

Lesson 3: Teacher Reference 1

Developing the M-E-F poster

In order to explain many natural phenomena, students need to be able to connect their observations with evidence of mechanisms that they cannot see directly. These observations usually take the form of changes in matter within a system or between systems, and the mechanisms might involve energy transfer due to unbalanced forces acting in the system. To integrate these ideas into a sensemaking framework, we introduce a key anchor chart, the Matter, Energy, and Forces poster, abbreviated as the **M-E-F poster**. Over the course of this and subsequent units, this will become a public record of important ideas and questions that students ask to explore the dynamic interactions between matter, energy, and forces. Lessons 2, 3 and 4 include major additions to this poster.

The M-E-F is a tool to support developing explanations of many natural phenomena that we explore in OpenSciEd high school. This tool encourages students to answer different questions about changes that are happening in the system from a matter, energy, and forces perspective. By asking these questions over and over throughout this unit and other units, the goal of this tool is to support students developing productive lenses that can help them identify areas of a phenomenon that require further exploration.

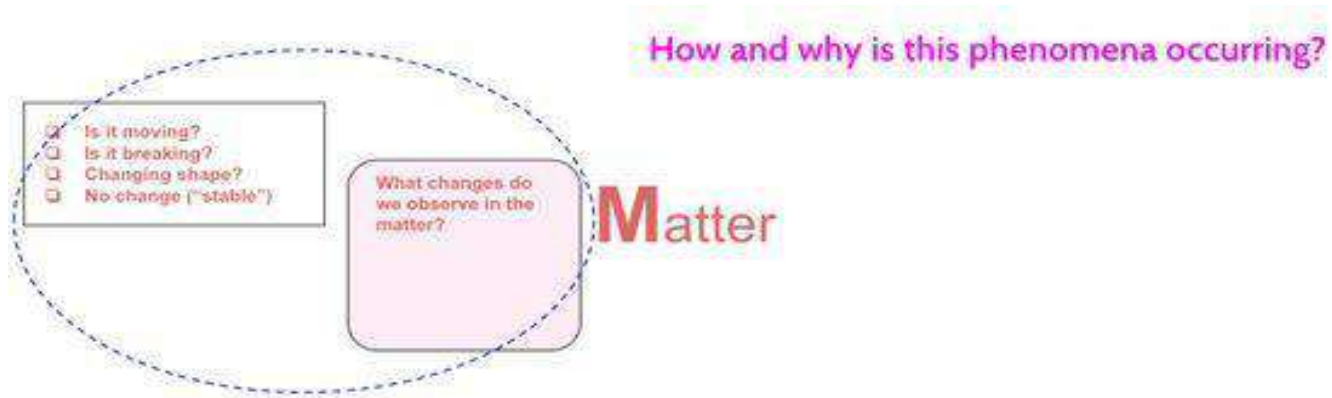
Development of the M-E-F poster in this unit

In **Lesson 2**, we introduce the idea that looking at changes in matter seems to be a first step to understand why a phenomenon is occurring. We add the following panel to the poster:

- “Matter” and “What changes do we observe in the matter?”

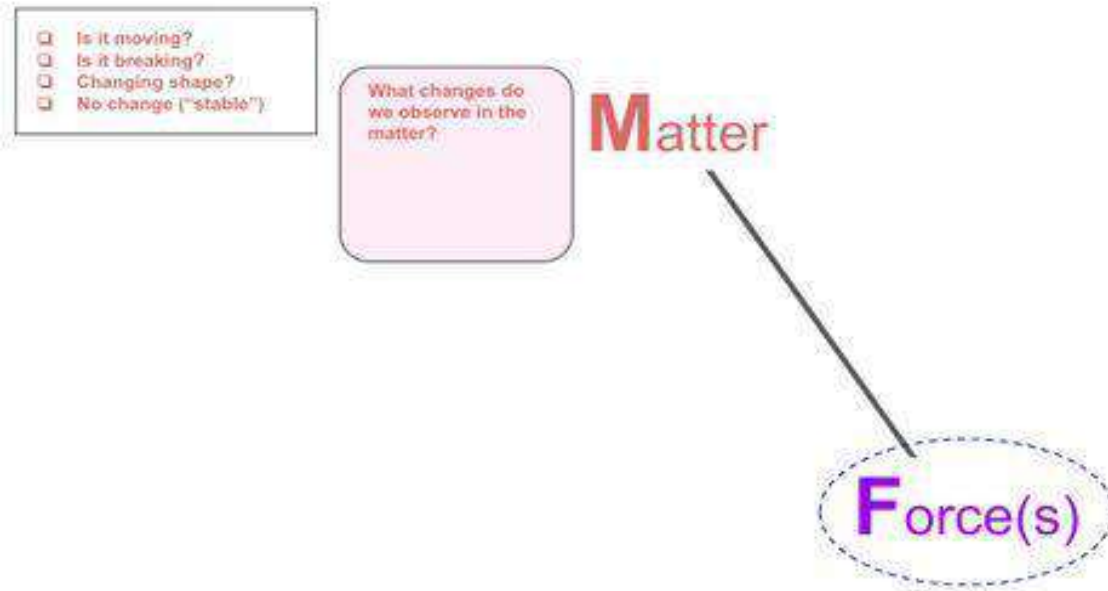
We also add the panel that lists the changes (in the form of questions) that students predicted we might observe in the matter:

- Is it moving?
- Is it breaking?
- Changing shape?
- No change (“stable”)



The investigations students carry out using forces acting on a physical system help us develop the idea that the changes in matter they are predicting (plate motion, Afar crack) are caused by forces, suggesting that forces are another important lens that can help us make sense of phenomena. We add the panel with "Force(s)" on it to the bottom black line that connects it to "Matter".

