detect products of glucose metabolism (e.g., sugar fermentation tests)

After Glycolysis - What Happens to NADH?

The Problem:

- Glucose \rightarrow 2 Pyruvate + 2 ATP + **2 NADH**
- but cells have **limited NAD⁺** supply
- **NADH must be recycled back to NAD⁺** or **glycolysis stops!**

Two Solutions:

- **If O₂ is available** (or another electron acceptor is present) \rightarrow **RESPIRATION**
 - NADH \rightarrow Electron Transport Chain
 - **Result:** Lots of ATP (~36 more!)
- **If NO O₂ available** \rightarrow **FERMENTATION**
 - NADH \rightarrow Transfers electrons to pyruvate
 - **Result:** No extra ATP (but glycolysis continues)

How do bacteria make ATP? **Respiration**

Respiration: The biochemical process in which the cells of an organism **obtain energy**, typically with the **intake of oxygen** and the **release of carbon dioxide** from the oxidation of complex organic substances.

Cellular respiration formula:

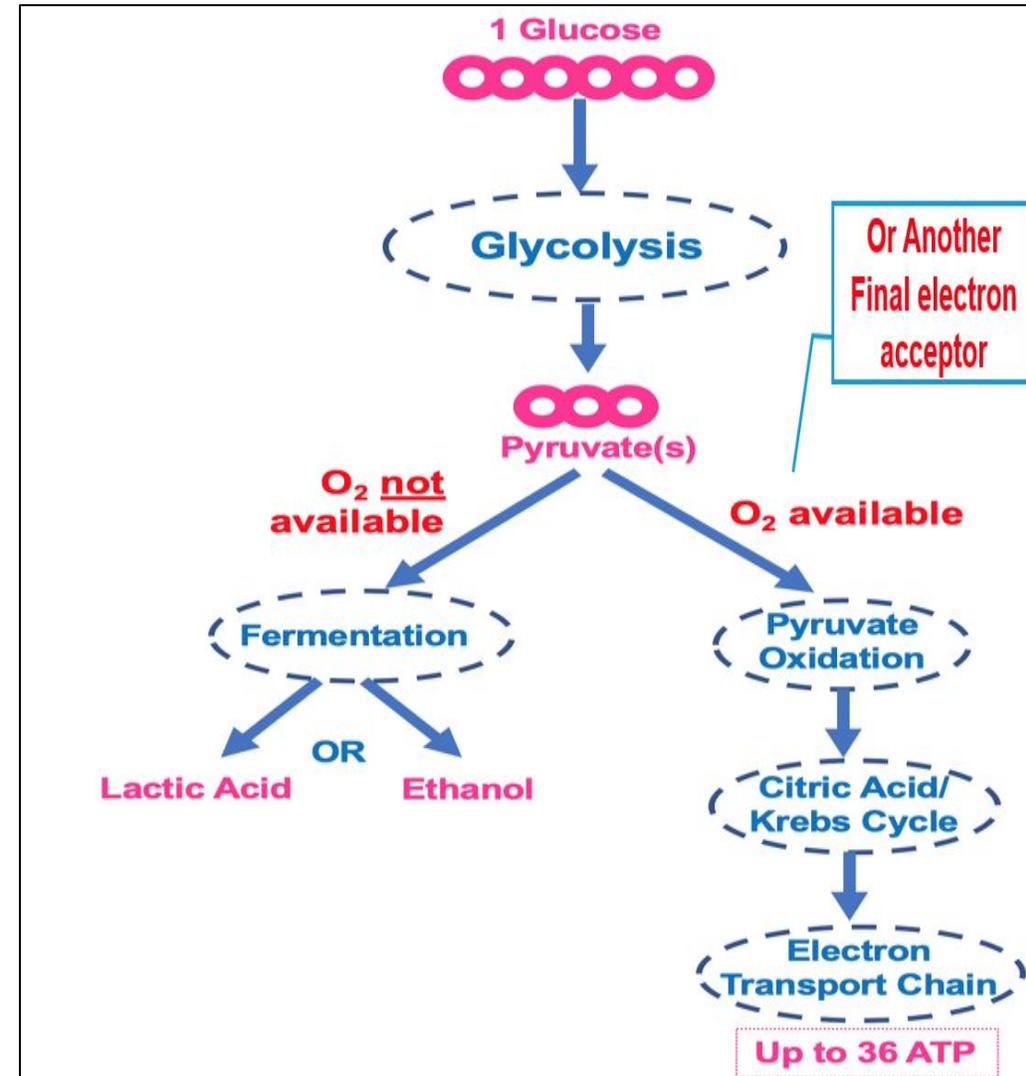


How do bacteria make ATP? **Respiration**

The Complete Process:

