Chapter 3–Critical Thinking: Science, Models, and Systems

Guiding Questions we will discuss after

- What are the strengths/limitations of models?
- What happened to the Rapa Nui on Easter Island?
- From the story can you identify:
- A system?
- Positive feedback?
- Negative feedback?
- Time Delay?
- Synergy?

What is Science?

Science:

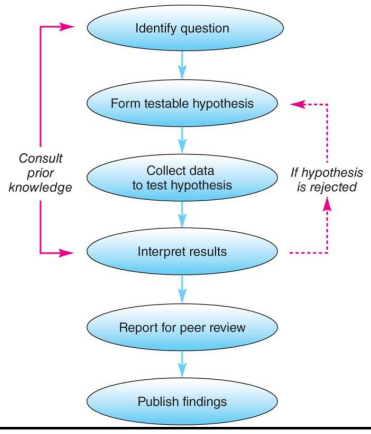
- Is a process for producing knowledge methodically and logically
- It depends on making precise observations of natural phenomena
- A cumulative body of knowledge produced by many scientists
- A way for us to explain how the natural world works and meet practical needs

Table 2.1 Basic Principles of Science

1.	*Empiricism:* We can learn about the world by careful observation of empirical (real, observable) phenomena; we can expect to understand fundamental processes and natural laws by observation.
2.	*Uniformitarianism:* Basic patterns and processes are uniform across time and space; the forces at work today are the same as those that shaped the world in the past, and they will continue to do so in the future.
3.	*Parsimony:* When two plausible explanations are reasonable, the simpler (more parsimonious) one is preferable. This rule is also known as Ockham's razor, after the English philosopher who proposed it.
4.	*Uncertainty:* Knowledge changes as new evidence appears, and explanations (theories) change with new evidence. Theories based on current evidence should be tested on additional evidence, with the understanding that new data may disprove the best theories.
5.	*Repeatability:* Tests and experiments should be repeatable; if the same results cannot be reproduced, then the conclusions are probably incorrect.
6.	*Proof is elusive:* We rarely expect science to provide absolute proof that a theory is correct, because new evidence may always undermine our current understanding.
7.	*Testable questions:* To find out whether a theory is correct, it must be tested; we formulate testable statements (hypotheses) to test theories.

Science Depends on Skepticism and Accuracy

- Ideally scientists are skeptical and unbiased.
- Scientists strive for:
  - accuracy - correctness of measurements
  - reproducibility - repeatability of results
    (repeating studies or tests is called replication)



Deductive & Inductive Reasoning

- Deductive reasoning - logical reasoning from general to specific
- Inductive reasoning - reasoning from many specific observations to produce a general rule
- It is also important to recognize the role of insight, creativity, aesthetics, and luck in research.

Hypotheses and Scientific Theories

- Hypothesis - a testable explanation
- Scientific theory - a description or explanation that has been supported by a large number of tests and is considered by experts to be reliable

Probability

- Probability is a measure of how likely something is to occur.
- Scientists often increase confidence in a study by comparing results to a random sample or a larger group.

Statistics

- Many statistical tests focus on calculating the probability that observed results could have occurred by chance (were random).
- Usually ecological tests are considered significant if this probability is less than 5%.
- The amount of confidence scientists have in the results depends upon the sample size as well. A large sample size is better than a small sample.

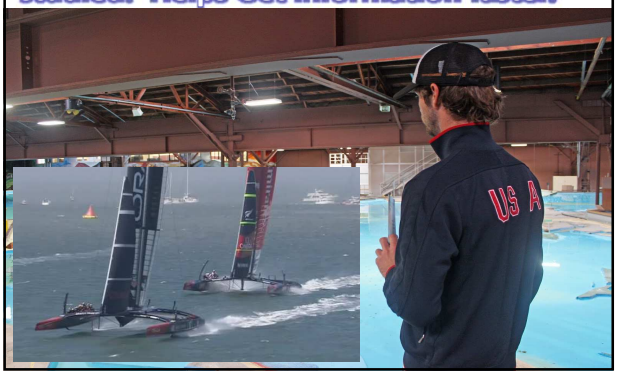
Experimental Design

- Natural experiment - involves observation of events that have already happened
- Manipulative experiment – some conditions are deliberately altered and all other variables are held constant
- Controlled study - comparing a treatment group to a control group which has not received the treatment
- Blind experiment - researcher does not know which group has been treated until after the data have been analyzed
- Double-blind experiment - neither the subject nor the researcher knows who is in the treatment group

Variables

- In each study there is one dependent variable and one or more independent variables.
- The dependent, or response, variable is affected by the independent variable.
- In a graph, the dependent variable is on the vertical (Y) axis and the independent variable is on the horizontal axis (X).