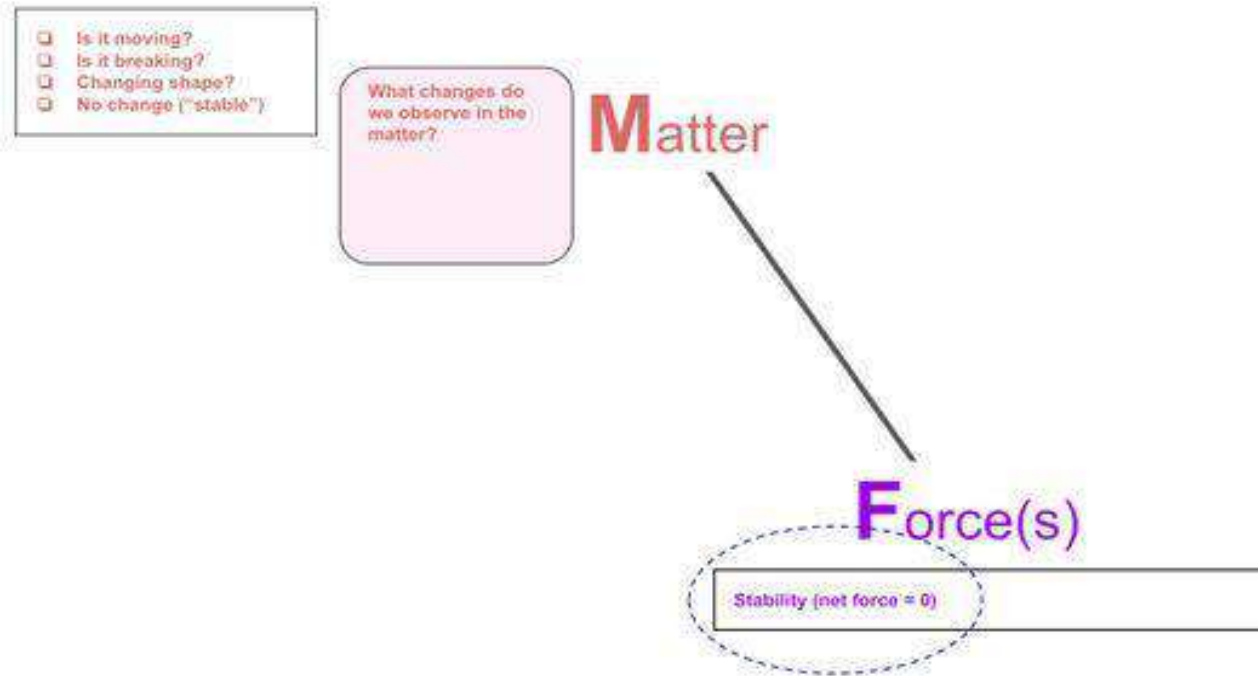
How and why is this phenomena occurring?



Later in the lesson, we figure out how balanced forces or a net force of zero can produce stability in matter. We use these ideas to add the following annotation under the "Force" section of the poster:

- Stability (net force = 0)

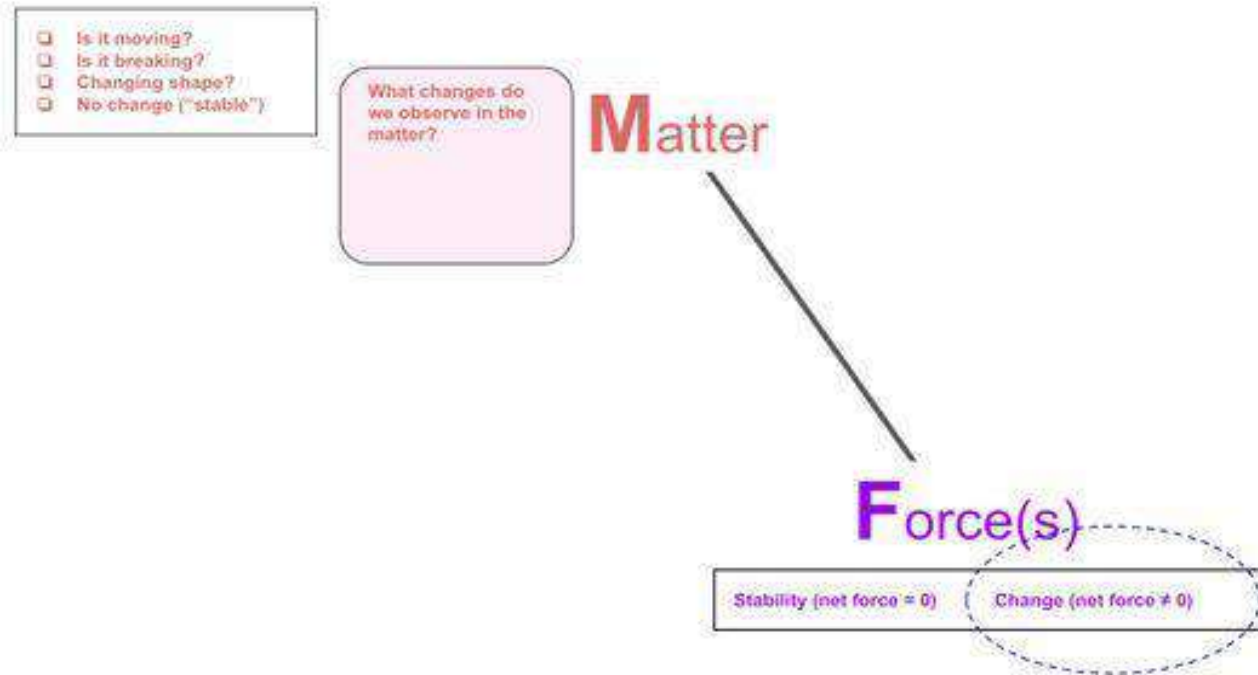
How and why is this phenomena occurring?



