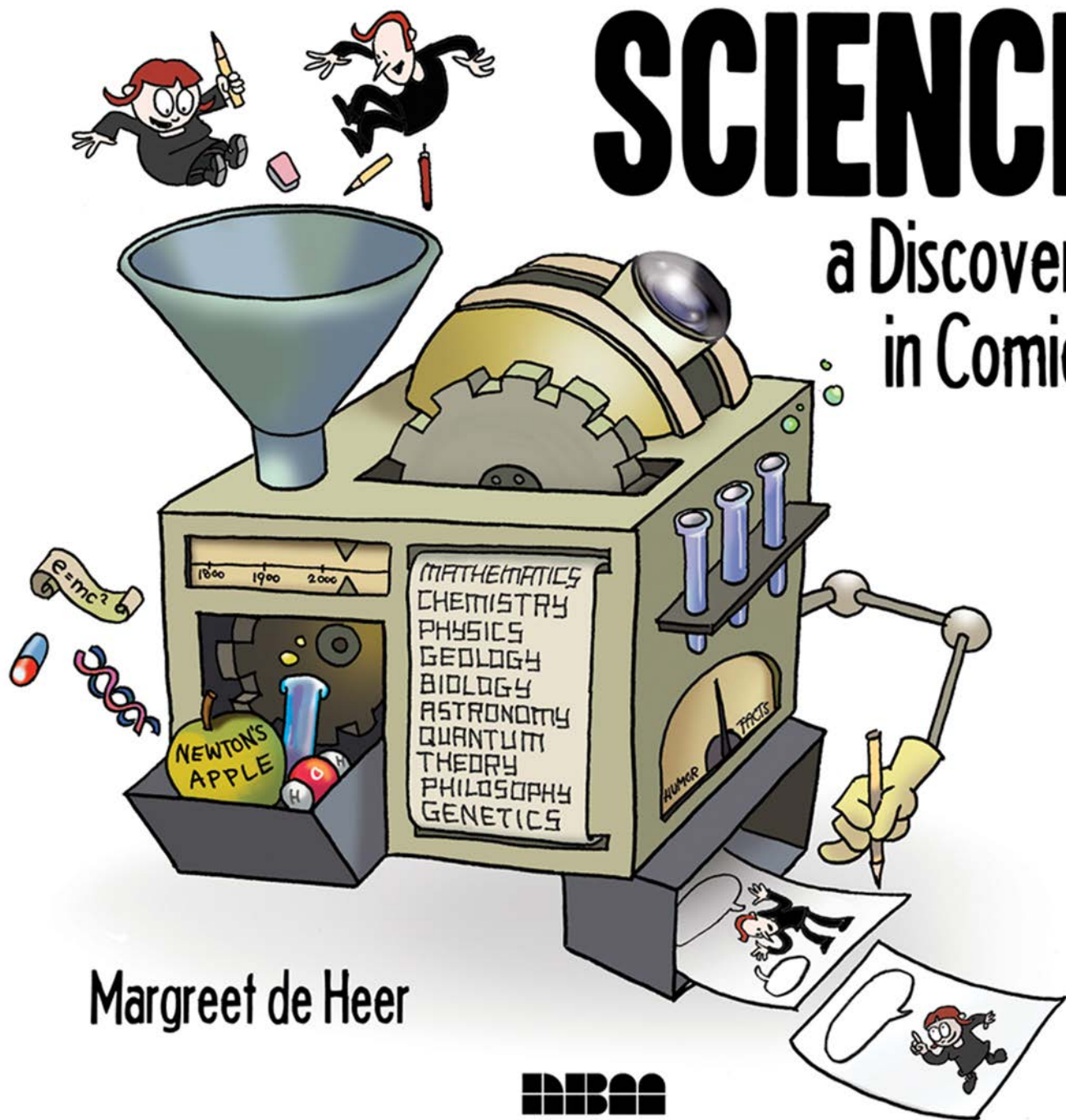


SCIENCE

a Discovery in Comics



Margreet de Heer

