

How Science Works: Processes, Nature, And Limits

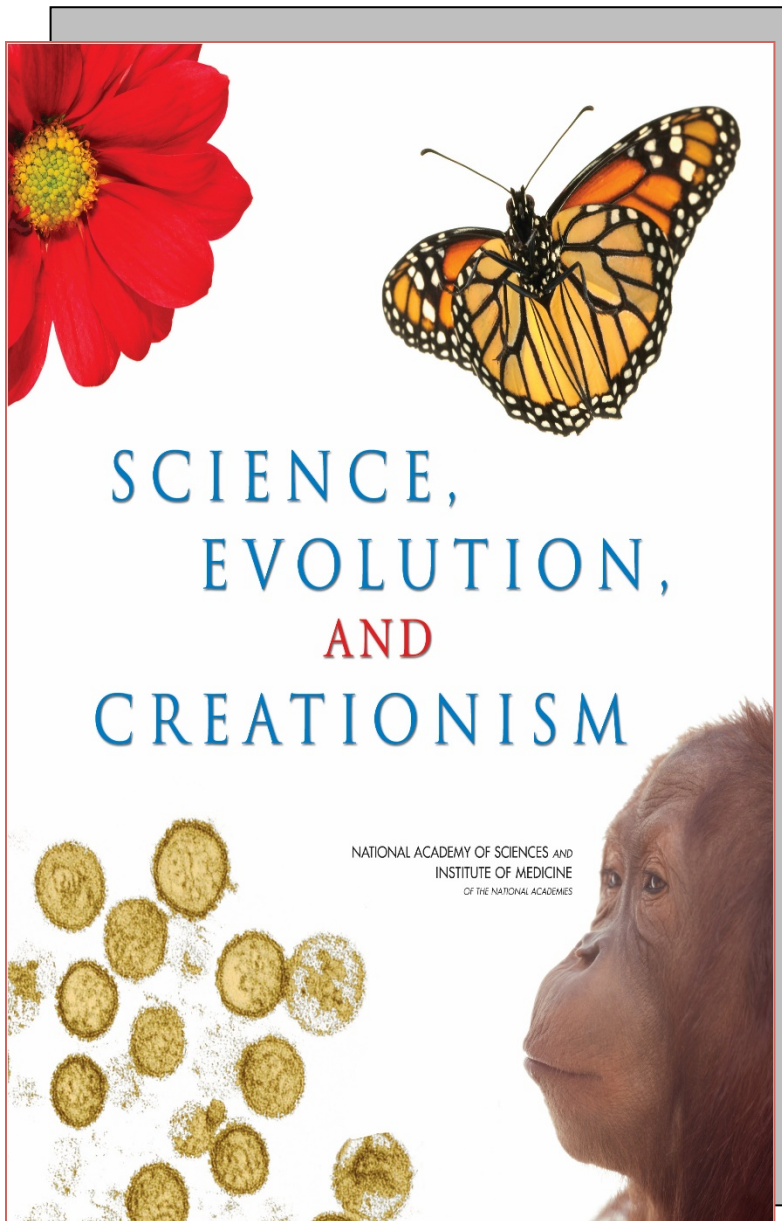


Lifetime Learning Institute
September 24, 2020

Jay Labov

National Academies of Sciences, Engineering, and Medicine (Retired)

jblabov@gmail.com



**Available for free
electronic
download at:
<http://nap.edu/sec>**



Understanding Science

how science *really* works

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Explore an interactive representation of the process of science.



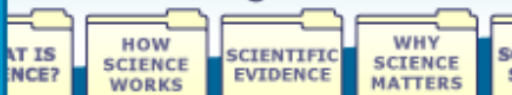
UNDERSTANDING SCIENCE 101

FOR TEACHERS

RESOURCE LIBRARY

Welcome! Take our [site tour](#), find out [what's new](#), or [subscribe](#) for updates.

Understanding Science 101



A primer on the nature and process of science.

For teachers



Our section of teaching resources on the nature and process of science.

Resource library



A browsable archive of articles, tutorials, interactive features and more.

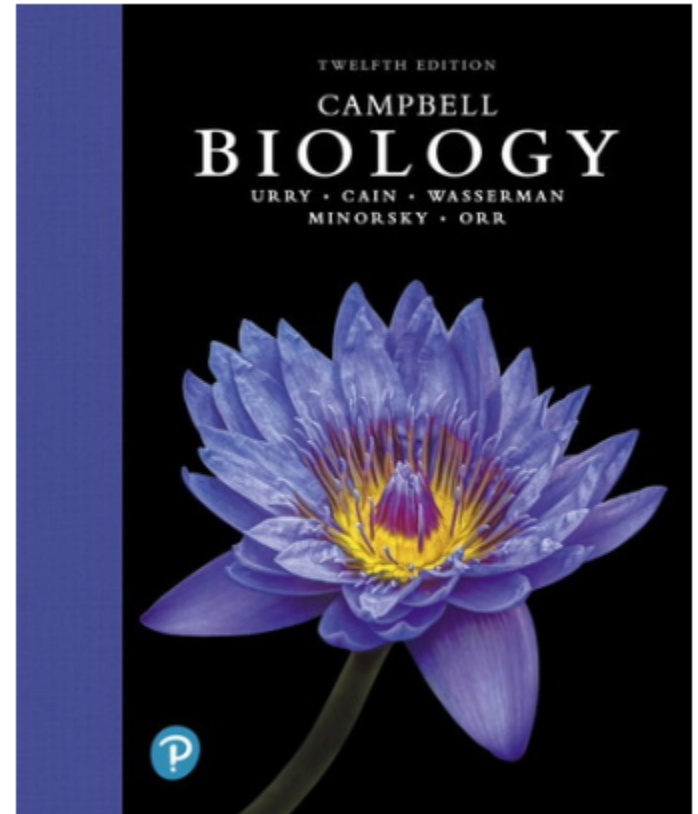
<https://undsci.berkeley.edu/>

How is Science Often Presented Now?

