

How do natural scientists **test** their ideas?

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Ruder Bošković Institute, Zagreb

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Split, September 19, 2015

my area of expertise: natural science



my area of expertise: natural science
physics



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physics
astroparticle physics



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...and, as a bonus of my talk:

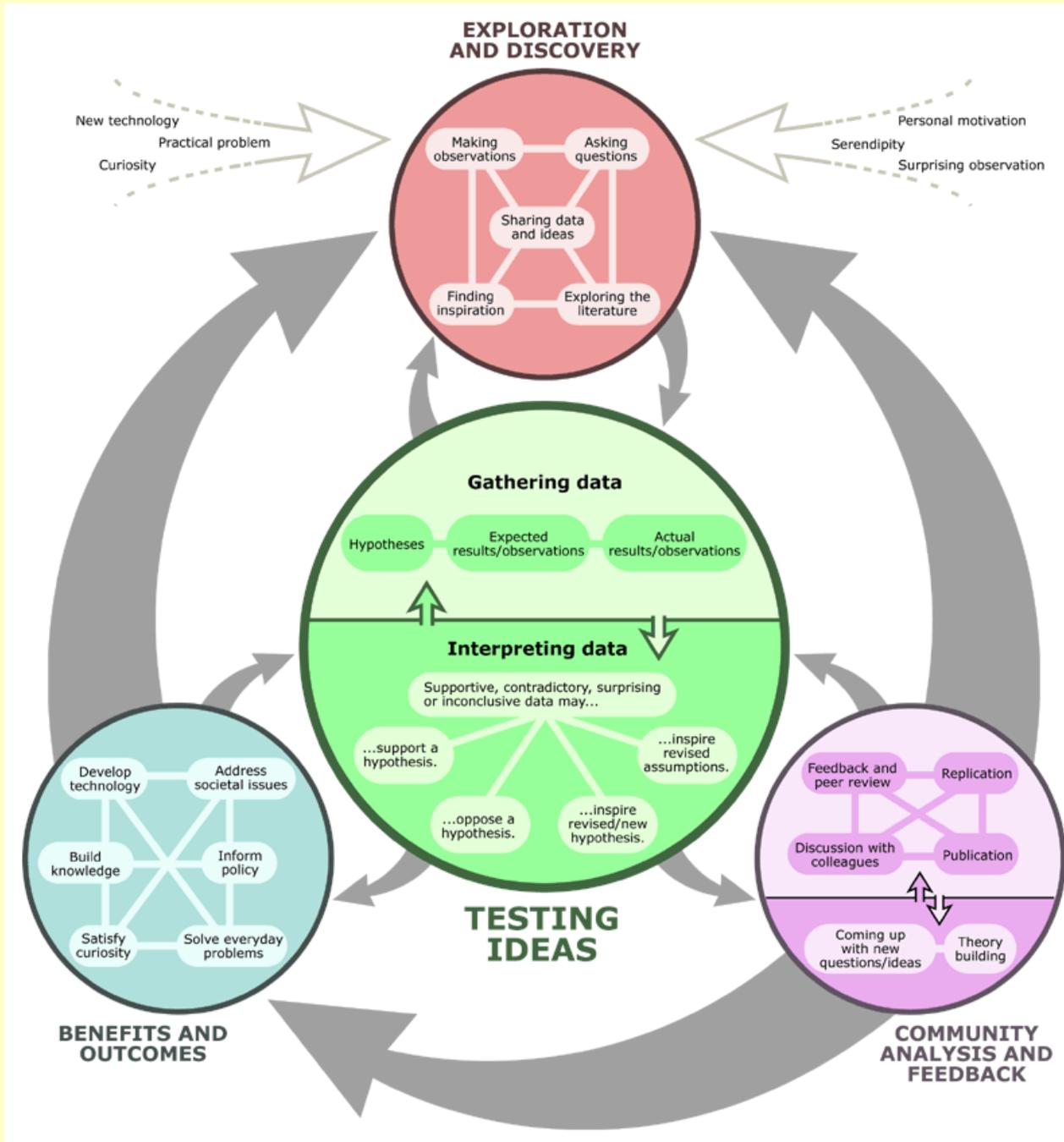
“Everything you always wanted to know about sex
(but were afraid to ask)”