1. Glucose → Glycolysis (2 ATP)
2. Krebs Cycle (2 ATP)
3. Electron Transport Chain (34 ATP)

Total: ~38 ATP per glucose



How do bacteria make ATP? **Respiration**

Types of respiration:

- **Aerobic respiration:** oxygen = final electron acceptor → water formed
 - **~38 ATP per glucose** (much more efficient than fermentation)
- **Anaerobic respiration:** uses other acceptors (nitrate, sulfate, CO₂)
 - Less ATP than aerobic, but more than fermentation

How do bacteria make ATP? **Respiration**

Why important in medicine:

- Explains why bacteria can live in different body sites (lungs vs. gut, wounds, abscesses)
 - Some pathogens adapt to oxygen availability (facultative anaerobes like *E. coli*)
- Antibiotics can target ETC (e.g., isoniazid in TB)

How do bacteria make ATP? Fermentation

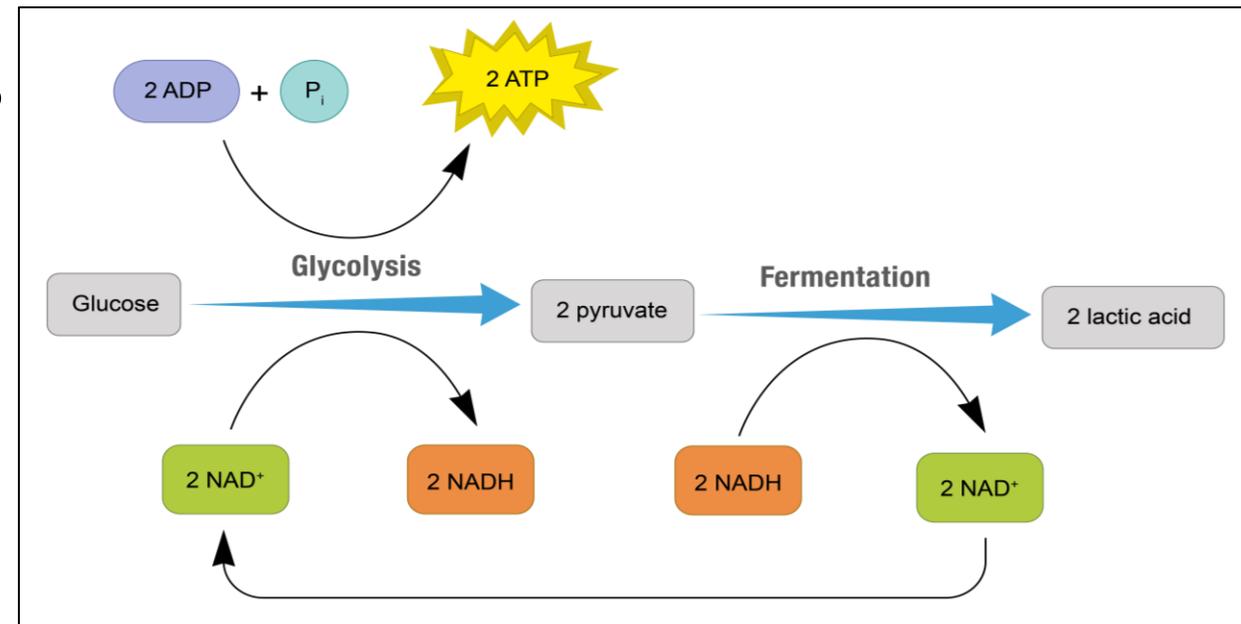
If respiration is not possible (no O₂, no alternative acceptor):

- Cell must regenerate NAD⁺ another way.
- Pyruvate accepts electrons from NADH → NAD⁺ (regenerated!)
- Produces various end products (acids, alcohols, gases)
- **NO additional ATP made!**