**Table of Contents for
CAMPBELL BIOLOGY 9e
AP* Edition
Highlighted with
Concepts Included in
the AP Biology
Curriculum Framework**

56 Chapters

Table of Contents is 16 pages



42. Circulation and Gas Exchange

KEY CONCEPTS

42.1 Circulatory systems link exchange surfaces with cells throughout the body

42.2 Coordinated cycles of heart contraction drive double circulation in mammals

42.3 Patterns of blood pressure and flow reflect the structure and arrangement of blood vessels

42.4 Blood components contribute to exchange, transport, defense, and disease

42.5 Gas exchange occurs across specialized respiratory surfaces

42.6 Breathing ventilates the lungs

42.7 Adaptations for gas exchange include pigments that bind and transport gases

Learning Goals for This Session:

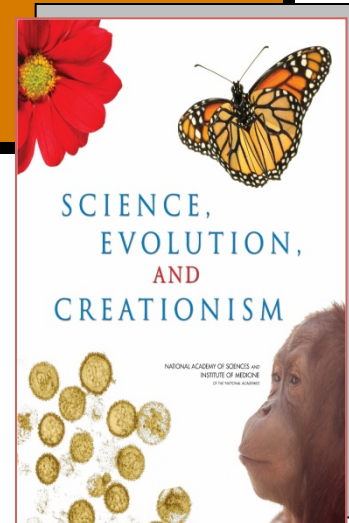
1. What, exactly, is science?
2. Processes of Science: Explore how scientific hypotheses are developed.
3. Discuss what constitutes scientific evidence (the nature and limits of science).
4. Briefly review new approaches to science education nationally and in Virginia.
5. Explore and Discuss Your Questions (as time permits)

1. What is Science?

DEFINITION OF SCIENCE

FROM THE NATIONAL ACADEMY OF SCIENCES AND INSTITUTE OF MEDICINE

The use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process.



Science is a blend of logic and imagination

Science demands evidence

Scientific ideas are durable

Science is a social activity

Science avoids bias

Scientific ideas are subject to change

The natural world is understandable

Testable

Observable

Tentative

Social

The Nature of Science

Uncertain

Natural

NATURE OF SCIENCE

vista.gmu.edu

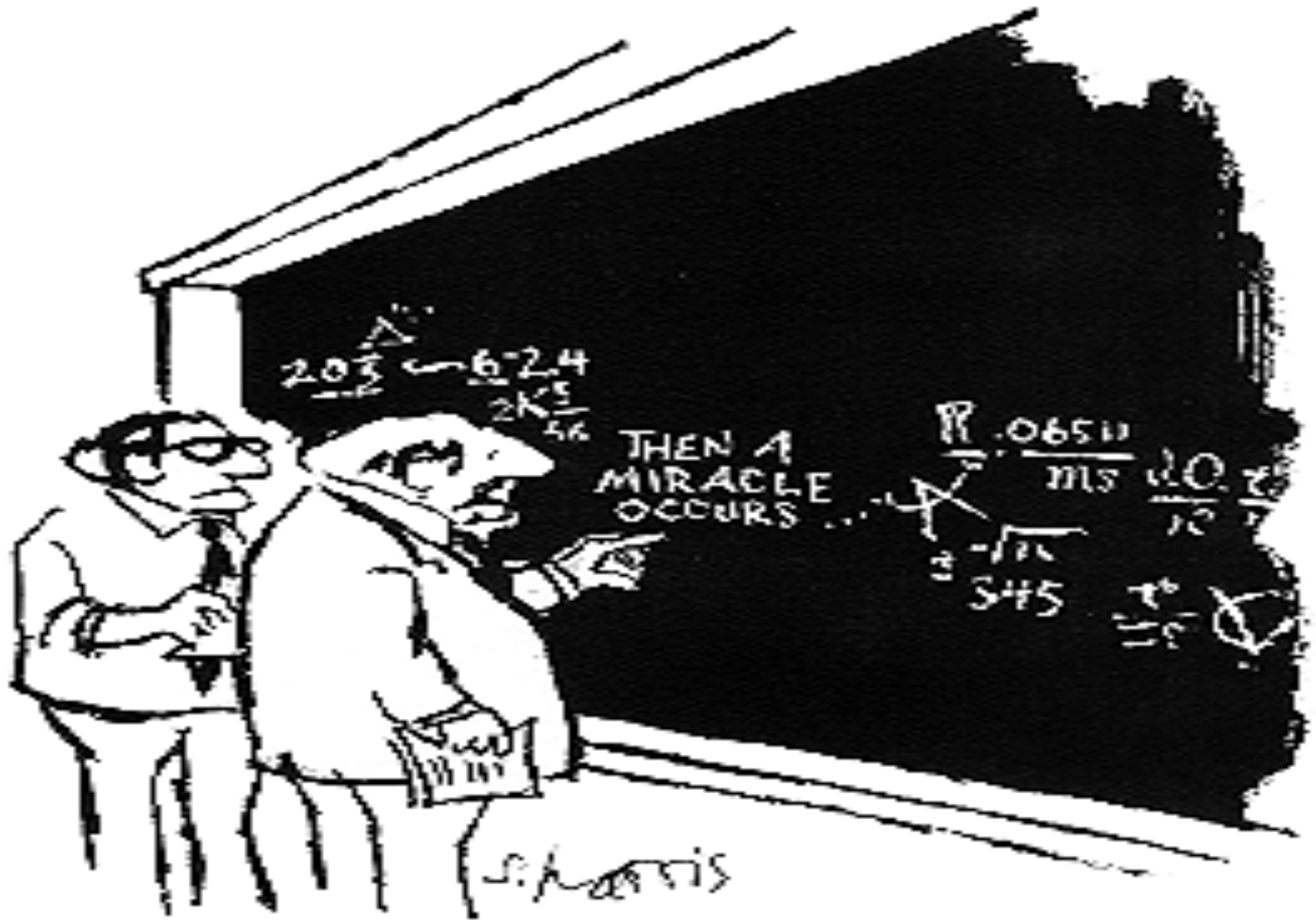


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What is Science?