In addition, we determined that the changes in an object's motion were caused by the presence of a nonzero net force acting on it. We add the following annotation under the "Force" section of the poster:

- Change (net force $\neq 0$)

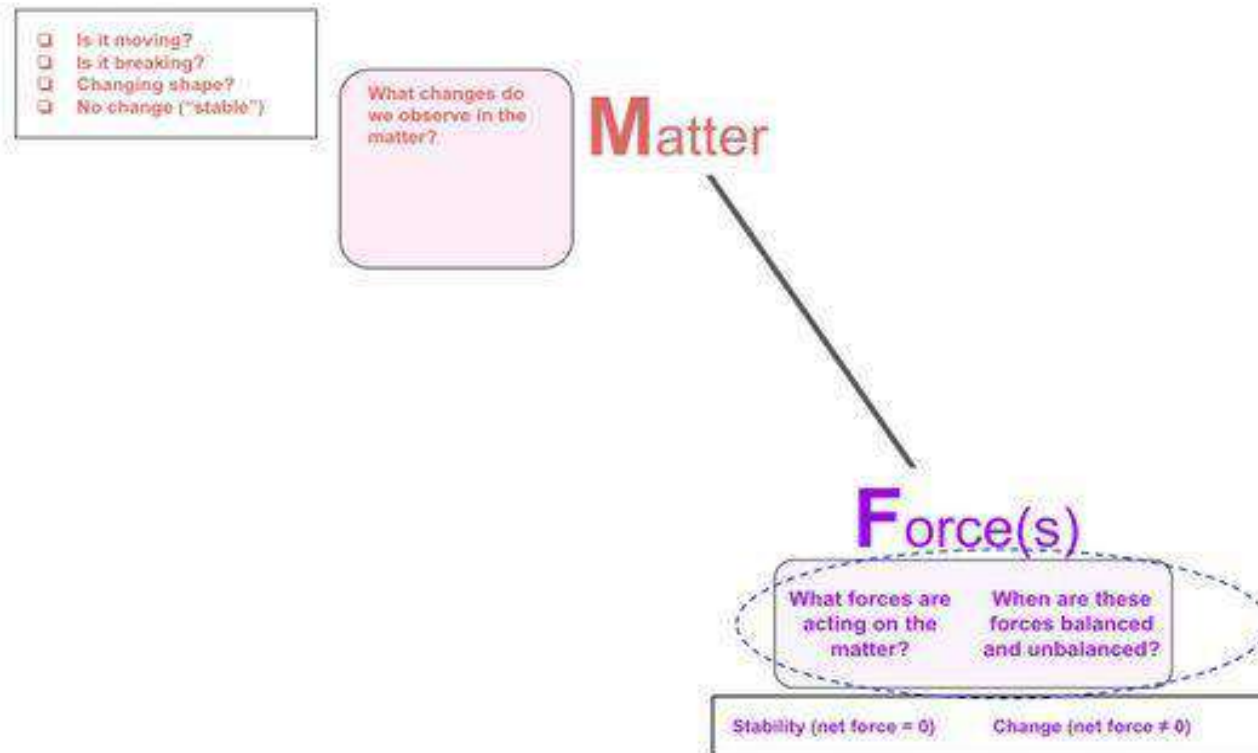
How and why is this phenomena occurring?



To synthesize the role of forces acting on a system, two prompts are added to the M-E-F poster:

- "What forces are acting on the matter?"
- "When are these forces balanced and unbalanced?"