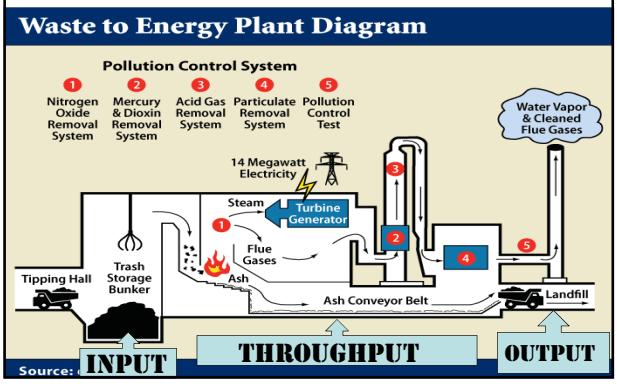
model - Simulation of a system being studied. Helps Get information faster.



Models

- Models are simple representations of phenomena. They can be physical models, model organisms, mathematical models, or other types of models.
- They allow scientists to study complex systems and predict the effect of conditions that are too difficult to create and control.
- When multiple models agree, scientists gain confidence.

A SYSTEM IS A GROUP OF INTERACTING ELEMENTS FORMING A COMPLEX WHOLE.



Systems

- are networks of interdependent components and processes, with materials and energy flowing from one component of the system to another.
- are a central concept in environmental science.
- examples include ecosystems, climates systems, geologic systems, economic systems

Inputs = What is needed.	Throughput = The amount that can flow through the system	Outputs = What comes out.

Click the link to the right. Try and identify different inputs, throughputs, and outputs.

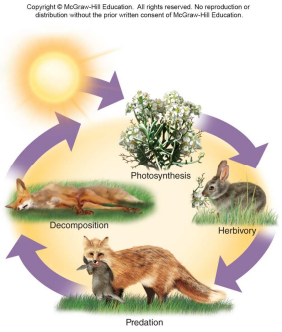
CLICK HERE

A Waste To Energy System

Inputs = What is needed.	Throughput = The amount that can flow through the system	Outputs = What comes out.
• Water • Waste • Turbine • Heat Exchanger • Furnace • Boiler • Storage Area	• Furnace burns waste at 850 degrees. • Boiler produces steam • Steam turns turbine • Scrubber/Filters to clean gas • 98% efficient	• Electricity • Waste Water • Fly Ash (hazardous waste) • Bottom Ash (non toxic recyclable) • Carbon Dioxide

Components of a System

- State Variables store resources such as matter or energy or have the pathways through which these resources move from one state variable to another (the plant and the animals illustrated here in Fig. 2.9 are each state variables).

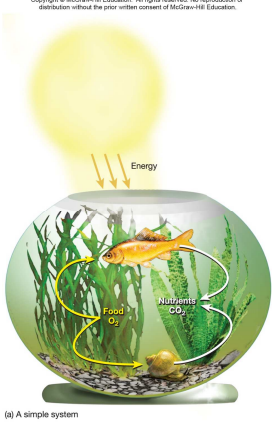


System Characteristics

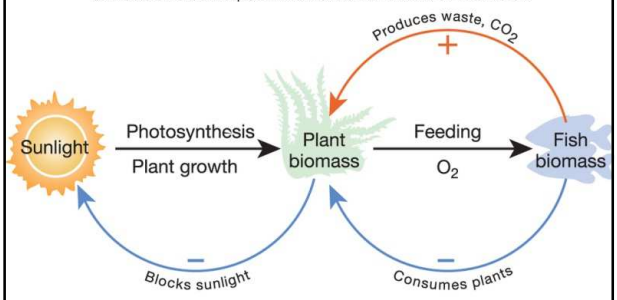
- A System can be closed or open.
  - Open – exchanges matter and energy with surroundings
  - Closed - self contained, exchanges no matter or energy with the outside
- Throughput –the energy and matter that flow into, through, and out of a system.
- Positive feedback loop – self perpetuating process, as an increase in a state variable leads to further increases in it
- Negative feedback loop – suppresses change within a system, helps to maintain stability in systems