What is Science?

- **Science focuses exclusively on the natural world. It does not deal with supernatural explanations.**



"I think you should be more explicit in step two"

What is Science?

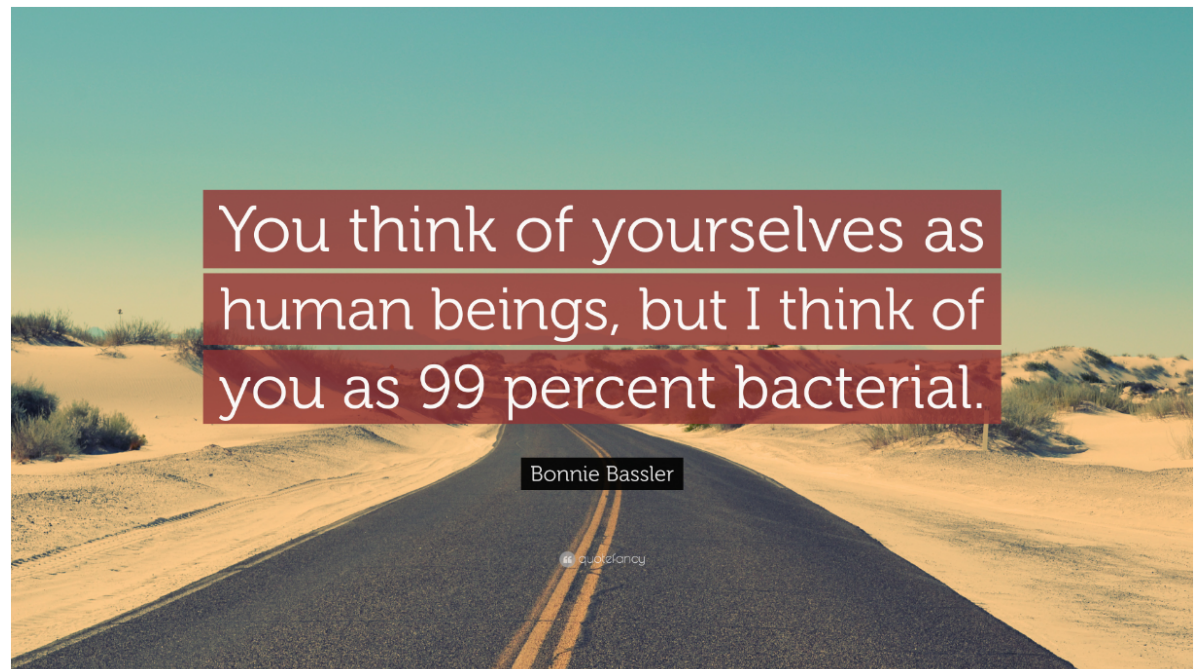
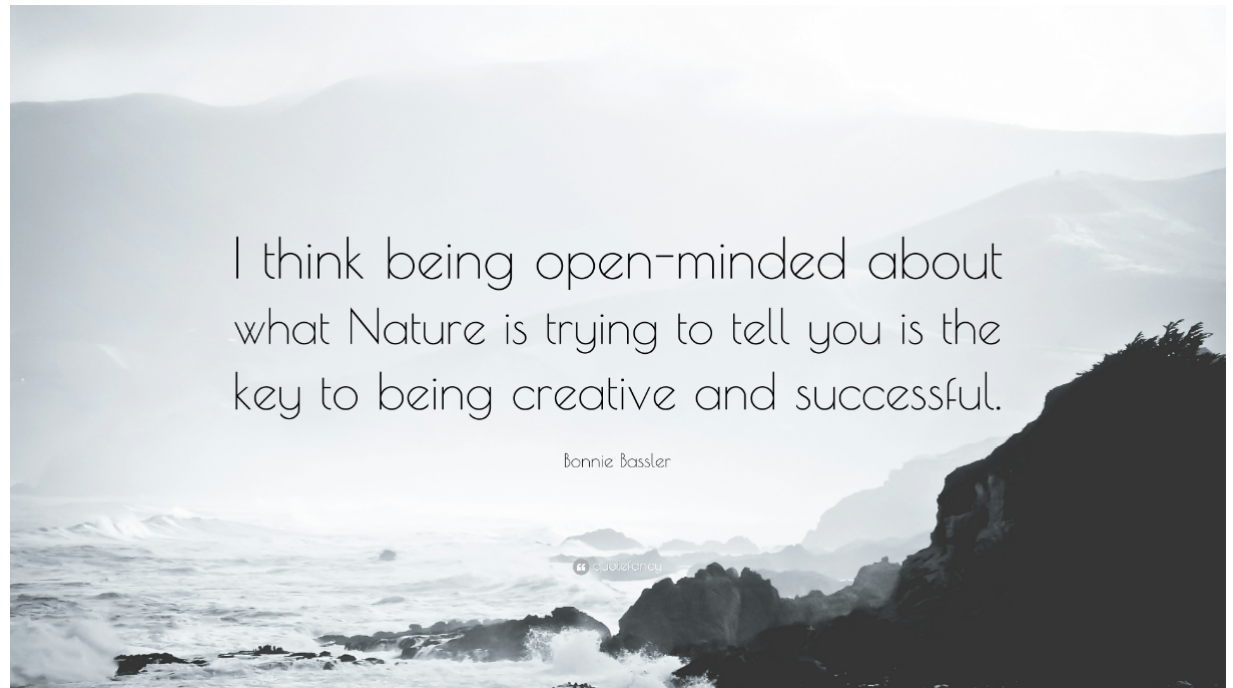
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- **Science is a way of learning about what is in the natural world,, e.g.,**
 - **how the natural world works,**
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- **Science is not simply a collection of facts; it is also a path to analyzing and understanding facts and observations.**



