

Electron Transport Chain Simulator

Name: _____ Period: _____ Date: _____

Open **peebedu.com** and navigate to **Electron Transport Chain Simulator**. Click the **Power Up!** button to begin. Read the introduction popup, which describes the inputs (NADH, FADH₂, O₂), the process (electron flow and proton pumping), the outputs (ATP and H₂O), and the significance of the electron transport chain.

Part 1 – Model Evaluation (MAPP Framework)

Scientific models are simplified representations of complex biological phenomena. Use the MAPP framework below to evaluate the Electron Transport Chain Simulator as a scientific model.

M – Mode

What type of model is the Electron Transport Chain Simulator? Describe how this computational simulation represents the process of oxidative phosphorylation within a mitochondrion. In your answer, identify at least three specific simulation elements (such as the electron flow animation through complexes, the H⁺ particles being pumped into the intermembrane space, the ATP synthase spinning animation, the oxygen molecules at the end of the chain, or the ATP counter) and explain what each one is designed to show about the electron transport chain.

A – Accuracy

(a) Identify two things this simulation represents **accurately** about the electron transport chain and oxidative phosphorylation. For each, name the specific simulation feature (e.g., the visible coupling between electron flow through complexes and H^+ pumping into the intermembrane space, the ATP synthase spinning only when the proton gradient is sufficient, or O_2 molecules accepting electrons and forming water at the final complex) and explain what aspect of the ETC it demonstrates.

(b) Identify two things this simulation **oversimplifies or leaves out** about the electron transport chain. Consider what you cannot observe in the simulation that would be important for a complete understanding of how electrons transfer energy through redox reactions to build a proton gradient. For example, think about whether you can see the actual chemical oxidation-reduction reactions at each complex, whether the proton counts represent real concentrations, and whether the simulation shows what happens to the cell when oxygen is completely absent.

P – Purpose

What is the learning goal of this simulation? Explain how the Electron Transport Chain Simulator is designed to help you understand how the transfer of electrons from NADH and $FADH_2$ through protein complexes is coupled to proton pumping, which creates the electrochemical gradient that drives ATP synthesis through chemiosmosis. In your answer, connect at least one specific simulation feature to the biological significance of oxidative phosphorylation for cellular energy production.

P — Permanency

Could this model change with new scientific evidence? Describe one way that new discoveries — such as structural studies revealing how ETC complexes organize into supercomplexes (respirasomes), or revised measurements of the exact number of protons pumped per electron pair — might change or improve a simulation like the Electron Transport Chain Simulator. Explain why scientific models, including computational simulations, are revised as new evidence becomes available.

Small-Group Discussion

With your group, discuss the following:

- What are the strengths of this simulation as a model for the electron transport chain and chemiosmosis?
- What are its limitations?
- If you could add one feature to improve this simulation, what would it be and why?
- How does manipulating the three sliders (temperature, electron carrier supply, and oxygen concentration) help you understand how changes in conditions affect ATP production?

Part 2 – NGSS Questions

1.

Simulation Task: Set the Electron Carrier Supply to Fast and the Oxygen Concentration to 5 (Medium). Click Start and watch for 30 seconds. Pay attention to the NADH and FADH₂ molecules arriving at the chain and the electrons moving through the protein complexes.

Describe the path that electrons follow from the moment an NADH molecule delivers them to the first protein complex until they reach the end of the chain. Explain why cells need a series of electron carriers arranged in a specific order rather than transferring all the energy in a single step.

HS-LS1-7

2.

Simulation Task: With the simulation running at Normal temperature and Medium carrier supply, observe the H⁺ particles being pumped from the matrix into the intermembrane space. Watch the gradient indicator and note when the status changes to "Active" and ATP synthase begins spinning.

Explain how the movement of H⁺ ions across the inner membrane creates a concentration difference between the intermembrane space and the matrix. Describe how this stored energy is then used by ATP synthase to produce ATP.

HS-LS1-7

3.