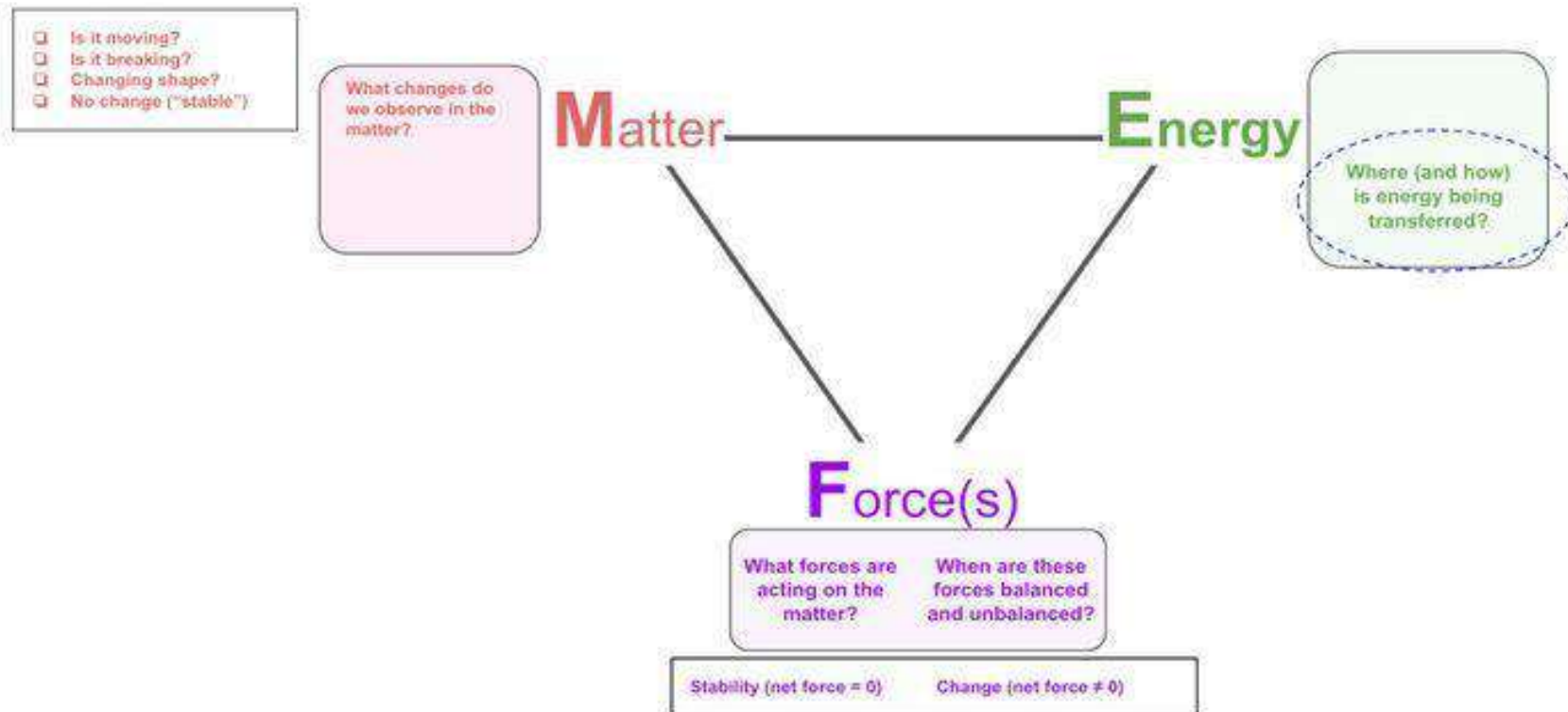
How and why is this phenomena occurring?



In the *Electricity Unit*, we explained many phenomena by thinking about energy transfer through the system. In **Lesson 3**, we use this lens again to try to explain what is happening in a foam model simulating how forces affect the matter in plates. We include a prompt that will help us make sense of energy transfer in a system:

- Where (and how) is energy being transferred?

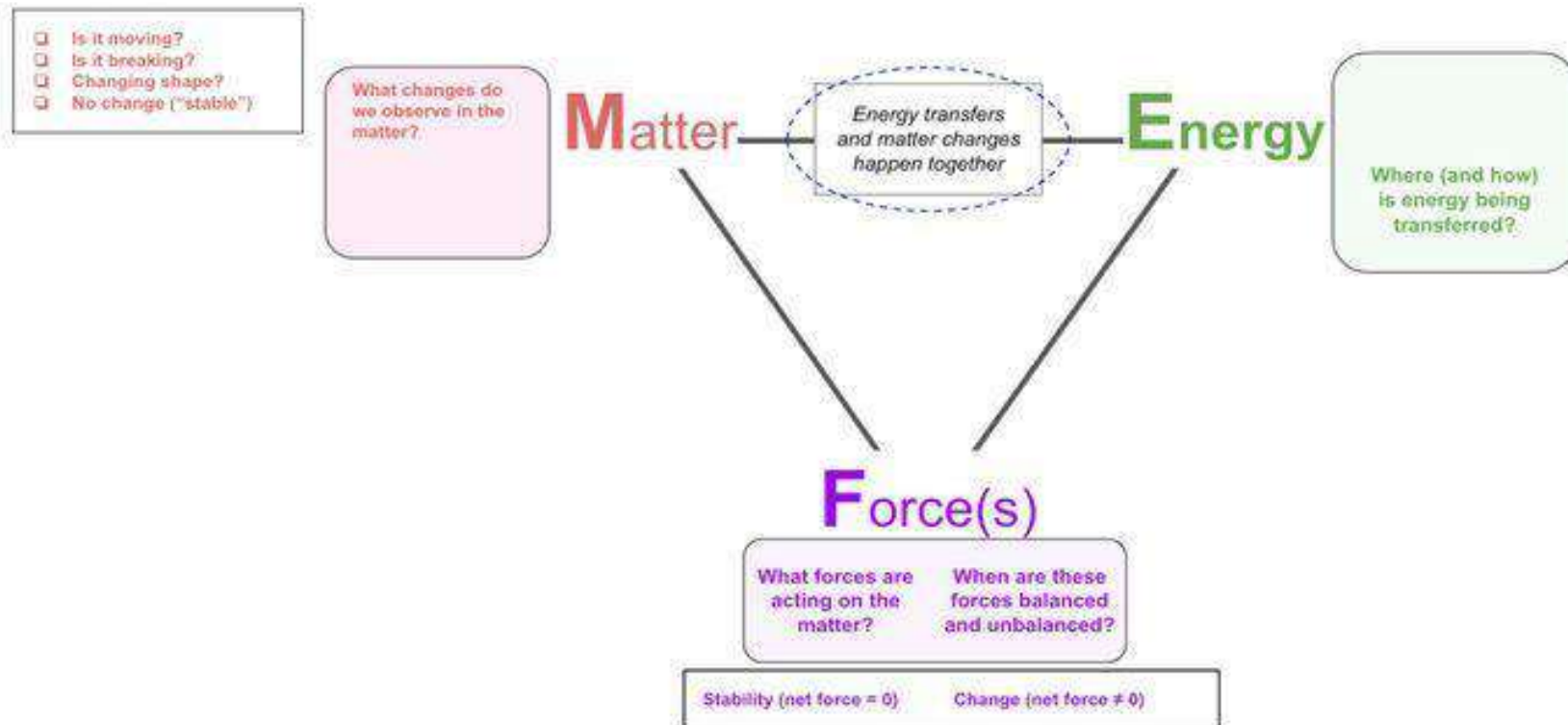
How and why is this phenomena occurring?