SCIENCE

A DISCOVERY IN COMICS

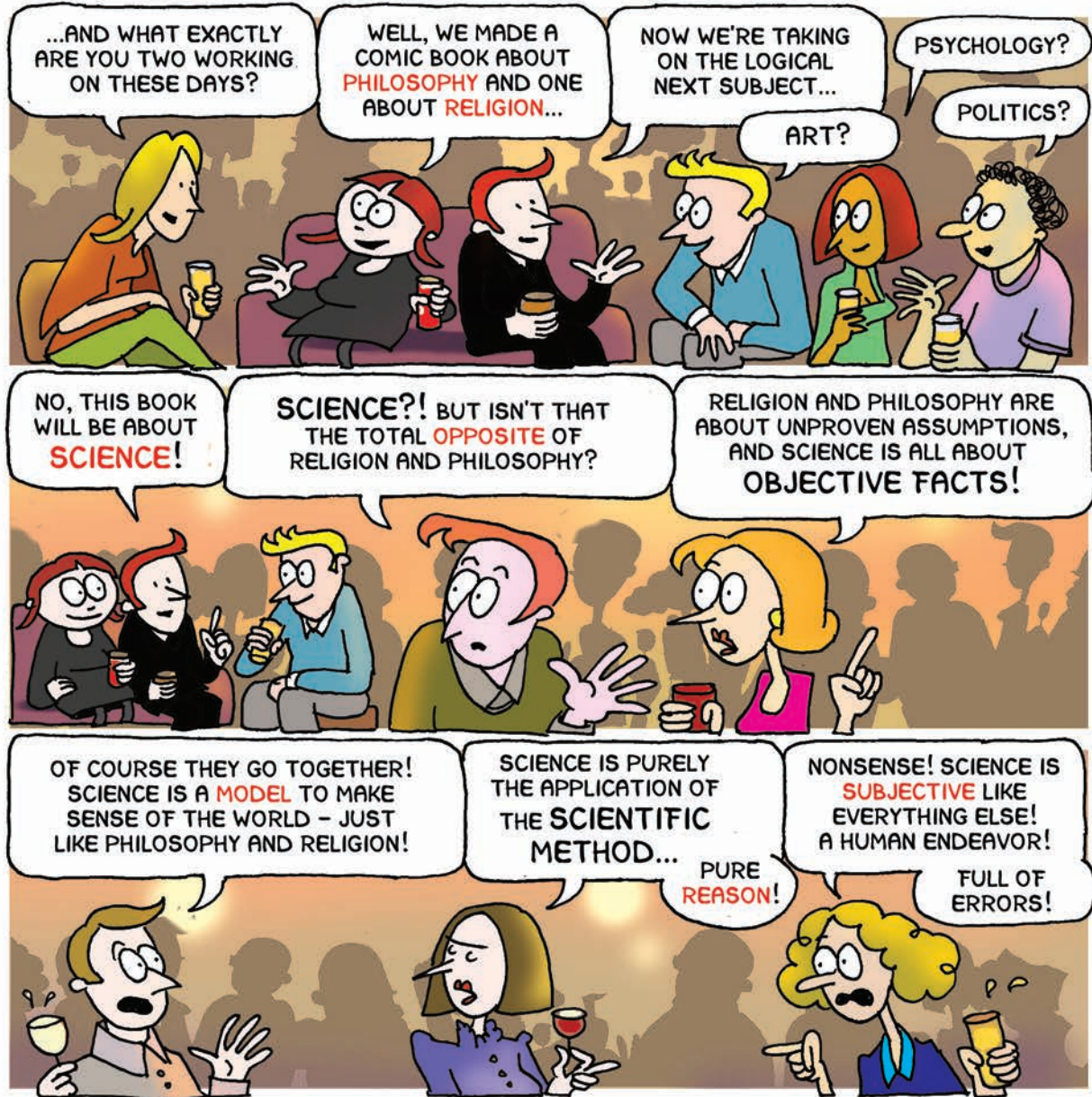