Prof. Bonnie L. Bassler
Molecular Biologist
Princeton University





“We sometimes forget about the creative part of science. I think you need time to daydream, to let your imagination take you where it can... I’ve noticed among the creative, successful scientists who’ve really advanced things, that was a part of their life.”

ELIZABETH H. BLACKBURN: MOLECULAR BIOLOGIST

2010

Nobel Laureate, 2010

Former President of the Salk Institute



Frazz

By Jef Mallett



 **Frazz**
By Jef Mallett

DON'T YOU FIND IT ODD THAT
EINSTEIN SAID IMAGINATION
BEATS KNOWLEDGE?



9-15



Frazz
By Jef Mallett

DON'T YOU FIND IT ODD THAT
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9-15

I MEAN,
WHO KNEW
MORE THAN
EINSTEIN?



HOW MANY PEOPLE
COULD IMAGINE
MORE THAN
EINSTEIN?

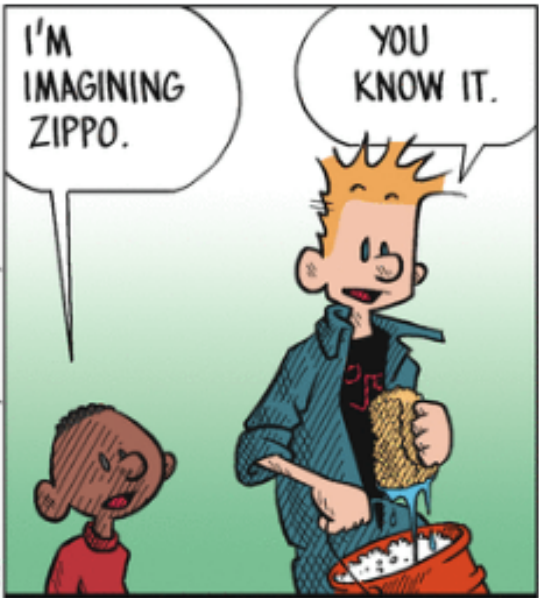
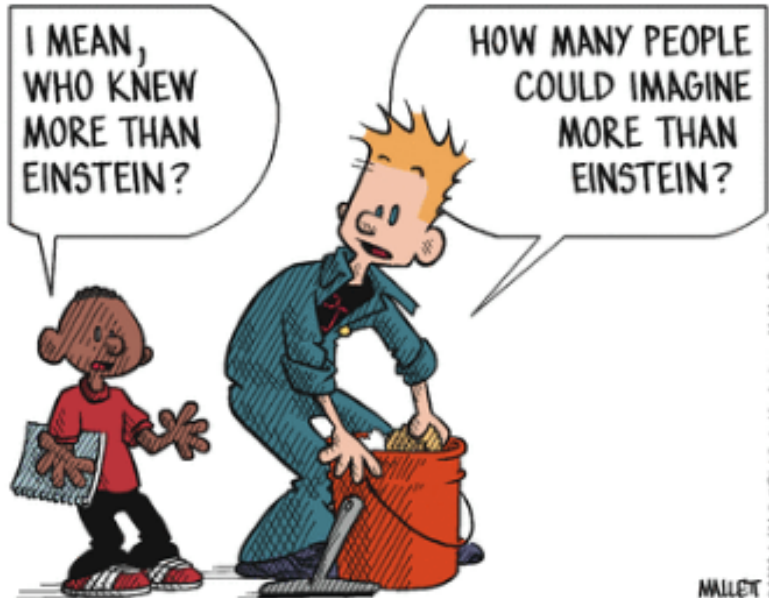
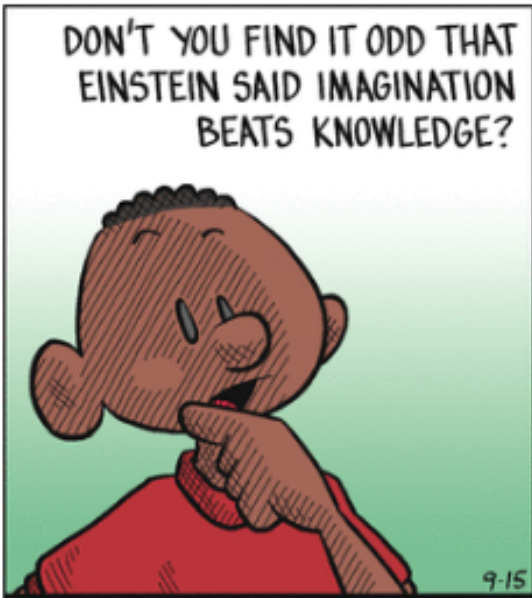


MALLET

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Frazz
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- **Science relies on testing ideas by figuring out what expectations are generated by an idea and making observations to find out whether those expectations hold true.**

“The good thing about science is that it's true whether or not you believe in it.”

– Neil deGrasse Tyson

Astrophysicist

American Museum of Natural History



“Science, however, is never conducted as a popularity contest, but instead advances through testable, reproducible, and falsifiable theories.”