Stability of Systems

- Equilibrium - dynamic state in which system is stable over time (homeostasis)
- Disturbance - periodic destructive events such as fire or flood that destabilize or change the system
- Resilience - ability of system to recover from disturbance
- State Shift –a severe disturbance in which the system does not return to normal but instead results in significant changes in some of its state variables



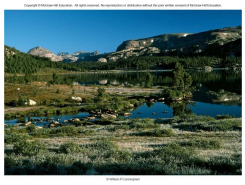
(a) A simple system



(b) A model of a system

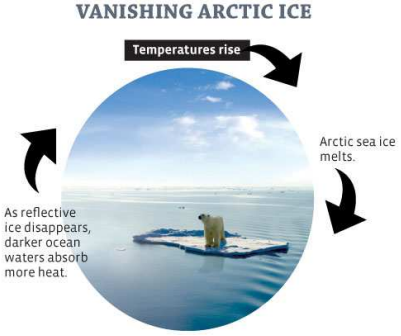
System Characteristics

Emergent properties are characteristics of a whole, functioning system that are quantitatively or qualitatively greater than the sum of the system's parts

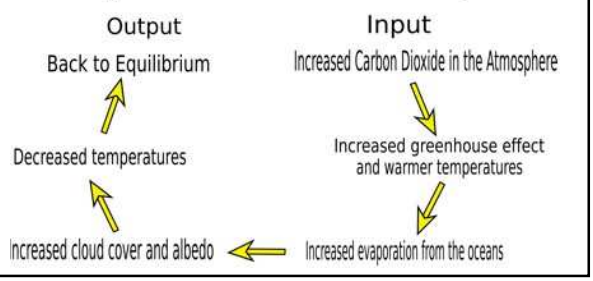


Beautiful sights and sounds can make a system such as this mountain meadow exciting to study.

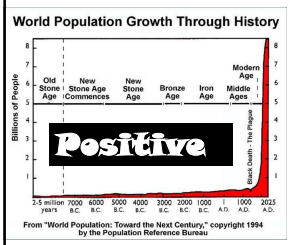
Positive Feedback Loop – enhance or amplify changes; this tends to move a system away from its equilibrium state and make it more unstable.



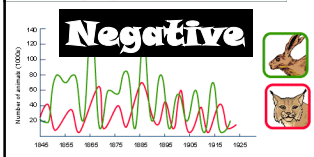
negative feedback loop – tend to dampen or buffer changes; this tends to hold a system to some equilibrium state making it more stable



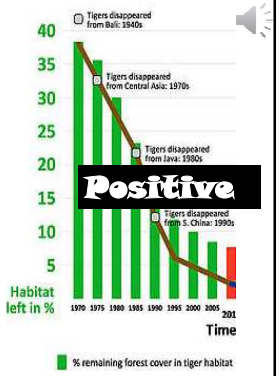
Positive or Negative Feedback?



Positive



Negative



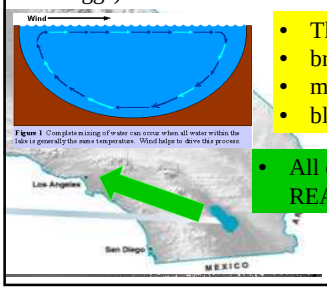
Positive

time delay The time between a cause and its effect

Where is the time delay in this example?