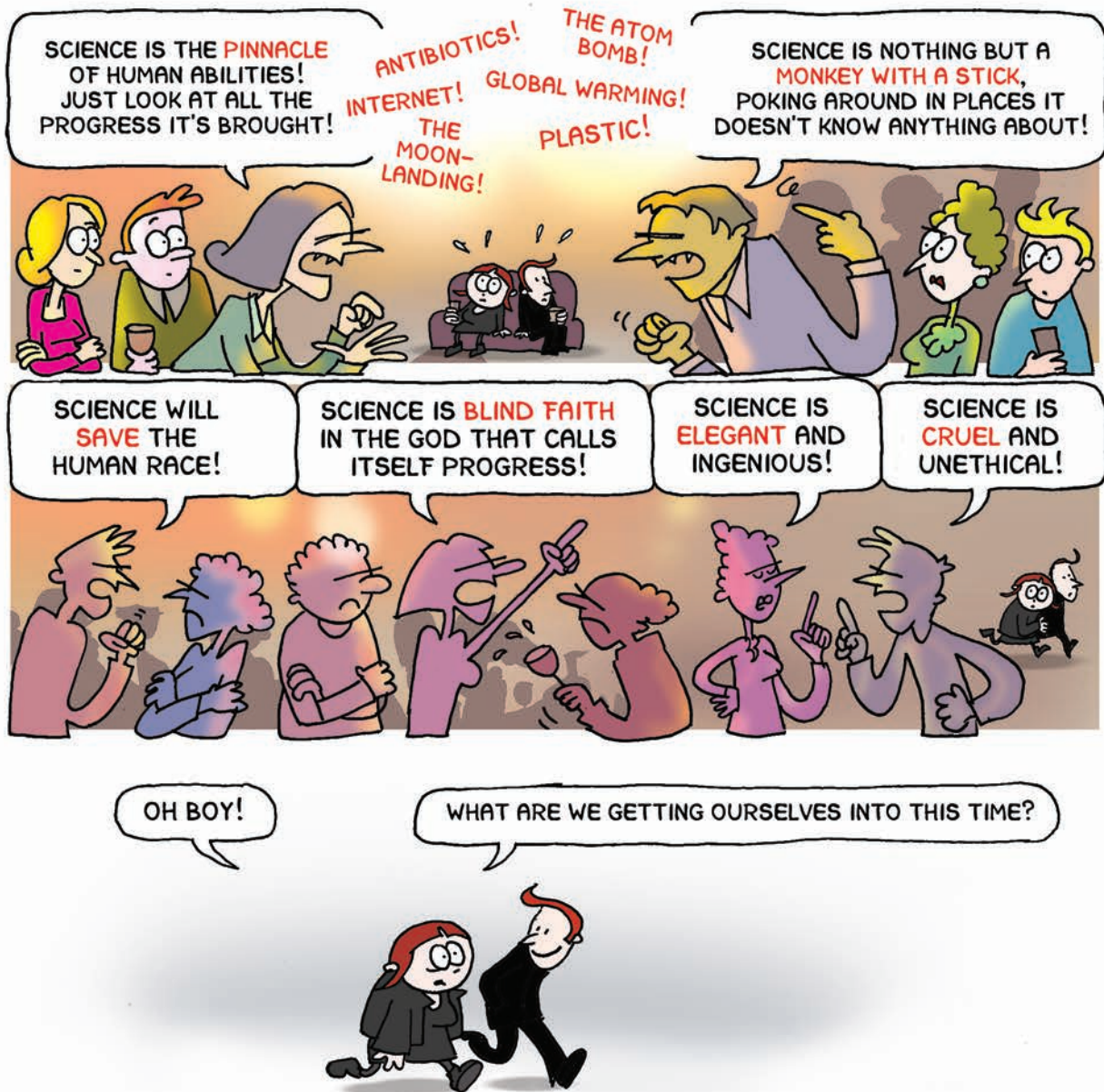
NANTIER • BEALL • MINOUSTCHINE

Publishing inc.