Based on the explorations with the foam model, we add the following idea to the poster on the line between the "Matter" and "Energy" panels:

- "Energy transfers and matter changes happen together"

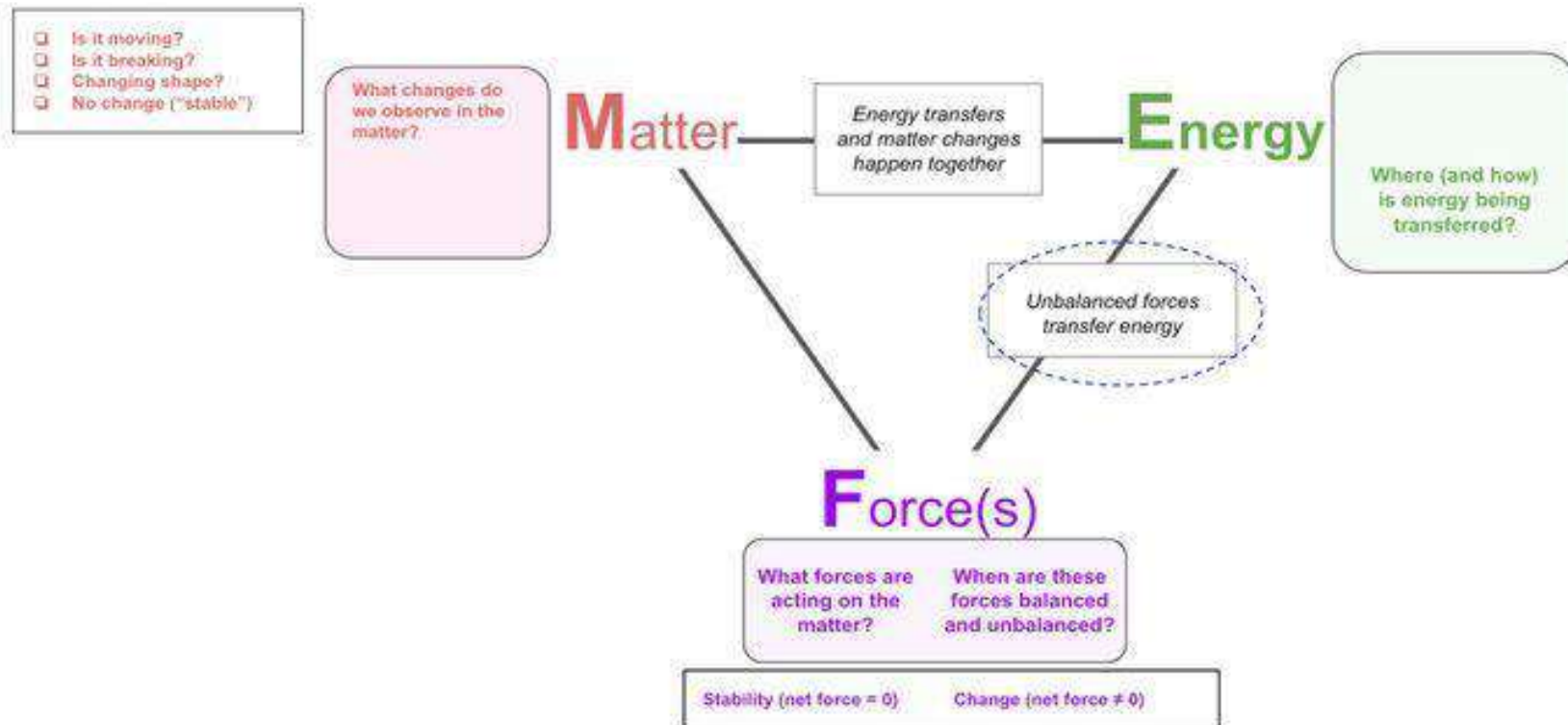
How and why is this phenomena occurring?



Later in the lesson, we will investigate the effects of changing the magnitude of the unbalanced forces applied to the system. From there, we will be able to reason out all the related changes in matter and energy. These ideas are used to add a new panel on the poster on the line between the "Forces" and "Energy" panels.

