Scientific Modeling:

An Overview

Quick write:
What is a scientific model?

What is a scientific model?

One definition:

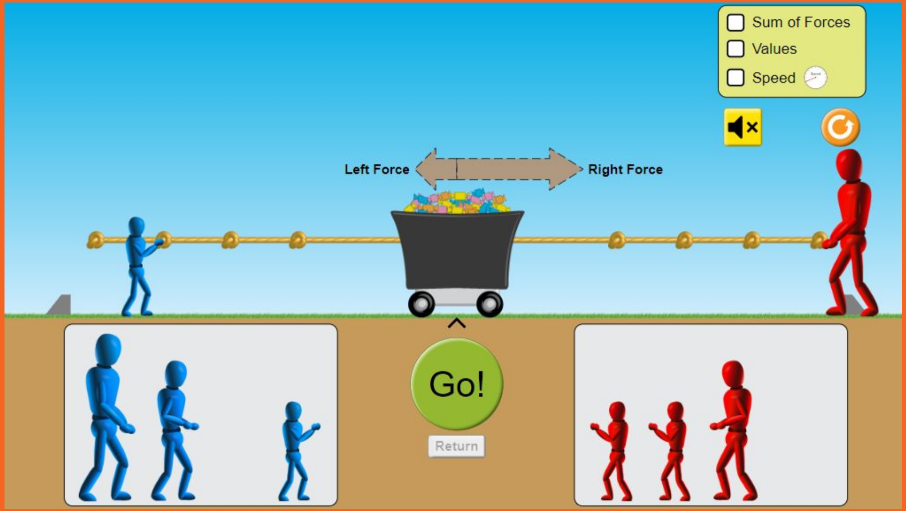
A scientific model is a way to simplify and represent a particular idea or phenomenon. The scientific model can explain how something works and can be used to make predictions. The model shows the seen and unseen factors of a phenomenon.

(Wingert et al., 2019)

What could a scientific model look like?

- ***physical*** (2-dimensional or 3-dimensional, may include diagrams)
- ***mathematical*** (includes a single formula or many formulae)
- ***conceptual*** (digital or print)
- a computer or physical ***simulation***
- ***combination*** of more than one of the above

(Carolina, 2019)



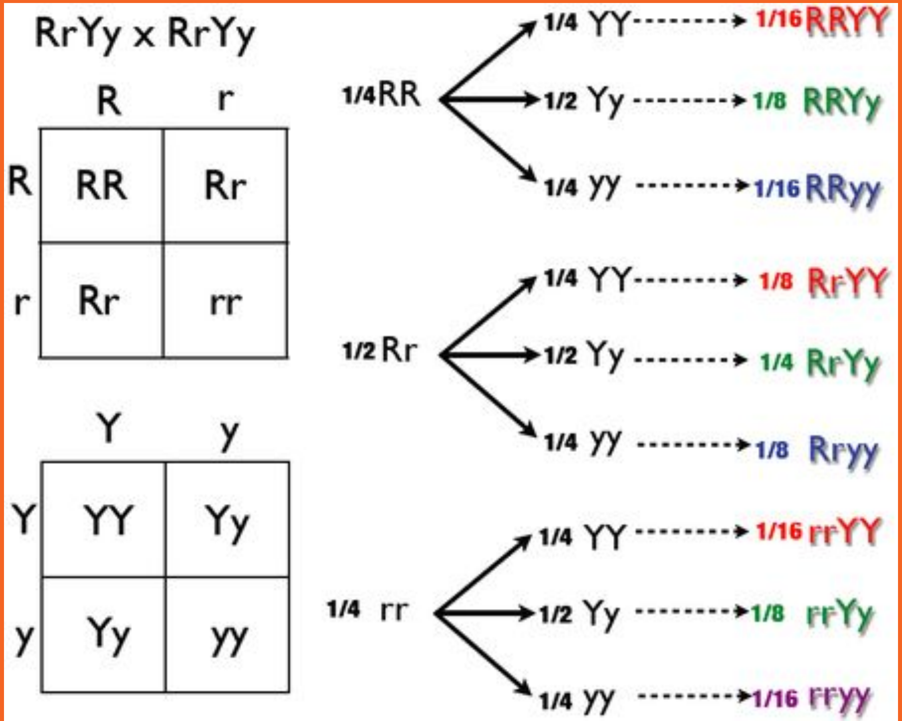
A computer simulation model of force and motion.

—— (PHET Interactive Simulations, 2019)

Why do we create scientific models?

- To explain complex data, build theories, create new hypotheses
- To provide a way to test ideas and "argue" about or debate them using evidence
- To both explain and predict what is/will happen with a phenomenon
- Drive future research and learning

(Wingert et al., 2019)



The Punnett Square as an example of a mathematical model for genetics.
(Wikipedia, 2019)

What makes a good scientific model?