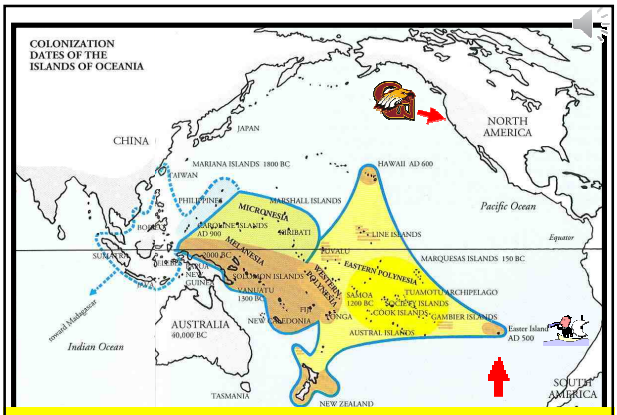
synergy - Positive or negative interaction of two or more processes creating a greater impact.

Put together the pieces of the puzzle.
60 MPH wind, Dead Fish, Hydrogen Sulfide (that smells like rotten eggs) at the bottom of a lake, a city of 7 million people.

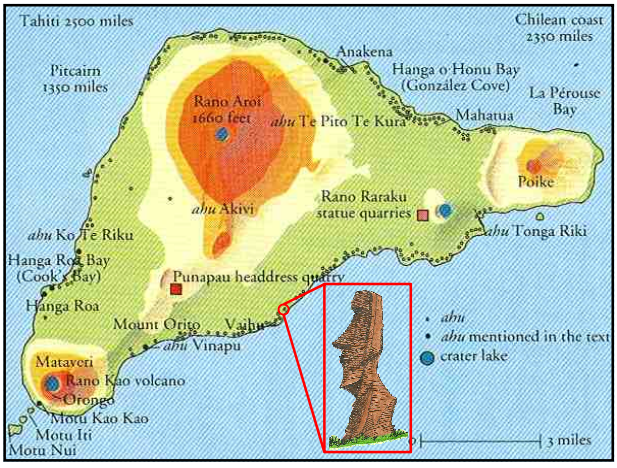


- The wind overturned the lake
- brought up hydrogen sulfide
- mixed with smell of dead fish
- blew into the LA area

- All of these things add up to A REALLY FOUL SMELL IN LA.



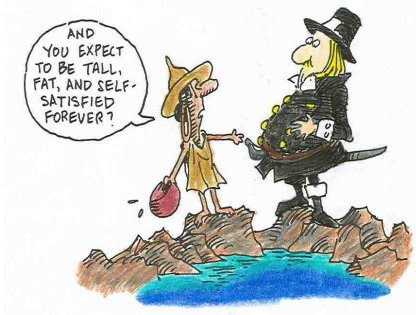
So Here's The Story



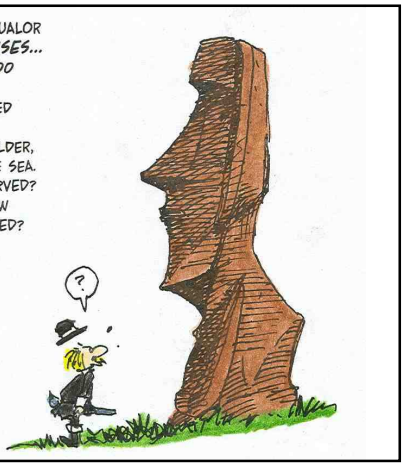
OUR STORY BEGINS IN A PLACE THAT'S BEEN CALLED THE MOST FAR-FLUNG INHABITED ISLAND IN THE WORLD: ***EASTER ISLAND***, A 64-SQUARE-MILE SPECK IN THE PACIFIC OCEAN, 2300 MILES FROM ANYWHERE.

REMOTE, BUT NOT ***DESERTED...*** FROM TIME TO TIME VISITORS DROPPED BY... LIKE THE DUTCH ADMIRAL ***ROGGEVEEN*** IN 1722. ARRIVING ON ***EASTER SUNDAY***, HE NAMED THE ISLAND AFTER THE DATE OF ARRIVAL, AND LEFT THE FIRST WRITTEN ACCOUNT OF THE PLACE AND THE PEOPLE WHO LIVE THERE.