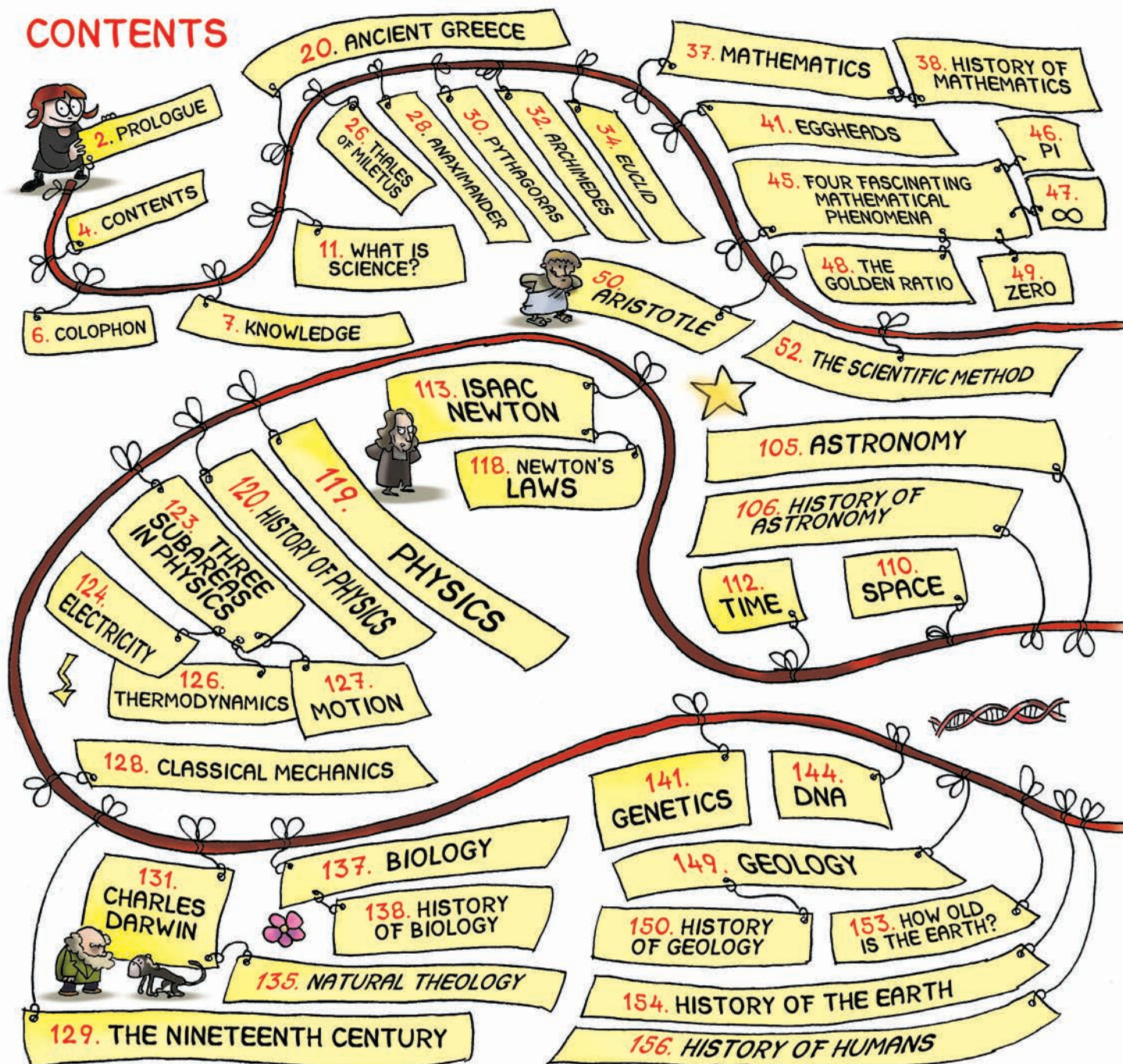
new york

PROLOGUE





CONTENTS



55. THE MIDDLE AGES

56. PERCEPTIONS OF THE MIDDLE AGES

58. TIMELINE OF THE MIDDLE AGES

60. WORLD VIEW

61. THE FIVE ELEMENTS

63. CHEMISTRY

68. HISTORY OF CHEMISTRY

70. THE PERIODIC TABLE

73. SUMMARY

64. CHEMISTRY'S ALL AROUND

77. MRS. SCIENTIST

82. DISREGARDED SCIENTISTS

93. THE SCIENTIFIC REVOLUTION

96. GALILEO GALILEI

98. SCIENCE & RELIGION

95. OLD & NEW IDEAS

85. THE RENAISSANCE

87. LEONARDO DA VINCI

158. THE TWENTIETH CENTURY

159. ALBERT EINSTEIN

161. $E=MC^2$

162. THE THEORY OF RELATIVITY

173. AND NOW?