A good model is:

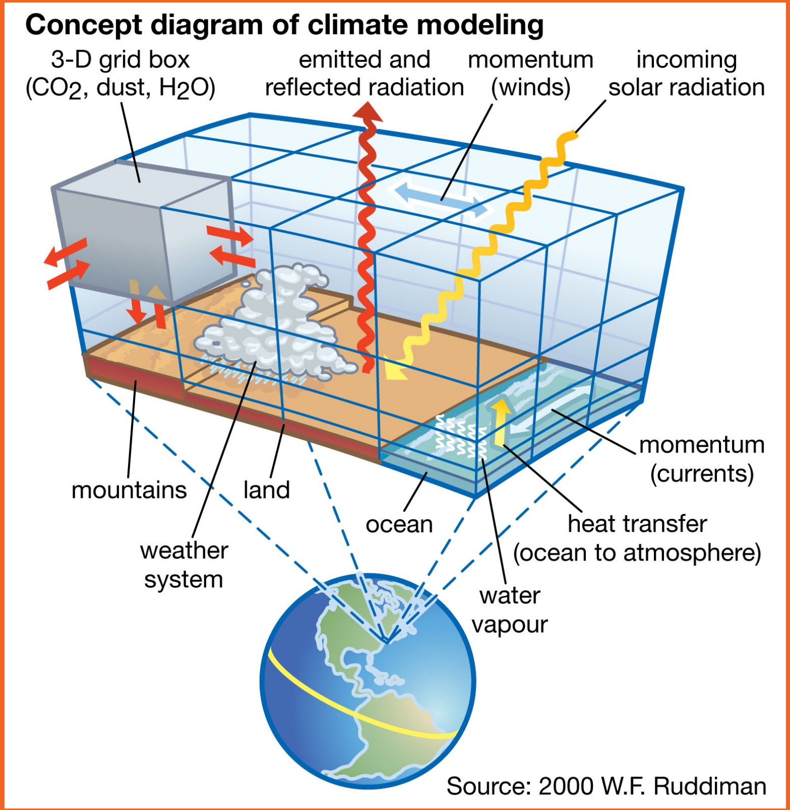
- **based on reliable observations.**
- **able to explain the characteristics of the observations used to formulate it.**
- **able to explain phenomena that were not used to develop the model.**
- **predictive.**
- **able to be refined when new, credible, conflicting observations arise.**
- **limited and simplifies a concept, theory, or object.**

(Carolina, 2019)

Creating scientific models

- Practice!
- Reflect on the model - does it help you explain and predict based on what you know?
- Recognize limitations.
- Use new evidence as it becomes available.
- Revise and improve.

(Carolina, 2019; Wingert et al., 2019)



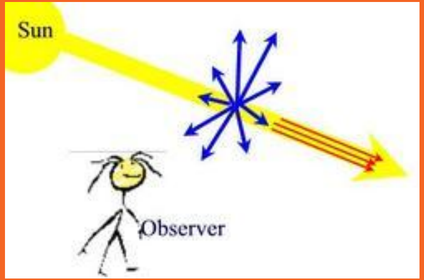
A diagram model of climate on Earth

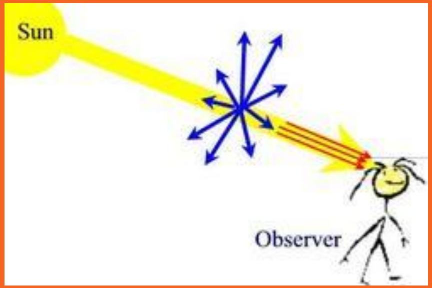
(Encyclopaedia Britannica, 2019)

Models are made to be revised!

Models change or are revised as more is learned about the phenomenon or idea. Don't be afraid to change your thinking and show it in a new or revised model!

(Wingert et al., 2019)





Red sun-sets and blue skies. The intensity of scattered light from the atmosphere increases with decreasing wavelength. In fact the intensity of scattered light is inversely proportional to the 4th power of wavelength. [The intensity of 450 nm blue light is more than 4 times larger than that of 650 nm red light]. The observer on the left sees a blue sky when looking up and the observer on the right sees a reddish sun. *More detail can be given and this can be extended into a mathematical model.*

A conceptual model for red sunsets and blue skies.

(SERC, 2019)

Revise, Refine, and Learn!

"Essentially, all models are wrong, but some are useful."
-George E. P. Box

How do we create scientific models?

Scientific Model Tips:

- The unseen is vital in a model: Draw both observable and unobservable features.
- Show time passing: Show how the event or processes change over time, for example in "before-during-after" panels.
- How to draw?: Find agreement in the group about what to draw (what to include in the model) and how to draw or represent that information.
- Keep track of activity: Keep track of what you learn from each activity and how it changes your thinking and your model.
- Multiple ways to communicate: Writing + drawing is really important.
- Can't do it all: Your model will have limitations. Know what they are and how they will affect your explanations and predictions!

(Windschitl, Thompson, & Braaten, 2018)

How do we evaluate our modeling process and product?