ACCORDING TO ROGGEVEEN AND OTHER 18TH-CENTURY REPORTS, SOME 3000 ISLANDERS EKED OUT A WRETCHED EXISTENCE BY FARMING BANANAS, SUGAR CANE, AND SWEET POTATOES FROM POOR, ROCKY SOIL. THE ONLY FRESH WATER CAME FROM MURKY LAKES INSIDE VOLCANIC CRATERS. THERE WAS SCARCELY A TREE ON THE ISLAND, AND THE PEOPLE WERE "SMALL, LEAN, TIMID, AND MISERABLE."

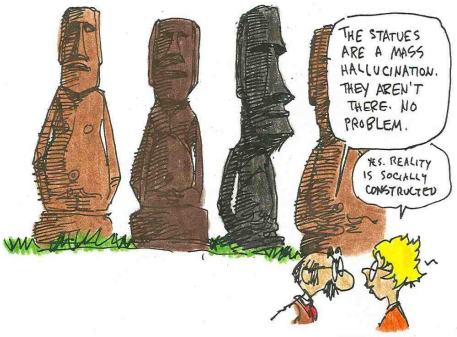


BUT AMIDST THE SQUALOR WERE SOME ***SURPRISES...*** ESPECIALLY SOME 800 ***MASSIVE STONE STATUES*** SCATTERED ACROSS THE ISLAND, SHOULDER TO SHOULDER, THEIR BACKS TO THE SEA. HOW WERE THEY CARVED? HOW QUARRIED? HOW MOVED? HOW ERECTED? AND BY WHOM?

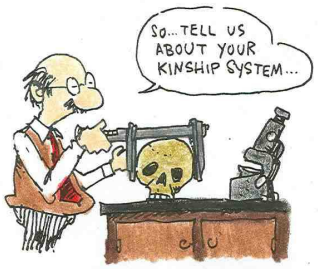


WHEN THE EUROPEANS ASKED WHERE THE STATUES HAD COME FROM, THE ISLANDERS GAVE THIS REPLY:

FAILING TO RECOGNIZE SARCASM WHEN THEY HEARD IT, THE EUROPEANS EMBARKED ON A SERIES OF WILD SPECULATIONS THAT HAVE CONTINUED TO THE PRESENT DAY: ***SPACEMEN*** SET UP THE STATUES WITH ***ANTI-GRAVITY DEVICES...*** A HIGHLY CIVILIZED ***LOST CONTINENT*** HAD SUNKEN INTO THE SEA, LEAVING ONLY EASTER ISLAND BEHIND... THEY WERE FLUNG INTO PLACE IN ONE PIECE BY ***VOLCANIC ERUPTIONS,*** ETC. ETC. ETC.



SINCE THE ISLANDERS HAD EITHER FORGOTTEN WHAT HAPPENED OR DIDN'T FEEL LIKE SHARING, IT WAS LEFT TO WESTERN SCIENTISTS AND HISTORIANS TO PIECE TOGETHER THE STORY WITH ***CALIPERS, SHOVELS, MICROSCOPES,*** AND ***ETHNOGRAPHIC SURVEYS.***



AND HERE IS WHAT THEY FOUND OUT...

AROUND THE YEAR 400, EASTER ISLAND WAS COLONIZED BY ***POLYNESIANS.*** VARIOUS FEATURES OF THE ISLANDERS' SKULLS, THEIR BLOOD TYPES, SOCIAL SYSTEM, LANGUAGE, AND CROPS ARE ALL POLYNESIAN.

POLLEN SAMPLES TAKEN FROM LAKE BEDS SHOW THAT THE ISLAND WAS THEN THICKLY COVERED WITH VEGETATION. HACKING OUT CLEARINGS FROM THE JUNGLE, THE POLYNESIANS BUILT AND PLANTED, AND SOON THEY ENJOYED A TYPICAL POLYNESIAN DIET OF YAM, TARO, BREADFRUIT, BANANA, SUGAR, COCONUT, CHICKEN, AND POLYNESIAN RAT (SMALL AND TASTY!).