175. THE STATE OF SCIENCE AT THE BEGINNING OF THE 21ST CENTURY

176. WHERE WILL IT LEAD?

181. INDEX

191. THANKS

165. QUANTUM THEORY

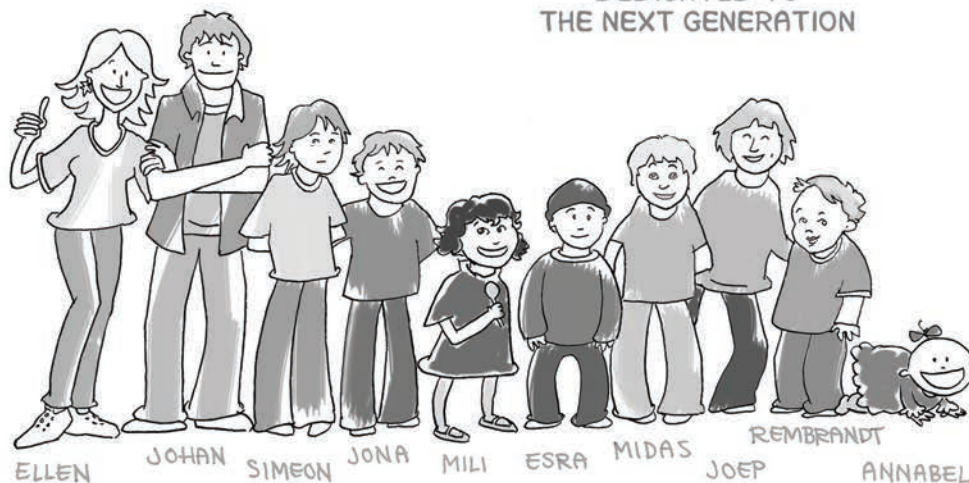
166. HISTORY OF QUANTUM THEORY

168. WAVE AND/OR PARTICLE

171. CLASSICAL MECHANICS vs. QUANTUM WORLD VIEW

172. THEORY OF EVERYTHING

DEDICATED TO
THE NEXT GENERATION



Copyright © 2012 Uitgeverij Meinema, Zoetermeer, The Netherlands
Copyright English translation © 2013 Margreet de Heer

Original title: Wetenschappen in Beeld
Published originally in Dutch by Uitgeverij Meinema, 2012

Publication in the U.S.: NBM Publishing, 2013
Printed in China
1st printing September 2013