the Universe

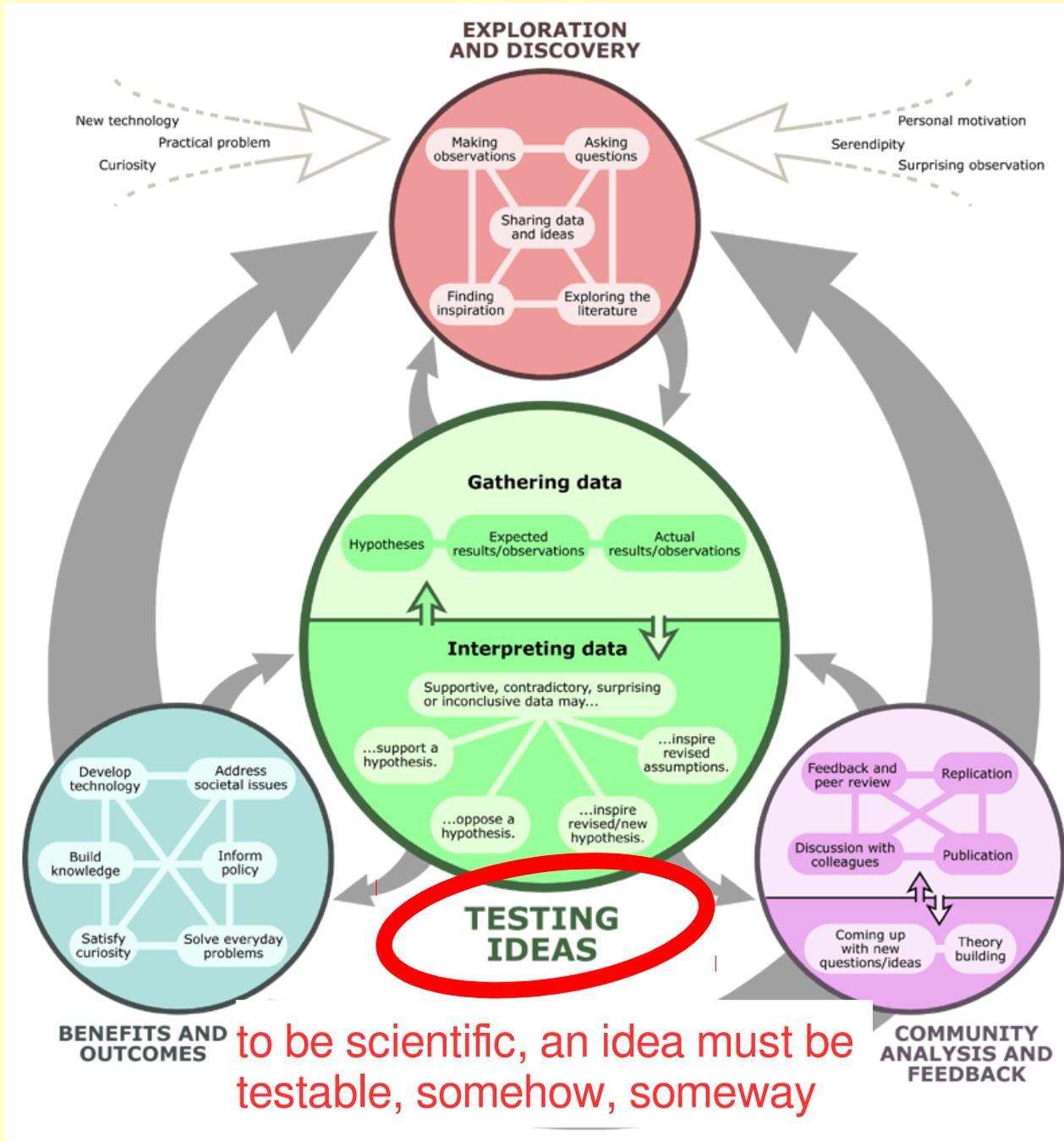
my interconnection with IT:

- (1) main job: development and maintenance of software for data quality control for the MAGIC telescopes
- (2) teaching of C and Python programming for physics students at Faculty of Science University of Zagreb
- (3) science columnist at Bug OnLine <http://www.bug.hr/>

the most important part of the scientific method...