- "Unbalanced forces transfer energy"

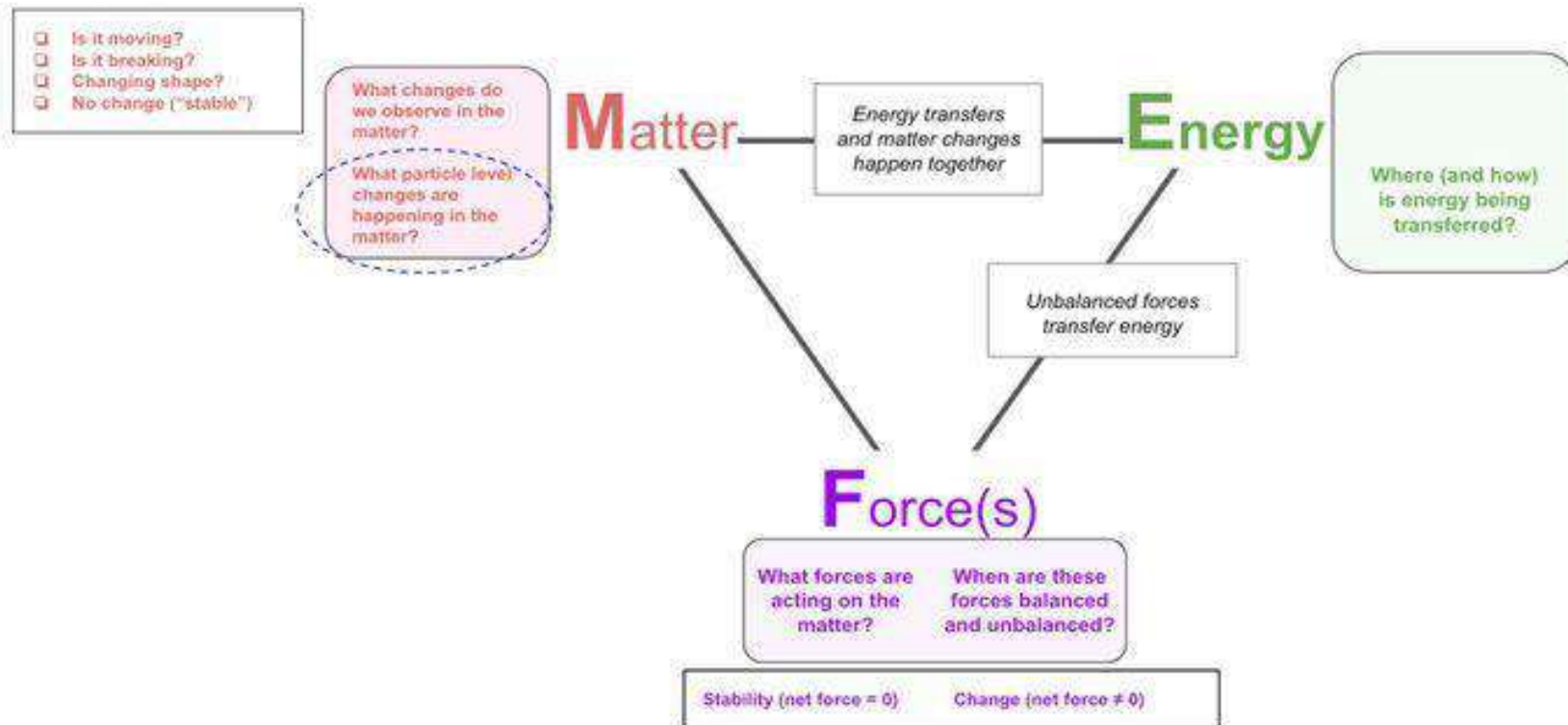
How and why is this phenomena occurring?



In **Lesson 4**, we bring the idea that paying attention to changes at the particle level helped us understand phenomena better in the past. We add the following panel to remind us of that going forward:

- “What particle-level changes are happening?”