THEIR LIFE WAS RICH... THEIR BABIES THRIVED... THEY POPULATED THE ISLAND WITH LITTLE EFFORT... AND IN THEIR COPIOUS SPARE TIME, THEY CARVED STONE MONUMENTS, ESPECIALLY ***STATUES.***

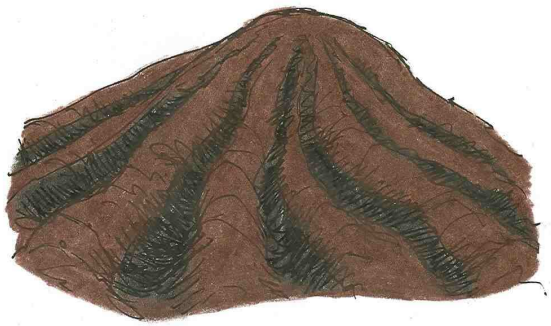
THE STATUES WERE MOVED AND SET UP WITH LOGS AND ROPE. RECENT EXPERIMENTS* HAVE PROVED THAT WHEN A STATUE IS STRAPPED UPRIGHT ONTO LOGS CARVED INTO SLED RUNNERS, AND RAISED ONTO A TRACK OF WOODEN ROLLERS, A COUPLE OF DOZEN PEOPLE COULD PULL IT EASILY!

SO THEY CUT DOWN A LOT OF TREES, NOT JUST FOR ROLLING STATUES, BUT ALSO FOR FIREWOOD AND BUILDING MATERIAL...

AND BY THE YEAR 1400, THERE WAS SCARCELY A TREE LEFT STANDING ON EASTER ISLAND...

AND WHAT GOOD ARE TREES?? YOU MIGHT ASK... READ ON...

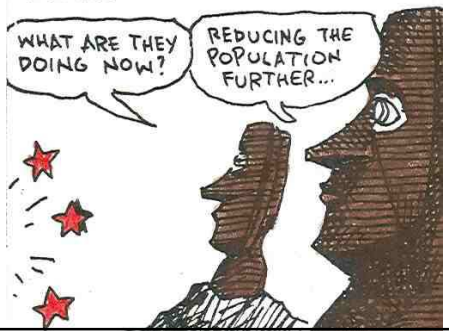
WHAT HAPPENED ON EASTER ISLAND? WHEN A TREE IS CUT DOWN AND ITS ROOTS DIE, THE TOPSOIL LOSES ITS ANCHOR. 4 TO 5 FEET OF EARTH MAY EVENTUALLY BE WASHED AWAY, AND THERE IS NO QUICK WAY TO REPLACE IT.



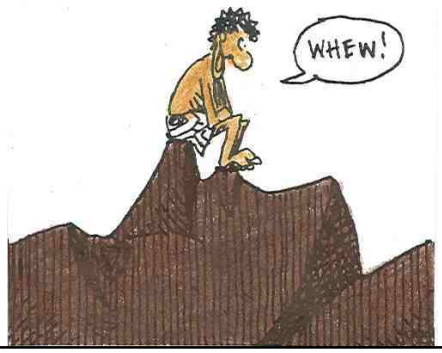
WITHOUT FORESTS TO ABSORB RAIN AND REPLENISH GROUNDWATER, THE ISLAND'S STREAMS AND SPRINGS DRIED UP... THE AIR BECAME LESS HUMID, AND RAINFALL DIMINISHED. AS FERTILE TOPSOIL ERODED, CROP YIELDS FELL... THERE WAS NO WOOD FOR HOUSES... NO FIBERS FOR FISHING NETS OR SAILCLOTH. NO LOGS FOR CANOES...

RIVALRY FOR RESOURCES LED TO PERMANENT WARFARE. UNFORTUNATELY, CLAN PRESTIGE WAS DISPLAYED BY *ERECTING STATUES*, SO THE LAST TREES WERE PROBABLY CUT DOWN IN A FRENZIED EFFORT TO SHOW OFF...

THE POPULATION PEAKED AT AROUND *7000* PEOPLE IN *1550* AND COLLAPSED SO QUICKLY THAT SOME *400* STATUES WERE LEFT UNFINISHED IN THE QUARRIES.