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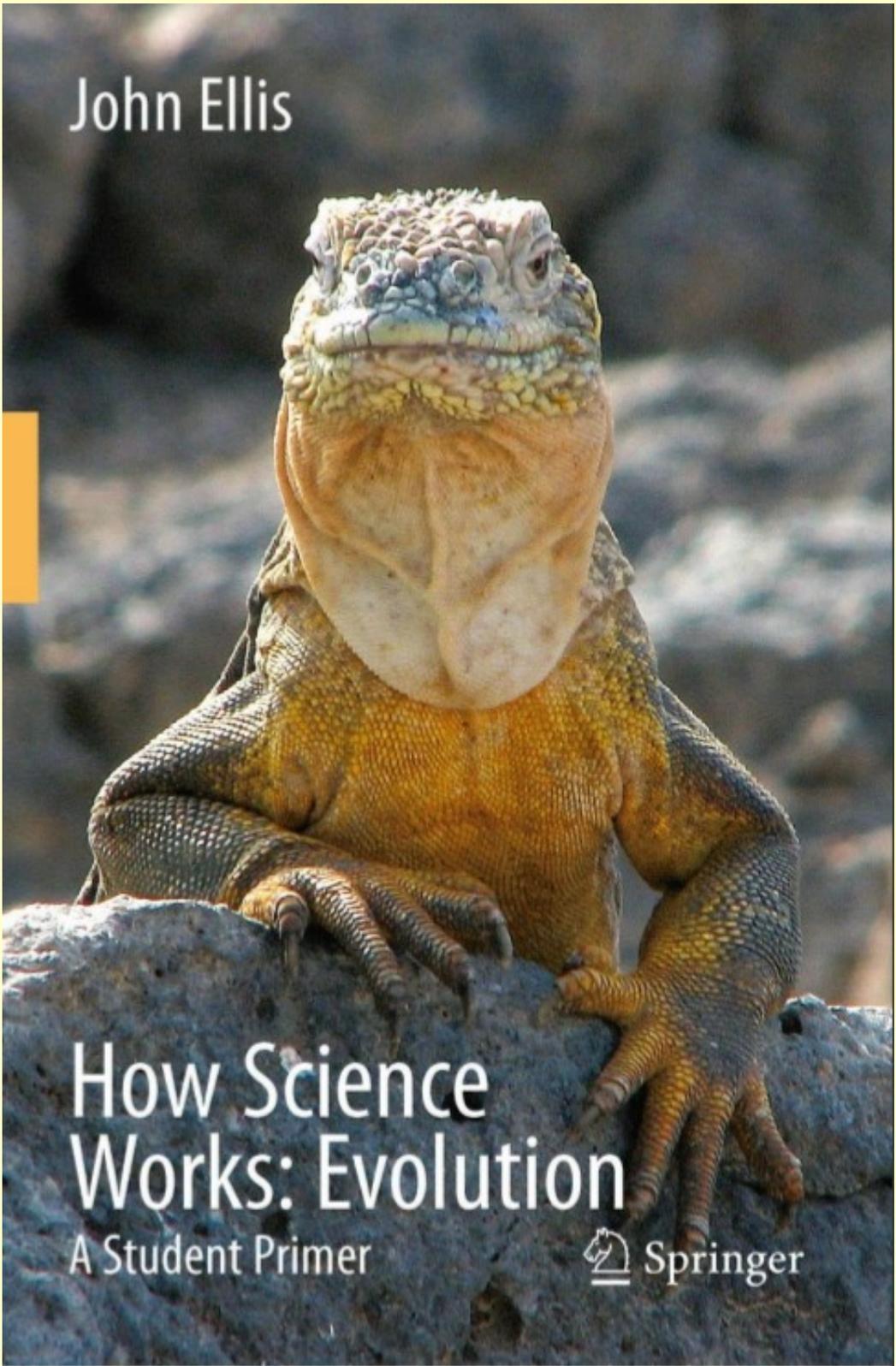


two sources:

(1) John Ellis
**How Science Works:
Evolution: A Student Primer**
Springer (2010)

feel free to contact me if you
want a PDF copy of the book
(with permission of the author)

John Ellis



How Science
Works: Evolution

A Student Primer

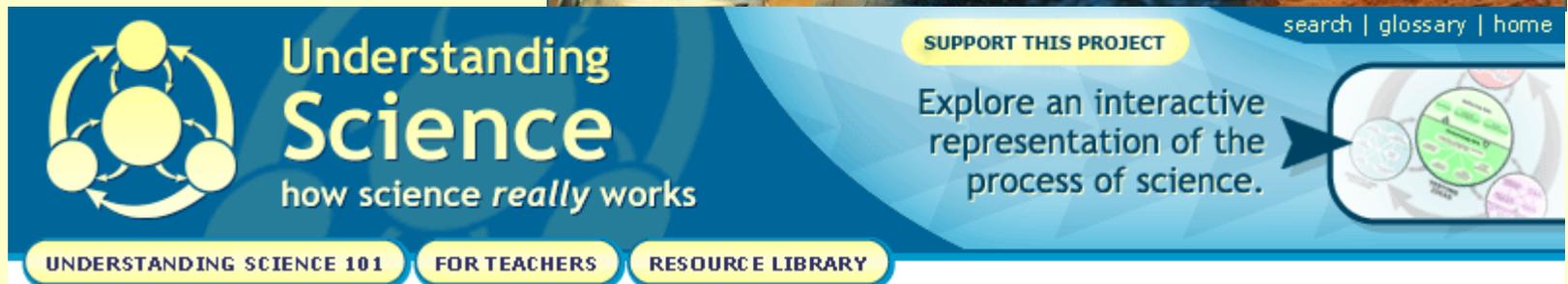
 Springer

two sources:

(2) **Understanding Science**
<http://undsci.berkeley.edu/>

The Understanding Science site was produced by the UC Museum of Paleontology of the University of California at Berkeley, in collaboration with a diverse group of scientists and teachers, and was funded by the National Science Foundation.

for the general public



Understanding Science
how science *really* works

SUPPORT THIS PROJECT

Explore an interactive representation of the process of science.

search | glossary | home

UNDERSTANDING SCIENCE 101 FOR TEACHERS RESOURCE LIBRARY

The banner features a central logo with three yellow circles and arrows forming a cycle. To the right, there is a navigation menu with 'search | glossary | home' and a 'SUPPORT THIS PROJECT' button. Below this is a call to action: 'Explore an interactive representation of the process of science.' with a blue arrow pointing to a circular diagram. At the bottom, there are three buttons: 'UNDERSTANDING SCIENCE 101', 'FOR TEACHERS', and 'RESOURCE LIBRARY'.

An overview

Science relies on **testing ideas** with evidence gathered from the natural world.

Science focuses exclusively on **the natural world**, and does not deal with supernatural explanations.

Science is not simply a collection of facts; rather it is a path to understanding.

You can apply an understanding of how science works to your everyday life.

TWO WAYS OF EXPLAINING THE WORLD

1. Supernaturalism:

Beyond the obvious physical world is another invisible world containing **active agents** that behave unpredictably

*All known human cultures throughout recorded history embrace this view that is based on **faith**, defined as accepting the authority of revelation, dogma and ancient texts.*

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2. Naturalism:

Everything there is belongs to the physical world that we all experience and that behaves according to **unvarying regularities** ("laws of nature")

*This view is very recent, is the dominant view amongst leading scientists today, and is based on **reason** applied to observations and experiments accessible to all.*

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THESE EXPLANATIONS ARE MUTUALLY EXCLUSIVE

What is science?

From the Latin *scientia* what means **knowledge**.

But, science is both: a body of knowledge and **a proces**.

The knowledge that is built by science is **always open to question and revision**. No scientific idea is ever once-and-for-all "proved."

Despite the fact that they are subject to change, scientific ideas are **reliable**.

We have good reason to trust scientific ideas: **they work!**

THE DISTINCTIVE ASPECTS OF SCIENCE

3. Uncertainty

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SCIENCE IS A SET OF **IDEAS** ABOUT
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These ideas are based on the best observational and experimental data available at the time but are always open to change to accommodate new data. Thus science has an inbuilt self-correcting mechanism that accounts for its unmatched success at improving the human condition.

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**BECAUSE FUTURE DISCOVERIES CANNOT BE PREDICTED
WE CAN NEVER BE CERTAIN THAT NEW DATA WILL NOT
CHANGE EXISTING IDEAS. THUS ALL SCIENCE IS THEORY
AND SCIENTIFIC THEORIES CAN NEVER BE PROVED**

How science works

Scientific Method (1 serving)

1. Ask a question.
2. Formulate a hypothesis.
3. Perform experiment.
4. Collect data.
5. Draw conclusions.

Bake until thoroughly cooked.

Garnish with additional observations.

Too simple!

How science works

misconception 1

The simplified scientific method implies that scientific studies follow a linear recipe.

But in reality, scientific investigations involve repeating the same steps many times.

How science works

misconception 2

The simplified scientific method implies that science is done by individual scientists working in isolation.

But in reality, science depends on interactions within the scientific community.

How science works

misconception 3

The simplified scientific method implies that science has little room for creativity.

But in reality, the process of science is exciting, dynamic, and unpredictable. Science relies on creative people thinking outside the box.

How science works

misconception 4

The simplified scientific method implies that science concludes.

But in reality, scientific conclusions are always revisable (able to be looked at again and possibly changed) in case new evidences become available.

HOW SCIENCE WORKS

THE IMPORTANCE OF DEFINITIONS

FACTS in science are **empirical** observations available in principle to everyone. Facts can be inferred as well as direct.

HYPOTHESES are imaginary **but testable** speculations that might explain some facts.

THEORIES are coherent conceptual models that explain whole sets of facts and that **withstand falsifiable predictions**.

Good theories are quantitative, propose mechanisms, and lead to the discovery of new phenomena.

**THUS TO BE A GOOD SCIENTIST YOU NEED
CURIOSITY, IMAGINATION AND SKEPTICISM**

HOW SCIENCE WORKS

SUMMARY

Source: US National Academy of Sciences

1. Scientists pose, test and revise multiple hypotheses to explain what they observe in the natural world.
2. Scientists use only natural causes to explain natural observations.
3. Science does not prove or conclude; science is always a work in progress.
4. Science is neither democratic nor dogmatic.
5. Scientific claims are subject to peer review and replication.
6. Science is a human endeavour but it cannot make moral or aesthetic decisions.