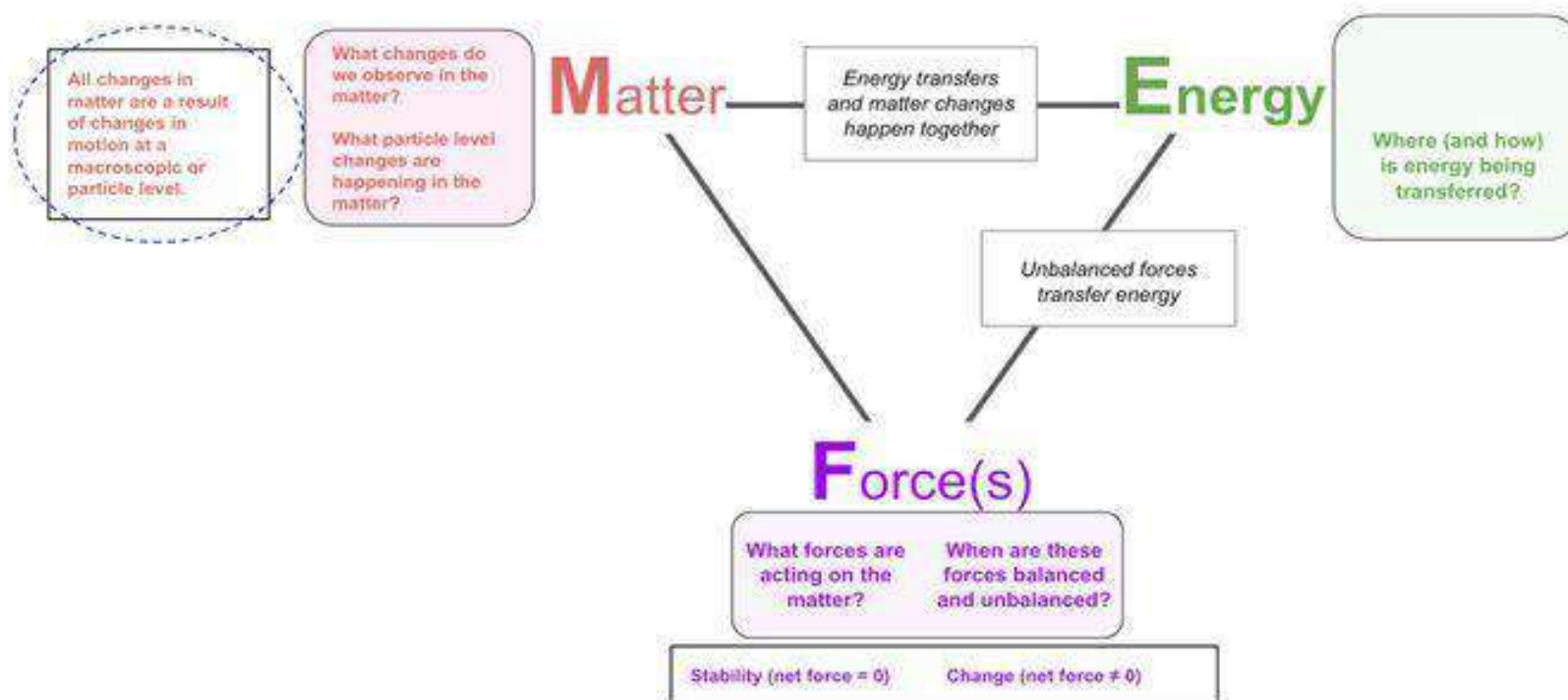
How and why is this phenomena occurring?



Up until this point, we have seen that unbalanced forces cause several types of changes: motion, shape change, and breaking. We use this insight to simplify the entire set of changes we listed under the "Matter" section on the M-E-F poster, as they are all changes in motion at different scales. The panel "Checklist of different matter changes," is replaced by the following panel in the top left corner of the M-E-F poster"

- "All changes in matter are a result of changes in motion at a macroscopic or particle level"

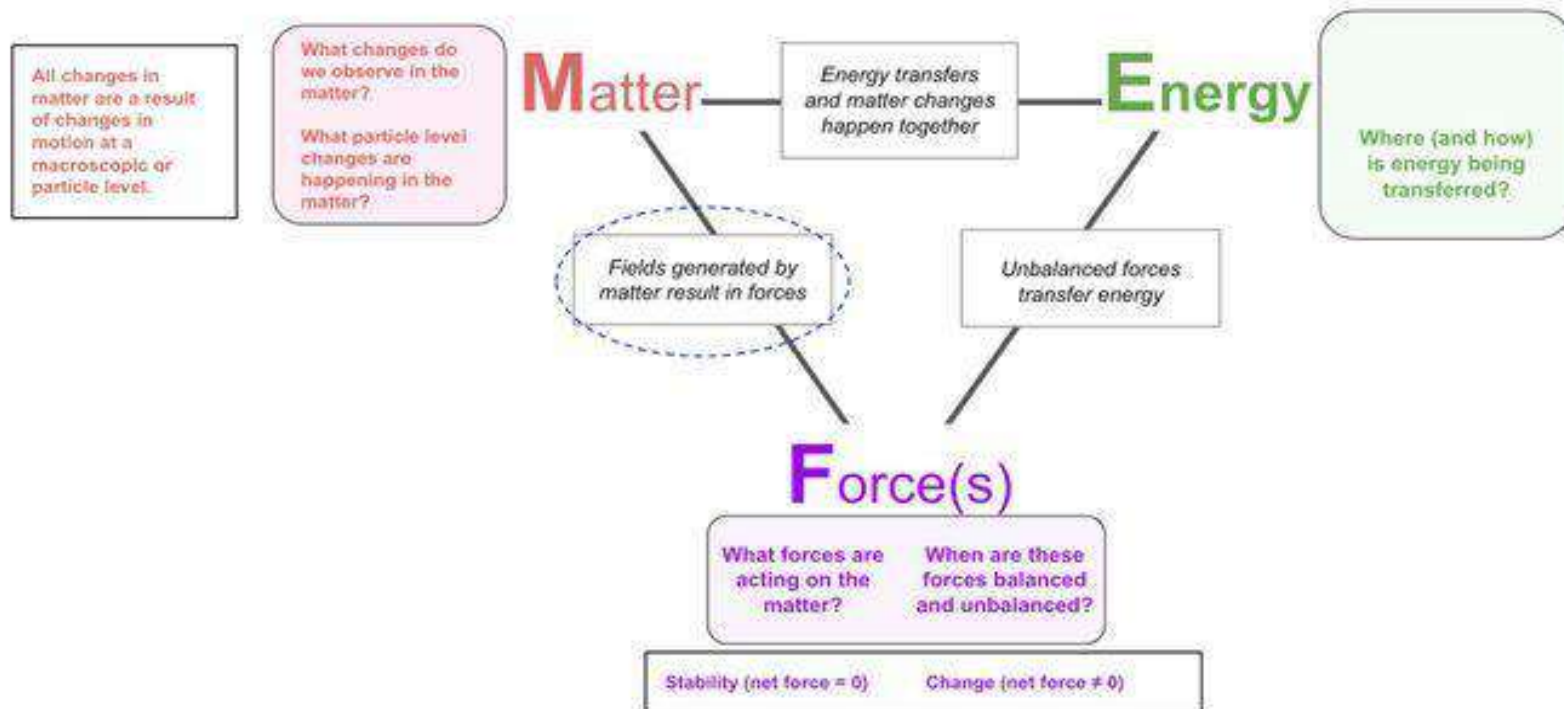
How and why is this phenomena occurring?