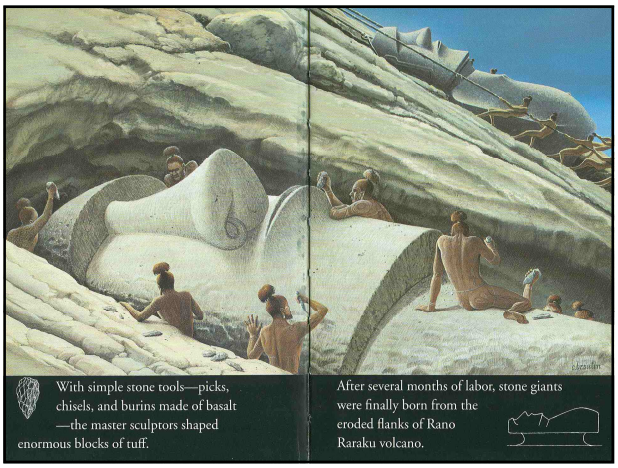
BUT THE RIVAL CLANS FOUGHT ON... THEY PULLED EACH OTHERS' STATUES DOWN... AND BY *1860*, EVERY STATUE ON THE ISLAND HAD BEEN TOPPLED.

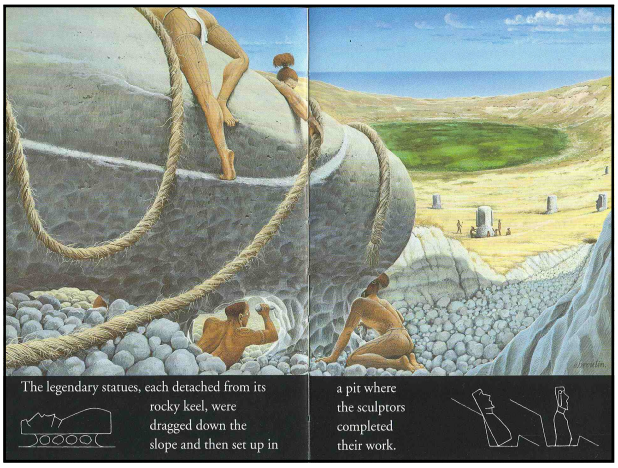


THE POINT OF THIS STORY IS NOT THAT THE PEOPLE OF EASTER ISLAND WERE SOMEHOW STRANGE, SILLY, OR DIFFERENT FROM ANY-ONE ELSE. QUITE THE CONTRARY: LIKE THE REST OF US, THEY WERE ***CREATURES OF HABIT,*** AND THEIR WAY OF LIFE—FARMING, FORESTRY, BUILDING, AND DISPLAY—WAS HARD TO CHANGE.

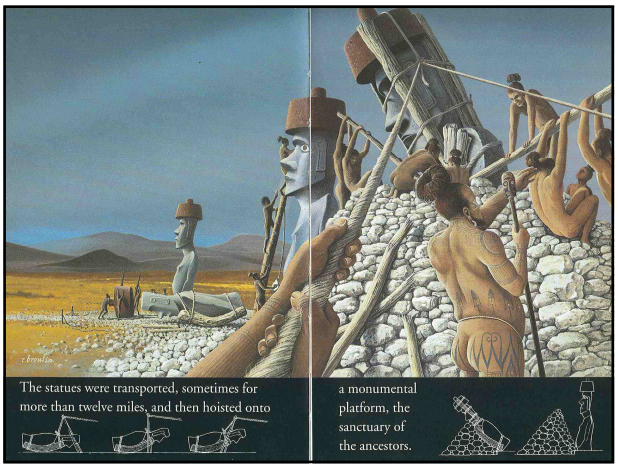
EASTER ISLAND IS VERY SMALL. FROM ITS SUMMIT YOU CAN SEE THE WHOLE THING. THE PERSON WHO CUT DOWN THE LAST TREE MUST HAVE KNOWN THERE WERE NO MORE—AND STILL HE CUT IT DOWN.