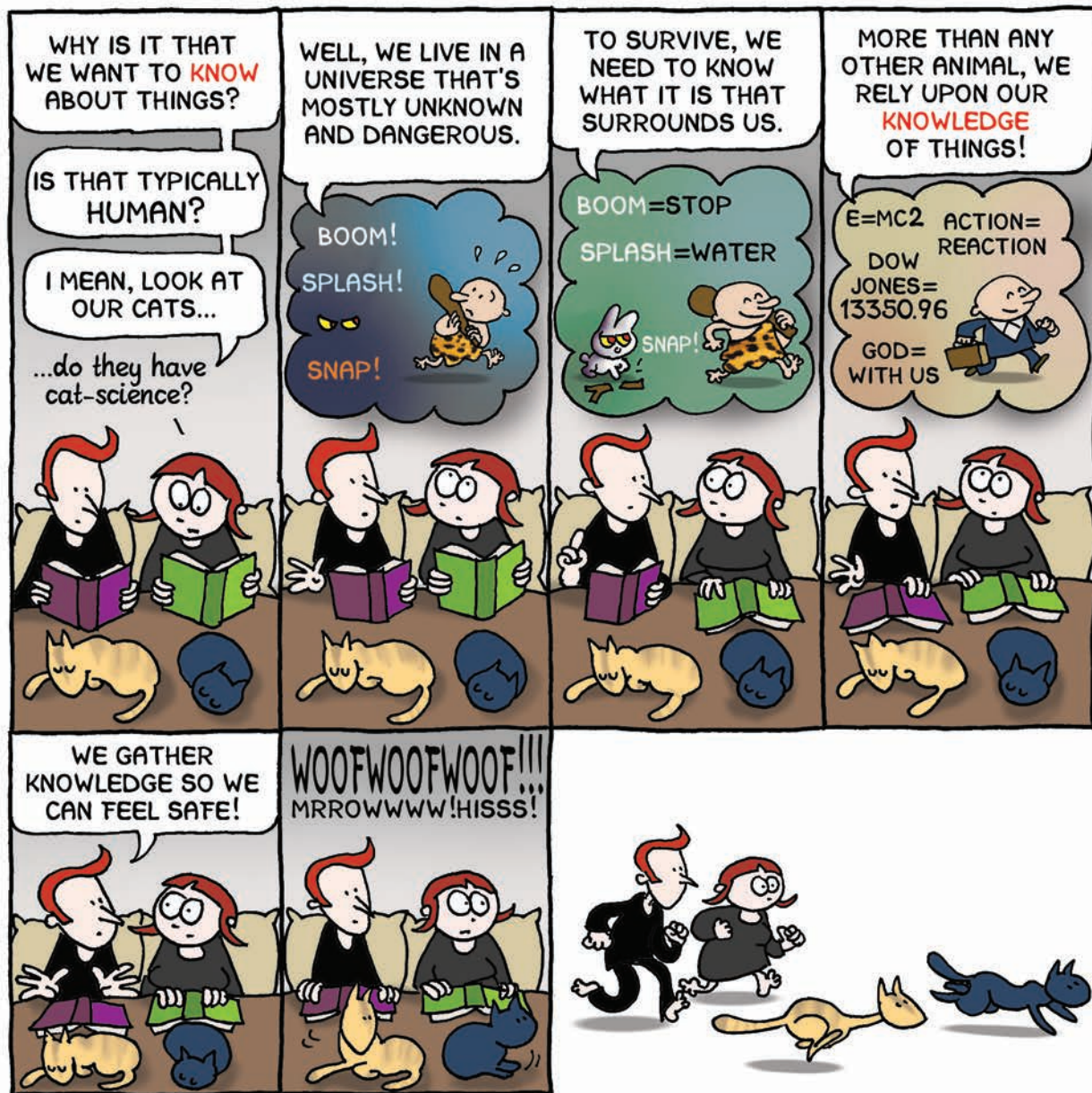
ISBN 978-1-56163-750-8
Library of Congress Control Number: 2013939851

Text & drawings: Margreet de Heer
Colors: Yiri T. Kohl

THE WORD
SCIENCE
IS DERIVED FROM THE LATIN WORD
SCIENTIA
WHICH MEANS
KNOWLEDGE

BUT WHAT DOES IT MEAN
TO
KNOW?





...SO OUR CATS ARE BEHAVING
SCIENTIFICALLY NOW...?