MICHIO KAKU: PHYSICIST

2014

Professor, City College of New York

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- **As new evidence is acquired and new perspectives emerge, these ideas can be, and often are revised.**

Science isn't a tall stack of hard facts; it's a difficult and deeply human process that lurches toward an approximation of the truth.



Joel Achenbach
Washington Post, page A1
July 24, 2014

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- **As new evidence is acquired and new perspectives emerge these ideas can be, and often are revised.**
- **Science is a community endeavor.**



"Being a scientist is a special privilege: for it brings the opportunity to be creative, the passionate quest for the answers to nature's most precious secrets, and the warm friendships of many valued colleagues."

— *Biochemist and neurologist Stanley B. Prusiner*

2. Processes of Science: How Scientific Hypotheses are Developed

(Group Participation)

Glossary of Terms Used in Teaching About the Nature of Science

- **Fact:** In science, an observation that has been repeatedly confirmed.
- **Law:** A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.
- **Hypothesis:** A testable statement about the natural world that can be used to build more complex inferences and explanations.
- **Theory:** In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.

Position 1

Position 2

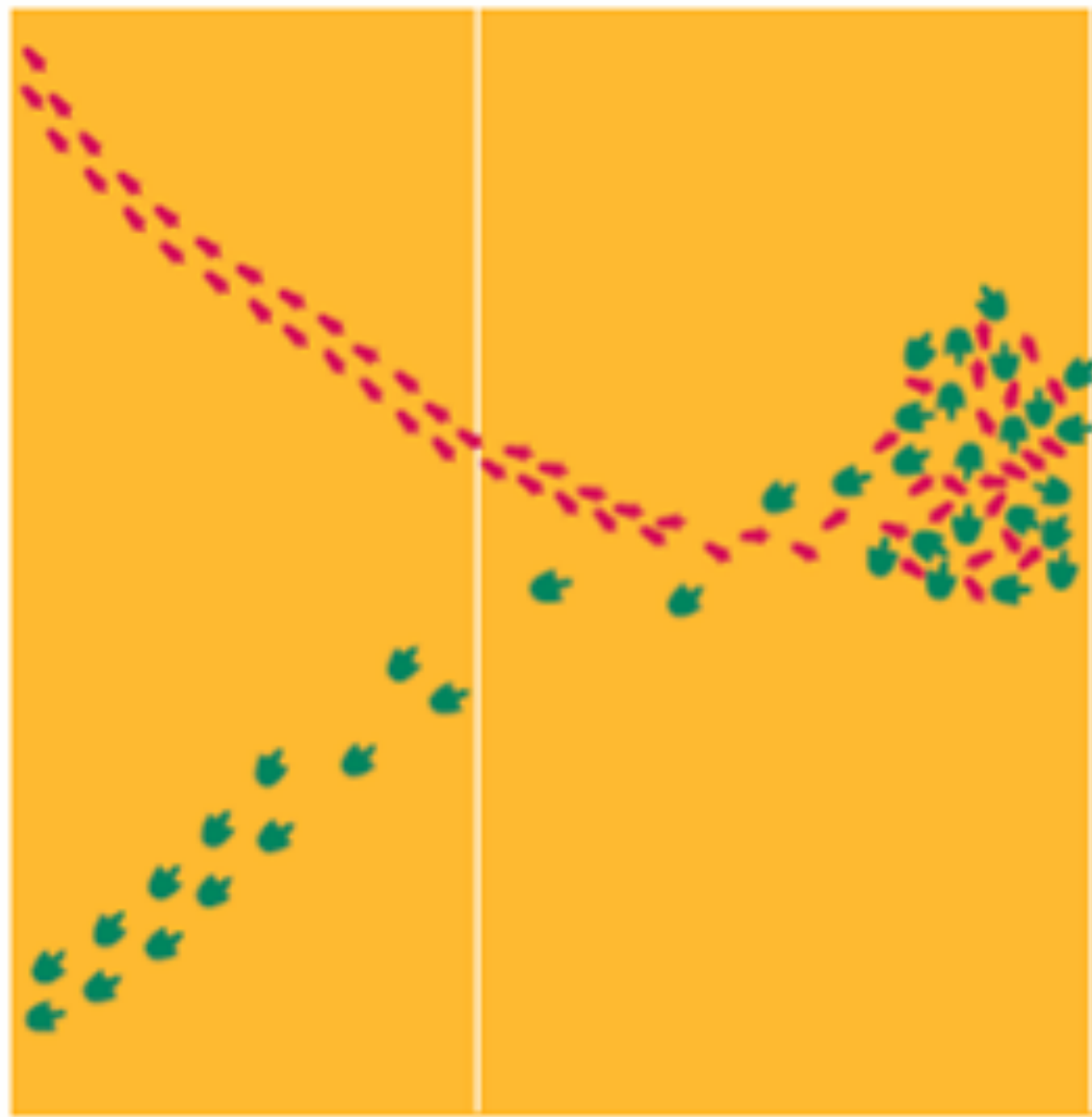
Position 3



Position 1

Position 2

Position 3

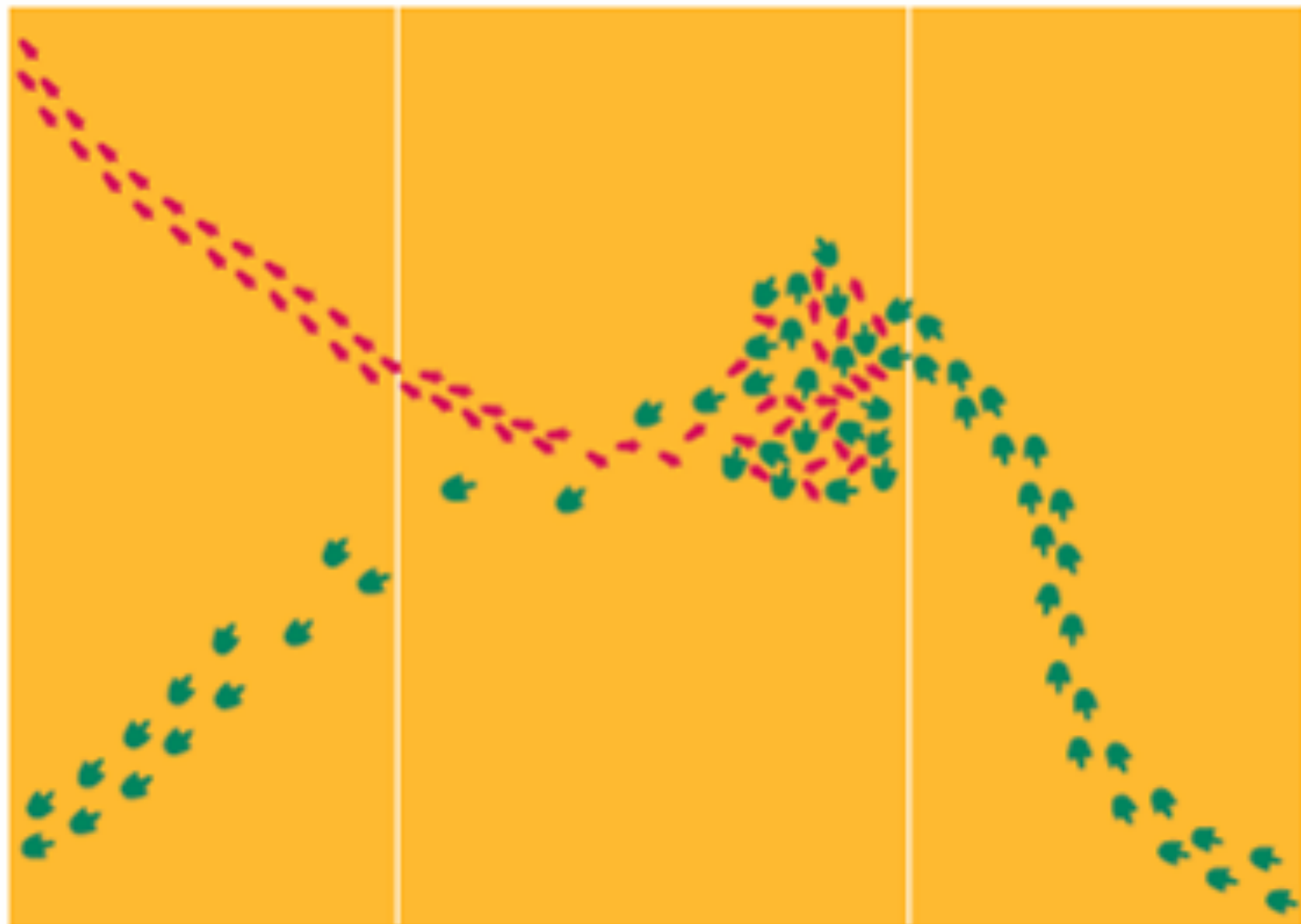


Position 1

Position 2

Position 3

Footprint Puzzle



Position 1

Position 2

Position 3

3. Discuss what constitutes scientific evidence (the nature and limits of science).

Is there anything that science is incapable of investigating?

Breakthroughs of 2020

- **Astronomers Detect Possible Sign Of Life In Venus's Atmosphere**