Simulation Task: Set the Oxygen Concentration slider to its maximum value (10) and run the simulation for 30 seconds. Then reduce the Oxygen Concentration slider to 1 (Low) and observe for another 30 seconds. Compare the electron flow, H^+ gradient, and ATP counter between the two conditions.

Describe the changes you observe when oxygen levels drop. Explain why oxygen is necessary for the electron transport chain to keep running and what happens to ATP production when oxygen is not available to accept electrons at the end of the chain.

HS-LS1-7

4.

Simulation Task: Run the simulation with Electron Carrier Supply set to Slow, then switch to Fast while keeping Temperature and Oxygen at Normal and Medium. Compare the ATP counter rate under both settings.

Explain how the supply of electron carriers (NADH and $FADH_2$) affects the rate of ATP production. Describe what this tells you about the relationship between the food molecules an organism breaks down and the amount of energy the organism can use for life processes.

HS-LS1-7

5.

Simulation Task: Set Temperature to Cold and run the simulation for 30 seconds, noting the ATP counter. Then set Temperature to Hot and run for another 30 seconds. Observe how the speed of electron flow, proton pumping, and ATP synthase rotation changes.

Describe how temperature affects the rate of ATP production in the simulation. Explain why an organism that cannot regulate its body temperature would produce energy at different rates in cold and warm environments, and how this would affect the organism's ability to carry out life functions.

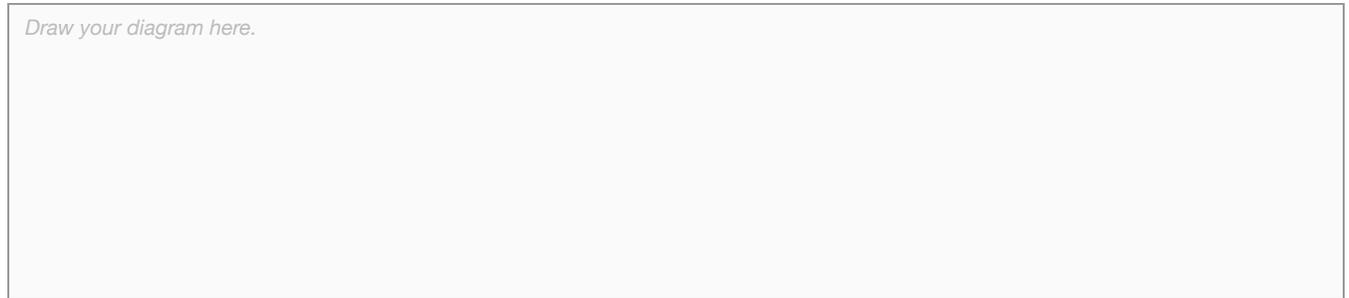
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6.

Simulation Task: Run the simulation at Normal temperature, Fast carrier supply, and Medium oxygen. Observe the full process: electron carriers arriving, electrons flowing through complexes, H⁺ ions being pumped across the membrane, H⁺ flowing back through ATP synthase, and ATP being produced. Also note the water forming at the end of the chain.

In the box below, draw a diagram of the inner mitochondrial membrane showing the flow of energy from electron carriers to ATP. Label the following: the intermembrane space, the matrix, two protein complexes pumping H⁺, the direction of H⁺ movement during pumping, ATP synthase with H⁺ flowing back through it, and ATP being produced. Use arrows to show the direction of energy transfer.

Draw your diagram here.



HS-LS1-7

7.

Simulation Task: Reset all sliders to their default values and run the simulation one final time. Watch the full cycle: NADH and FADH₂ delivering electrons, protons being pumped, ATP synthase spinning, and water forming. Consider that the carbon-containing molecules broken down earlier in cellular respiration originally came from food, which traces back to carbon fixed by photosynthetic organisms.

The electron transport chain is the final stage of cellular respiration, a process found in nearly all organisms on Earth — from bacteria to plants to animals. Explain how the movement of carbon and energy through ecosystems depends on cellular respiration. Describe how the carbon atoms in the food an organism eats are connected to the CO₂ released earlier in respiration and the ATP produced at the electron transport chain.

HS-LS2-5