Rubric for Student's Scientific Modeling

Base Scoring Elements	Not Yet			Approaches Expectations		Meets Expectations		Advanced
	0	1	1.5	2	2.5	3	3.5	4
1) Explains Phenomena: Does my model explain the phenomenon?		Model does not explain the phenomenon of the investigation.		Model includes some of the relevant parts of the model to explain what *caused* the phenomena. Model might include text and diagrams.		Model connects all relevant components and relationships (observable and unobservable) of the model to explain what *caused* the phenomena. Model includes text and diagram(s) to describe model pieces and processes.		Model includes the relevant parts of the model to explain what caused the phenomena (as in Level 3)—as well as additional components and relationships that fit the scientific model.
2) Fits with Evidence: Does my model fit with the evidence collected?		Evidence is not correctly related to the model.		Model correctly incorporates some of the evidence collected through the investigations.		Model refers to a sufficient amount of relevant evidence collected through investigations.		Model fits with all of the evidence collected and describes additional evidence that could be collected.
3) Builds on Science Ideas: Does my model incorporate established scientific ideas?		Model does not include relevant science ideas.		Model includes some of the essential concepts to explain the phenomena—but not all that are needed.		Model includes essential disciplinary science concepts AND crosscutting concepts needed to explain the phenomena.		Model includes essential science concepts and other relevant science ideas.
4) Clarity of Communication: Would someone else be able to understand my model?		Model is not clearly described **OR** norms are not followed.		Model is somewhat clearly described **OR** minimal norms are followed.		Model is communicates ideas with only slight confusion for others. Follows most norms.		Communication of model clearly shows student's thinking so others can understand. Follows norms.
5) Generality: Can my model be used to explain or predict related phenomena?		Model is not related to phenomena beyond the focal phenomenon **OR** I do not use my model to predict how another phenomenon occurs.		I attempt to use my model to make a prediction, but I do not fully describe the outcome of changing one or more components **OR** I am missing some connections between my model & different phenomenon.		Model-based explanation predicts the outcome of changing one or more components of the model **OR** Model is used to predict and explain how a different phenomenon occurs.		Description of the model is applied to the phenomenon of the investigation, a parallel phenomenon **OR** Model predicts/explains an additional related phenomenon
6) Considers Others' Ideas: Did I consider how other people might explain the phenomenon?		Model does not consider the ideas of others.		Models mentions how it is different from the ideas of others.		Model-based explanation considers alternative explanations for the phenomenon and clearly highlights why my model provides a better explanation.		Model considers alternative explanations of others, highlights why my model is better and provides evidence for that.
7) Revising My Model: Do I describe how I have refined my model based on new evidence and/or my developing understanding?		I vaguely explained how I changed my model but did not connect my changes to evidence **OR** I did not revise my model.		I explain how I changed my model to better explain what caused the phenomenon, but only loosely connected my changes to evidence.		I explain how I changed my model to better explain what caused the phenomenon as I gathered new evidence and/or developed new ideas about components or relationships of the model.		I explain how I changed/added to my model to better explain what caused the phenomenon and clearly connected to newly gathered evidence and/or ideas about components or relationships of the model.
8) Evaluating Limitations of My Model: Do I describe the limitations of my model?		No limitations defined or only cosmetic changes suggested.		Some explanation of limitations. Little connection to the phenomena the model represents.		I explain what simplifications I have made in my model compared to the phenomena from the natural or built world.		I explain the limitations of my model and discuss how this limits its use to explain related phenomena. Suggest improvements and unanswered questions.

Resources:

Encyclopaedia Britannica, Inc. (https://www.britannica.com/science/scientific-modeling**)**

Carolina Biological
(https://www.carolina.com/teacher-resources/Interactive/how-to-make-a-good-scientific-model/tr39525.tr**)**

PHET Interactive Simulations (University of Colorado)
(http://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html**)**

Science Education Resource Center at Carleton College
(https://serc.carleton.edu/sp/library/conceptmodels/index.html**)**

Wikipedia "Punnett Square" (https://en.wikipedia.org/wiki/Punnett_square**)**

Windschitl, M., Thompson, J., & Braaten, M. (2018). *Ambitious Science Teaching*.
(http://questlc.org/assets/models-and-modeling-an-introduction1.pdf**)**

Wingert, K., Wagner, M., Shouse, A., Spodaryk, S., & Chowning, J. (2019). STEM Teaching Tools Brief 8
(http://stemteachingtools.org/brief/8**)**

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Primary School (K-2)	Elementary School (3-5)	Middle School (6-8)	High School (9-12)
Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.	Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.	Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
Distinguish between a model and the actual object, process, and/or events the model represents. Compare models to identify common features and differences. Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s). Develop a simple model based on evidence to represent a proposed object or tool.	Identify limitations of models. Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. Develop and/or use models to describe and/or predict phenomena. Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	Evaluate limitations of a model for a proposed object or tool. Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed. Use and/or develop a model of simple systems with uncertain and less predictable factors. Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Develop and/or use a model to predict and/or describe phenomena. Develop a model to describe unobservable mechanisms. Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Design a test of a model to ascertain its reliability. Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Use a model to provide mechanistic accounts of phenomena. Develop a complex model that allows for manipulation and testing of a proposed process or system. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

NGSS Developing and Using Models Progression From NSTA:

https://ngss.nsta.org/Practices.aspx?id=2