- **Scientists Observe A Star Circling A Black Hole That Proves Einstein's Theory Of Relativity**
- **NASA's InSight Mission Discovers Seismic Activity On Mars**
- **Researchers Successfully Transplant Lab-Grown Heart Muscle Cells**
- **NASA's Transiting Exoplanet Survey Satellite Finds An Earth-Sized Planet In A Habitable Zone**
- **Scientists Make A 3,000-Year-Old Mummy Speak**
- **Scientists Create Transparent Organs To Understand How To Build New Ones**
- **Scientists Create An Artificial Genome That Reproduces On Its Own**
- **Researchers Develop An Implant That Could Help Restore Sight To The Blind**
- **The Most Comprehensive Map Of Cancer Genomes Allows Researchers To Better Understand The Disease**
- **Scientists Release Genetically Engineered Moths**
- **The FDA Approves The First Drug To Treat Peanut Allergies In Kids**
- **Scientists Use A Technique Called CRISPR To Edit A Gene Inside A Patient's Body**

<https://www.ranker.com/list/scientific-breakthroughs-of-2020/sammy-leary>

Many neuroscience issues abut against human values

- The nature of the mind
 - Mind-body-soul concepts
 - Free will vs. determinism
- The ability for anyone to look into your brain and watch your mind in action
 - Darkest secret thoughts
 - Lie detecting

Other issues are coming

- Ability to predict behaviors
- Mind-reading
- Understanding of consciousness
- Ability to treat disorders
- Ability to enhance behavioral performance
 - Moral enhancement?

All are potentially contentious

Recent Medical Breakthroughs with Gene Therapy

Science

Boys with a rare muscle disease are breathing on their own, thanks to gene therapy

By [Jocelyn Kaiser](#) May. 2, 2019 , 5:20 PM

WASHINGTON, D.C.—A new gene therapy treatment has had striking results in nine boys born with myotubular myopathy (MTM), a rare disease that causes extreme muscle weakness often from birth.