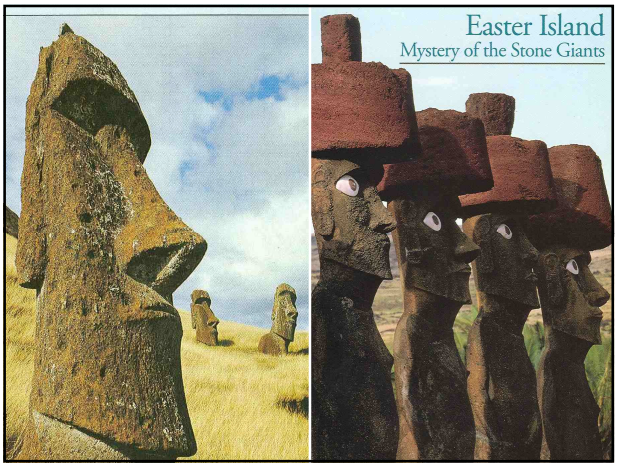
LIKE THE PEOPLE OF EASTER ISLAND, THE PEOPLE ON THE REST OF THE EARTH ARE RAPIDLY CHANGING THEIR ENVIRONMENT. ARE WE DOOMED TO A POPULATION CRASH AND A BARREN LANDSCAPE? OR CAN WE SUSTAIN A GREEN FUTURE FOR OURSELVES AND THE PLANET?





The Moai "Walked There"


The statues were transported, sometimes for more than twelve miles, and then hoisted onto
a monumental platform, the sanctuary of the ancestors.


Easter Island
Mystery of the Stone Giants


Moai and palms

Easter Island landscape today.

The civilization on Rapa Nui (Easter Island) almost became wiped out due to **unsustainable resource use**

How did they unsustainably use their resources?

Consensus and Conflict

- Scientific consensus (general agreement among informed scholars) stems from a community of scientists who collaborate in a cumulative, self-correcting process.
- Paradigm shifts (great changes in explanatory frameworks) occur when a majority of scientists agree that an old explanation no longer works very well.

Recognizing Pseudoscience

Table 2.2 Questions for Baloney Detection
1. How reliable are the sources of this claim? Is there reason to believe that they might have an agenda to pursue in this case?
2. Have the claims been verified by other sources? What data are presented in support of this opinion?
3. What position does the majority of the scientific community hold in this issue?
4. How does this claim fit with what we know about how the world works? Is this a reasonable assertion or does it contradict established theories?
5. Are the arguments balanced and logical? Have proponents of a particular position considered alternate points of view or only selected supportive evidence for their particular beliefs?
6. What do you know about the sources of funding for a particular position? Are they financed by groups with partisan goals?
7. Where was evidence for competing theories published? Has it undergone impartial peer review or is it only in proprietary publication?

Now try and answer these questions

- What are the strengths/limitations of models?
- What happened to the Rapa Nui on Easter Island?
- From the story can you identify:
- A system?
- Positive feedback?
- Negative feedback?
- Time Delay?
- Synergy?

Answers to the questions

- **A system?**
  - **Input – rock (tools), trees, rope**
  - **Throughput – carving, moving, standing them up**
  - **Output – Big statue standing up at the beach.**
- **Positive feedback? Cutting trees for houses, tools, moving statues, firewood… people will live and reproduce making more people who need more trees for houses, etc.**
- **Negative feedback? Population increased and then crashed due to lack of resources.**
- **Time Delay?**
  - **Takes time for trees to regrow.**
  - **Takes time for the climate to dry out because of the loss of topsoil.**
- **Synergy? Loss of soil + lack of trees = less food, less rain.**

- Strength of Models – get info faster, help understand things that are complex, very big, very small.
- Limitations of Models – can't show everything, not 100% accurate.
- A system? Input – trees. Throughput – making houses. Output - houses
- Positive feedback? Carving statues for prestige, more statues higher stature, leads to more statue carving.
- Negative feedback? Using trees for houses, canoes, rolling statues… then they ran out of trees.
- Time Delay? Cutting Trees to move statues – later the topsoil was blown away or washed away (eroded)
- Synergy? Cutting of trees, + less rain, + less resources + competition = worse off.

- Strength of Models – fast, gives information, can work on small/large things.
- Limitations of Models – can't include all the variables.
- A system? Trees System: input – trees throughput – cutting down trees, shaping them, building houses – output – house.
- Positive feedback? Cutting trees for canoes, feeds more people, reproduce, need more canoes, cut more trees.
- Negative feedback? Human population – population built up, when people ran out of resources, population crashed.
- Time Delay? Trees cut down (time) erosion (time) less fresh water
- Synergy? Individuals come together to make clans.