

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

**Dario Hrupec**

Ruder Bošković Institute, Zagreb

**Festival 15**, Microsoft Innovation Center  
Split, September 19, 2015

my area of expertise: natural science





my area of expertise: natural science  
physics





my area of expertise: natural science  
physics  
astroparticle physics





my area of expertise: natural science  
physics  
astroparticle physics  
gamma ray astronomy





my area of expertise: natural science  
physics  
astroparticle physics  
gama ray astronomy  
**VHE gama ray astronomy**





my area of expertise: natural science  
physics  
astroparticle physics  
gama ray astronomy  
**VHE gama ray astronomy**

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

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

the Universe



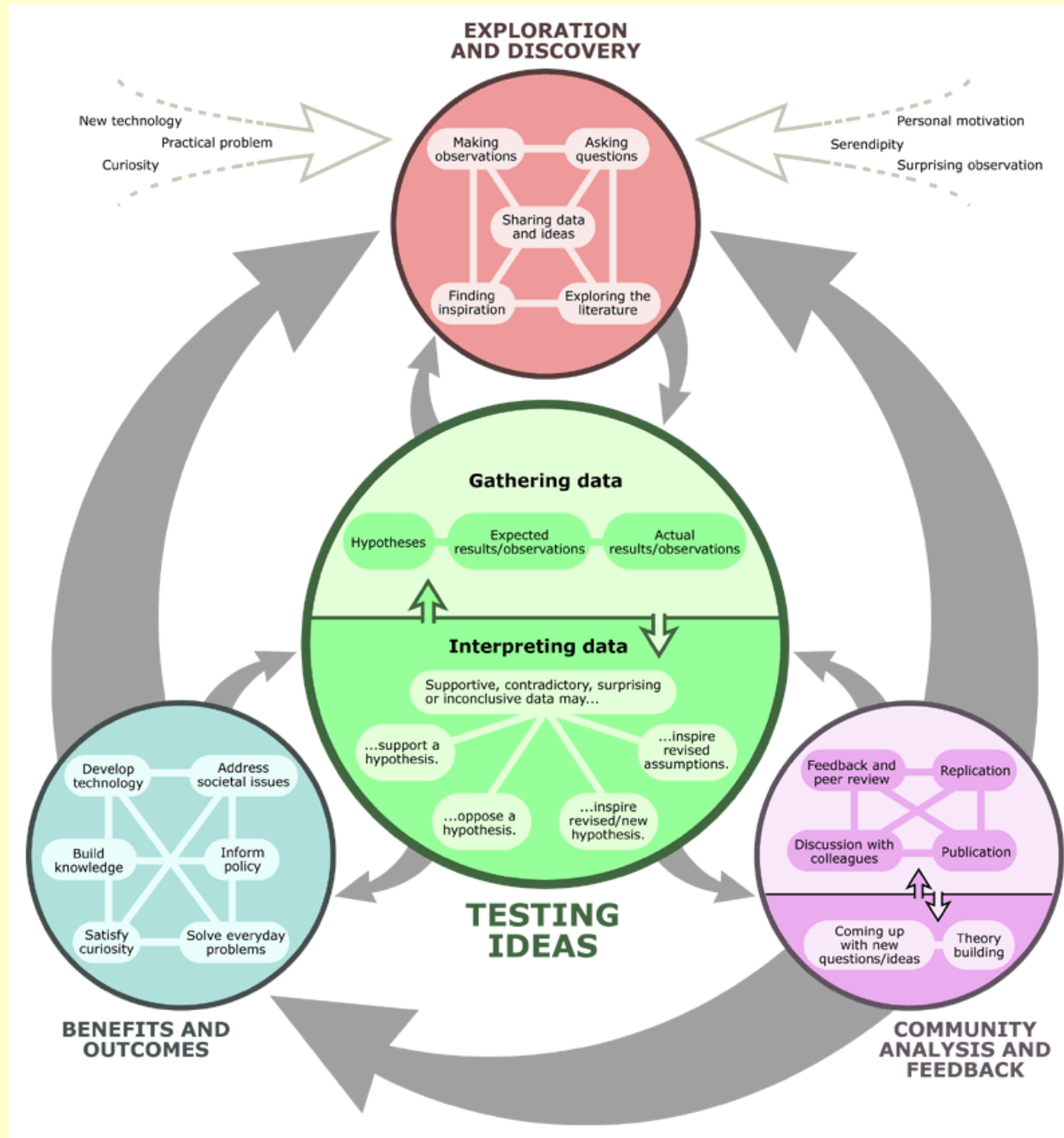
## my interconnection with IT:

- (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/>



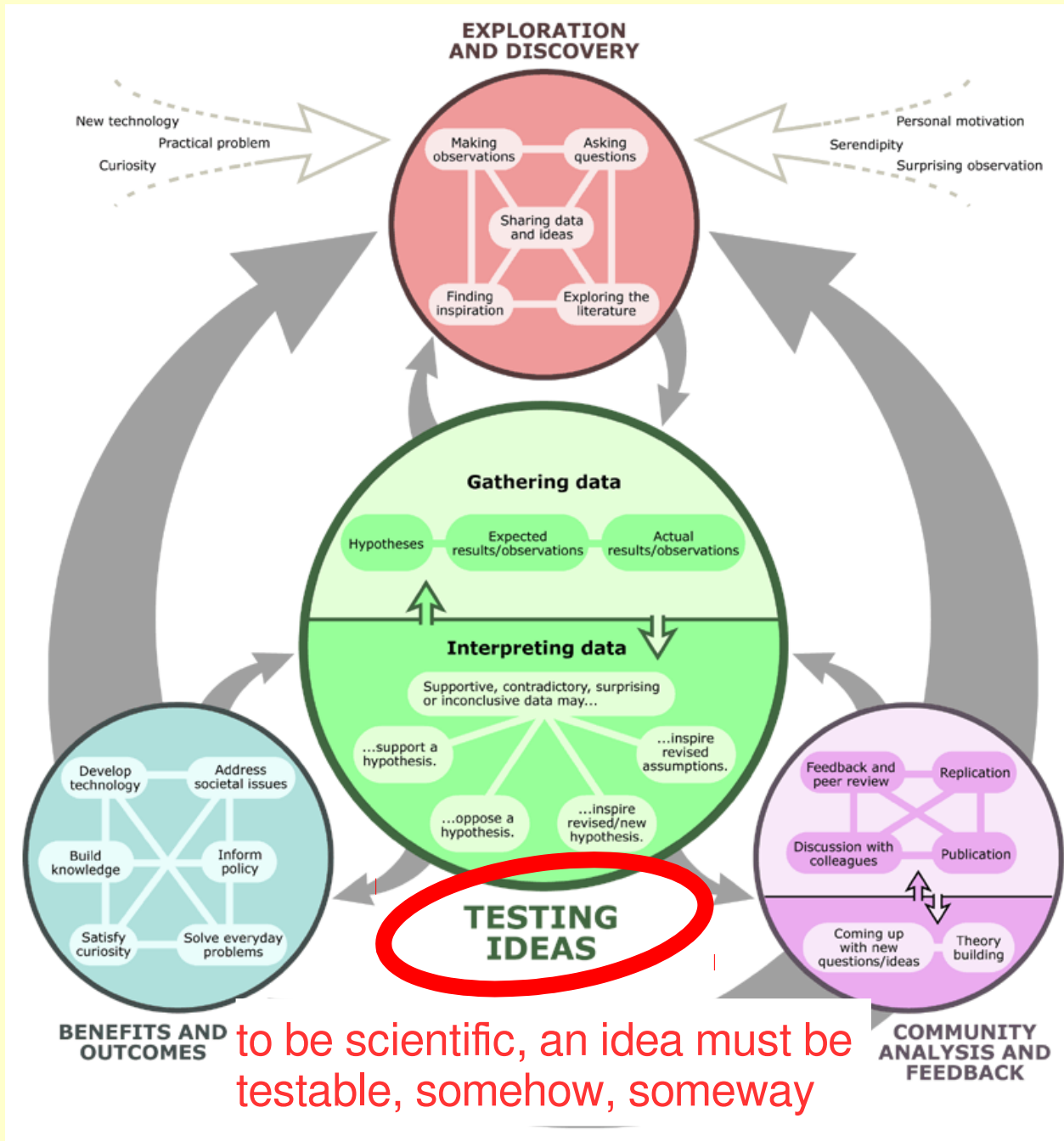


# the most important part of the scientific method...





# the most important part of the scientific method...

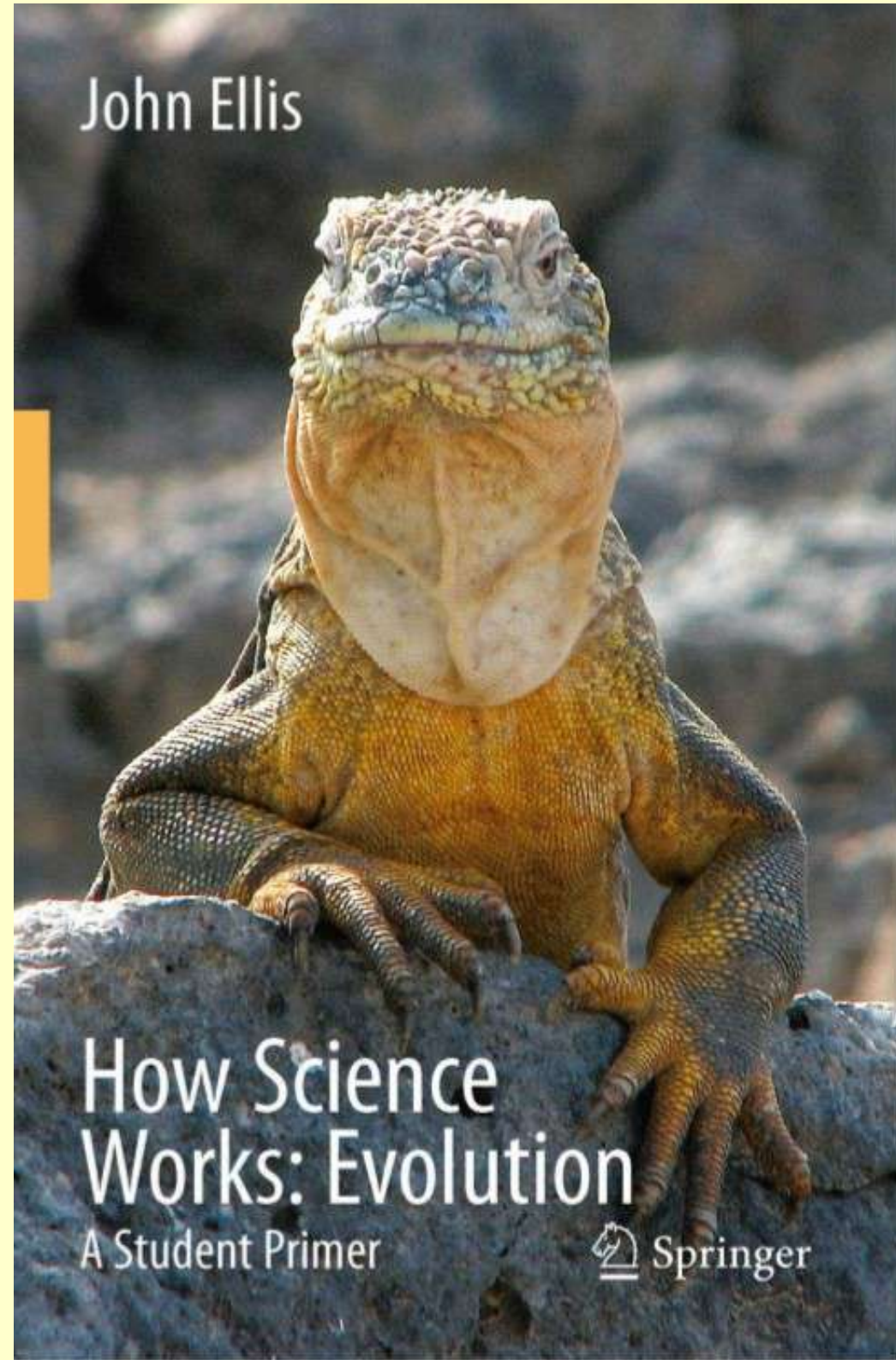




**two sources:**

(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)





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



# 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.*



# 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.*

## 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.*



# 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.*

## 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.*

**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**

**Contrary to popular opinion, all scientific understanding is  
PROVISIONAL**

# THE DISTINCTIVE ASPECTS OF SCIENCE

## 3. Uncertainty

Contrary to popular opinion, all scientific understanding is  
**PROVISIONAL**

SCIENCE IS A SET OF **IDEAS** ABOUT  
HOW THE UNIVERSE WORKS

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.

**BUT**



# THE DISTINCTIVE ASPECTS OF SCIENCE

## 3. Uncertainty

Contrary to popular opinion, all scientific understanding is  
**PROVISIONAL**

SCIENCE IS A SET OF **IDEAS** ABOUT  
HOW THE UNIVERSE WORKS

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.

**BUT**

**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.