BUILDING & MODELING IMMUNE FUNCTION

Student Design Brief & Interactive Lab Handout

The Scenario: You are part of the body's primary line of cellular defense. An infection has just breached the physical barriers, and the innate immune system must quickly identify, contain, and communicate the presence of these foreign invaders. Using your provided foam modeling components, your mission is to engineer physical cell structures that demonstrate how the body detects structural "red flags."

Part 1: The Cellular Spec Sheets

Review the biological blueprints below. Use your modeling components to build representations that meet these real-world constraints.

The Macrophage (The Hunter)

First responders on the scene of an infection. They crawl through tissue spaces seeking threats to eliminate.

- **Dimensions:** Around 10 to 20 micrometers (µm) in diameter.
- **Morphology:** Highly flexible, dynamic outer boundary forming broad membrane extensions called *pseudopods*.
- **Sensors:** Equipped with generic pathogen receptors.
- **Core Mechanism:** Must bind intact invaders trigger engulfment and process them internally.

🦠 The Microbe (The Invader)

Foreign organisms (such as bacteria) attempting to bypass host barriers to multiply.

- **Dimensions:** Significantly smaller, typically ranging from 1 to 5 micrometers (µm) in diameter.
- **Morphology:** Maintained by a rigid outer *cell wall* for protection. Can feature surface swimming tails (*flagella*) or sticky outer coatings.
- **The Red Flags:** Covered entirely in distinct molecular patterns (like Lipopolysaccharide or Peptidoglycan) that give away its alien identity.

⚠️ The Tabletop Scale Challenge

A true human macrophage is **3 to 15 times larger** than a single bacterial microbe! If you model an entire intact microbe on your desk, your macrophage model would be too large to fit on the table.

Modeling Strategy: Construct your microbe model completely but only show a curved edge or section of your macrophage membrane to preserve the actual size relationship.

Part 2: Engineering Your Components

- ☐ Outer Membrane Boundary (Loose & Flexible)
- ☐ Surface Pathogen Sensors (Generic Shape)
- ☐ Internal Digestive Compartment (Endosome loop)
- ☐ Internal Pathogen Sensors (Deep Alarm System)
- ☐ Chemical Alarms (Cytokine signaling pieces)
- ☐ Rigid Cell Wall / Outer Shell Loop
- ☐ Surface Structure Feature (e.g., Flagella tail)
- ☐ Surface Molecular "Red Flags" (PAMPs)
- ☐ Hidden Internal Material (Genetic strands / Debris)
- ☐ Loose Pathogen Fragments (Scattered viral debris)

Part 3: Tactical Defense Simulations

Execute the following two defense scenarios with your models.

SIMULATION A Bumping the Perimeter (Whole-Microbe Capture)

1. **Initial Contact:** Advance your intact, whole microbe model toward the macrophage. Physically make contact between a surface "red flag" on the microbe and an *outside* sensor on the macrophage.
2. **The Engulfment:** Use the membrane pieces to sweep completely around the intact microbe, pulling it inside the cell within a digestive compartment.
3. **The Core Digestion:** Once safely sealed inside, fuse the vesicle with a lysosome to model digestion.
4. **Internal Red Alert:** Touch those newly exposed internal pieces to the *inside* sensors which face inside the endosome toward the digested fragments. Trigger the release of your chemical alarm pieces outside the cell to summon help.

SIMULATION B Sweeping up the Scrap (Loose Debris Detection)

1. **The Debris Trap:** Place loose, shattered pathogen fragments directly onto the table surface representing PAMP debris.
2. **The Blind Sweep:** A dendritic cell can sample the loose debris for threat signals.
3. **The Deep Tripwire:** The dendritic cell displays the fragments on surface receptors which it carries to a lymph node for sampling.

Part 4: The Simple Cell Reference Key

As you wrap up Part 1, preview how your local response bridges directly to the adaptive immune system in our next session.

Cell Model	Visual Metaphor	Receptor Blueprint	Activity Target
Macrophage	**The Hunter (Pac-Man)** A fluid, morphing blob that actively roams.	Generic sensors sitting on both the outside & inside boundaries.	Targets, binds, and swallows whole **microbes** from the tissue.
Dendritic Cell	**The Net (Spiderweb)** A stationary cell with long, branching arms.	Sticky, generic receptors covering extensive surface areas.	Catches **loose pathogen fragments** and travels to alert the lymph node.

CRITICAL ANALYSIS QUESTION

Based on your simulation, explain why it is vital for a first-responder immune cell to possess sensors on the INSIDE of its digestive compartments rather than relying exclusively on surface-level receptors.