The Washington Post

Democracy Dies in Darkness

[Health & Science](#)

Gene therapy cures infants suffering from 'bubble boy' immune disease

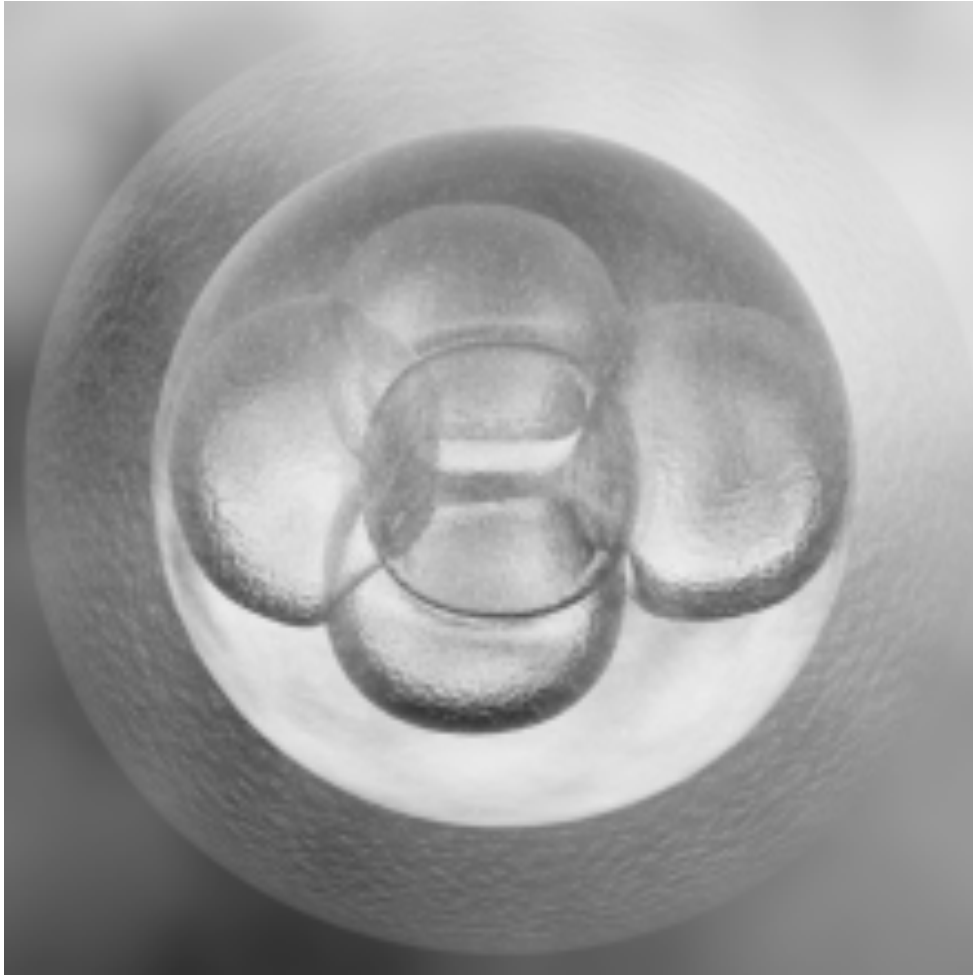
TheScientist

EXPLORING LIFE. INSPIRING INNOVATION

[Two Patients Treated with CRISPRed Cells in Immunotherapy Trial](#)

Shawna Williams | Apr 16, 2019

One person with multiple myeloma and one with sarcoma are the first so far to receive the genetically engineered T cells in the study.



Fertility Clinics Sought Advice from Scientist Who CRISPRed Babies

By Chia-Yi Hou

Emails reveal that a facility in Dubai and others have asked geneticist He Jiankui for help in gene-editing embryos.

What Can't Science Do?

(Despite Our Best Efforts Sometimes to Make it Do These Things)

- Science cannot draw conclusions about supernatural explanations.
- Science doesn't make aesthetic judgments.
- Science doesn't make moral judgments.
- Scientific knowledge and discoveries indicate the evidence for **what** was, is, and what may happen in the future. It doesn't tell **whether** or **how** to use that knowledge (Another reason why science must be a community endeavor).

4. Changing Approaches to Science Education Nationally and in Virginia

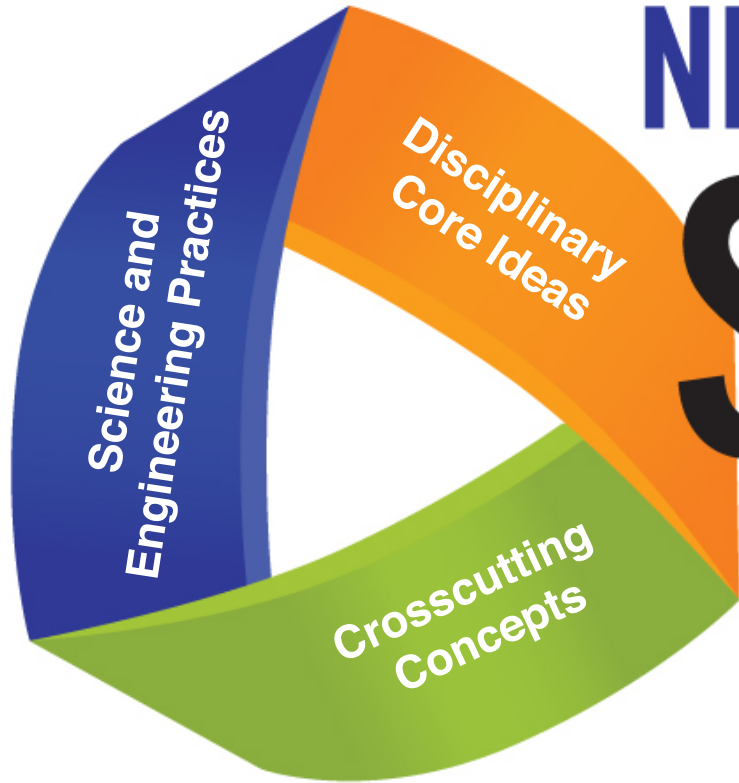
AP Redesign

Biology, Chemistry, Physics (2012-16)