Glucose → 2 Pyruvate (via **glycolysis**) = 2 ATP

Pyruvate → Fermentation products = 0 ATP

TOTAL: = 2 ATP



How do bacteria make ATP? Fermentation

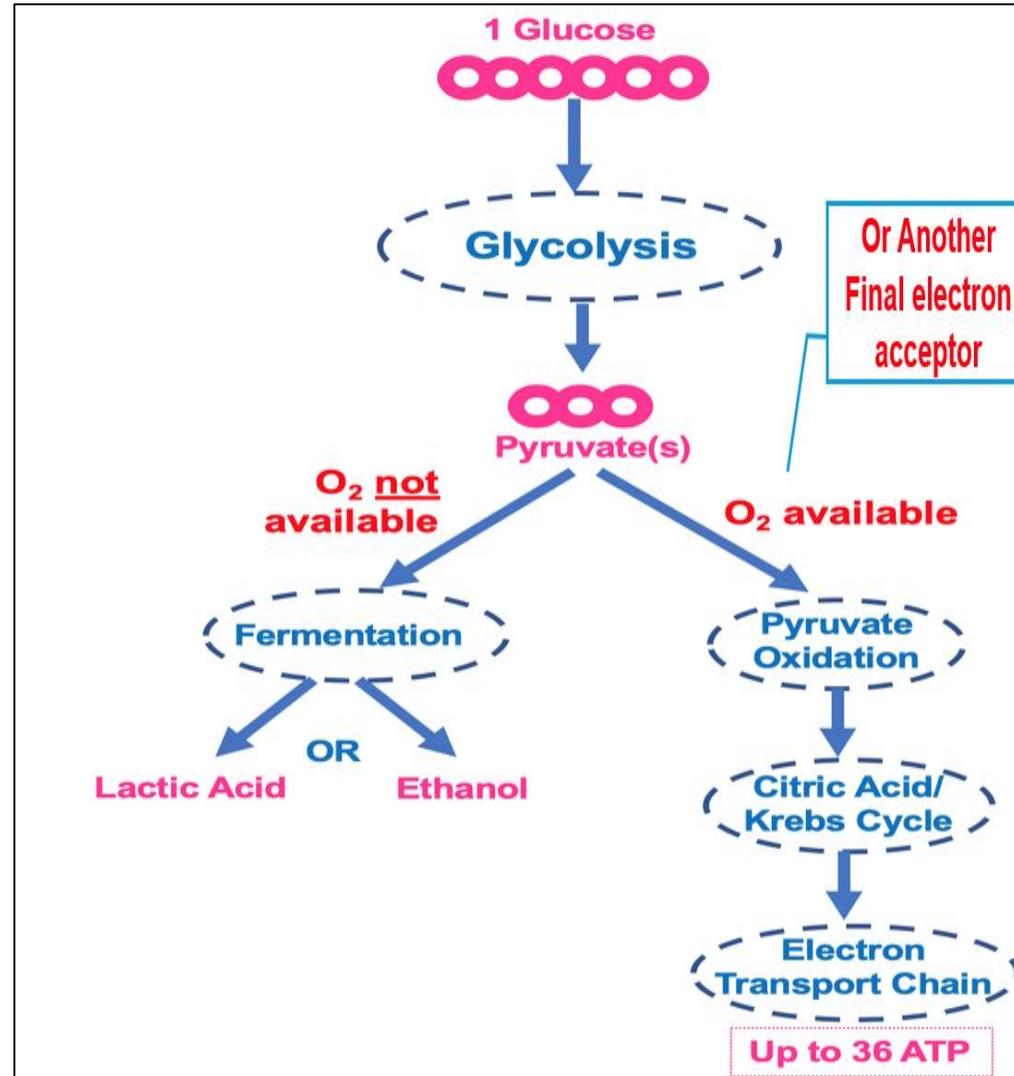
Why bacteria use it:

- Keeps glycolysis running, so the cell at least gets its **2 ATP/glucose**.
- Allows survival in oxygen-poor environments

Clinical link:

- **Tissue damage:** acids & gases can harm host (e.g., *Clostridium perfringens* → gas gangrene)
- **Diagnosis:** labs detect fermentation end-products
 - Sugar fermentation tests (lactose, glucose, etc.)
 - Gas production in culture tubes

Summary:



Summary Table

	Aerobic Respiration	Anaerobic Respiration	Fermentation
Needs O₂?	YES	NO	NO
Uses ETC?	YES	YES	NO
Final e⁻ Acceptor	O ₂	Nitrate/Sulfate	Organic (pyruvate)
Krebs Cycle?	YES	YES (usually)	NO
NADH Recycling	ETC	ETC	Direct (to pyruvate)
ATP Made	~38	~15-30	2
Location in Cell	Cell membrane	Cell membrane	Cytoplasm
Efficiency	 HIGH	 MEDIUM	 LOW

Thank you