We use different models to investigate the interactions between matter, energy, and forces at the particle level. We develop the idea that in a solid, the electric fields produced by electrons and protons result in forces that act on neighboring particles in ways that explain all sorts of macroscopic behavior. Based on this, the following panel is added between the “Matter” and “Force(s)” panels on the line connecting them on the M-E-F poster:

- “Fields generated by matter result in forces”

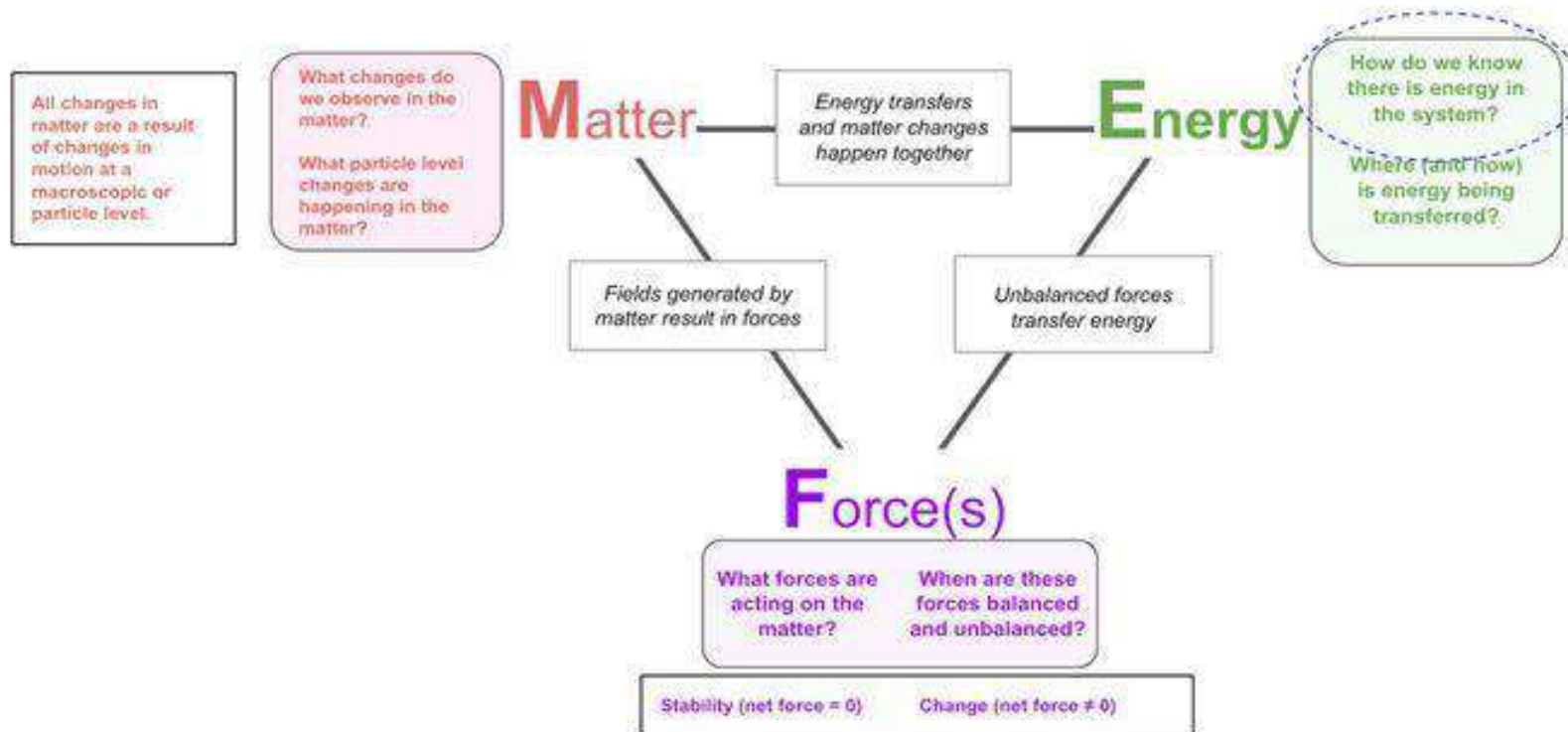
How and why is this phenomena occurring?



From an energy perspective, we elevate the idea that identifying evidence of energy in the system can help us make sense of changes that are taking place in a system. The following panel is added to the top right corner of the M-E-F poster:

- "How do we know there is energy in the system?"

How and why is this phenomena occurring?



At the end of this lesson, we revise some of the manifestations of energy transfer in a system. Using these ideas, the remaining 4 panels are added to the right side of the M-E-F poster:

- “Sound, heat, light, electricity, elastic deformation ... are some combination of:”
- “Kinetic energy associated with the motion of objects or particles ”
- “ and/or ”
- “Stored in a field associated with position/orientation between the objects /particles”

How and why is this phenomena occurring?