- Science Panels
 - Big Ideas / Unifying Themes
 - Enduring Understandings
 - Competencies
 - Evidence Models (Formative Assessments)
- Evidence of Learning
 - The student can use representations and models to communicate scientific phenomena and solve scientific problems.
 - The student can use mathematics appropriately
 - The student can engage in scientific questioning
 - The student can perform data analysis and evaluation of evidence
 - The student can work with scientific explanations and theories
 - The student is able to transfer knowledge across various scales, concepts, and representations in and across domains

Big Ideas/ Unifying Themes of the New AP Biology Course

- The process of evolution drives the diversity and unity of life.
- Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.
- Living systems store, retrieve, transmit and respond to information essential to life processes.
- Biological systems interact, and these systems and their interactions possess complex properties.



NEXT GENERATION
SCIENCE
STANDARDS

Dimensions of the Framework



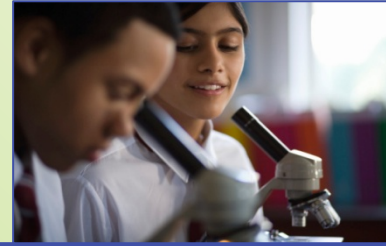
- Science and Engineering Practice
- Crosscutting Concepts
- Disciplinary Core Ideas

Science and Engineering Practices



1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

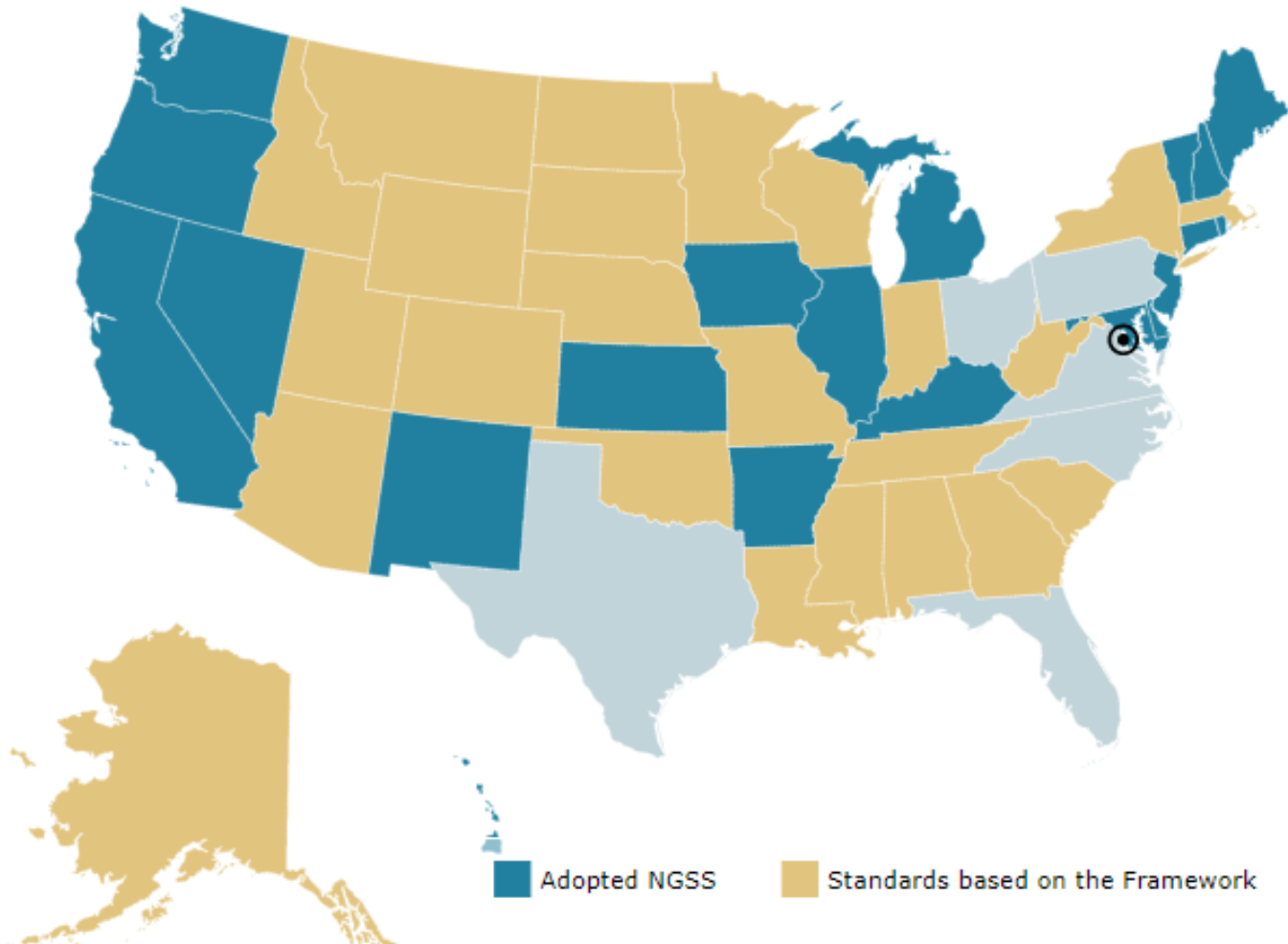
Crosscutting Concepts



1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

K-12 Science Standards Adoption

Click on a state for more information!



A Closing Thought:

“For me, I am driven by two main philosophies: know more today about the world than I knew yesterday and lessen the suffering of others. You'd be surprised how far that gets you.”

– Neil deGrasse Tyson

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Thank you!!
Questions??