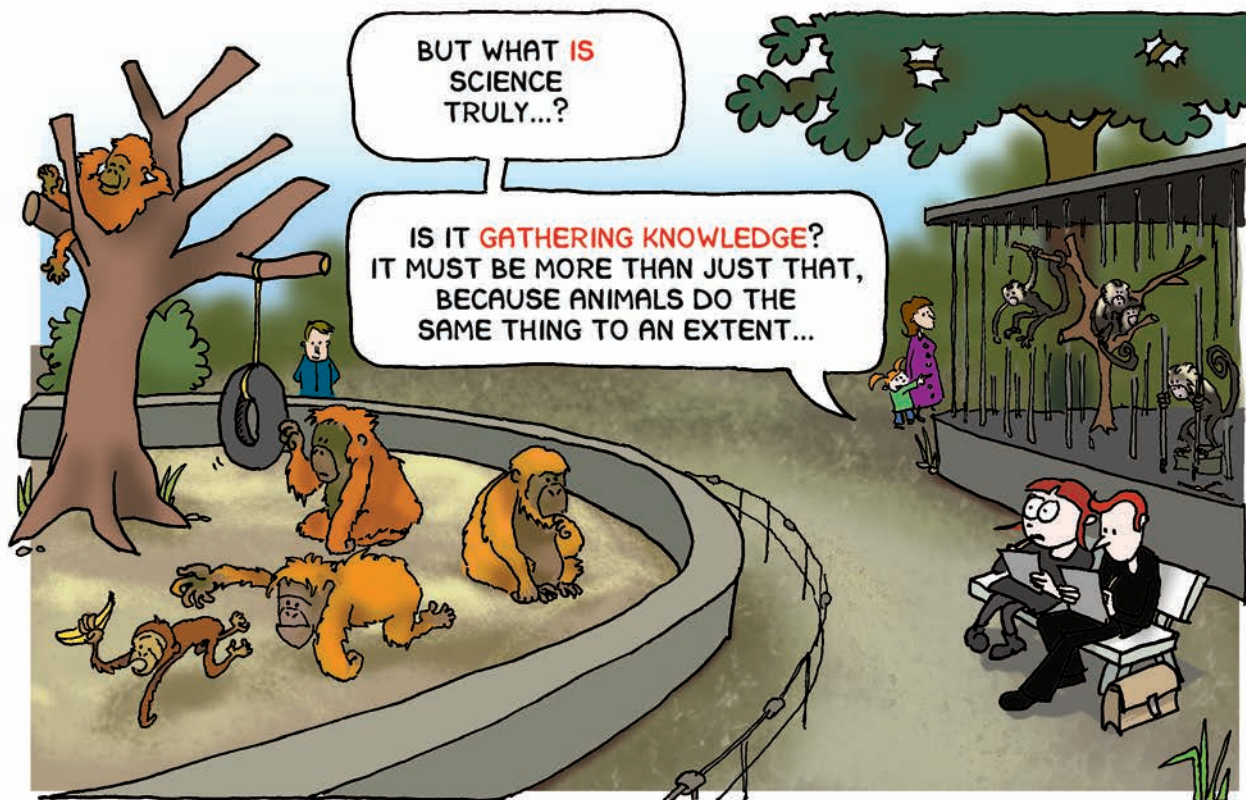
AHA, IT'S THAT
NEIGHBOR'S DOG...

...AND HE CAN'T REACH
US! WE'RE SAFE!

MRROWWMRROWWW!

WOOFWOOFWOOFWOOF!!!







BUT ISN'T SCIENCE SUPPOSED TO BE INTELLIGENT AND ELEGANT AND INGENUOUS?

CONCISE FORMULAS?

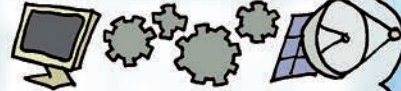
$$E = mc^2$$

DELICATE PROCESSES?



YES.

PROGRESSIVE TECHNOLOGIES?



BETTER AND BETTER THEORIES?

EVOLUTION

RELATIVITY

QUANTUM THEORY

SCIENCE IS
SECURING KNOWLEDGE...



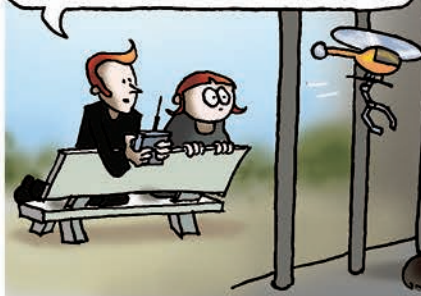
...SO WE CAN **PASS ON**
OUR KNOWLEDGE...



...AND **BUILD** ON
THAT KNOWLEDGE!



WE ARE NOT THE ONLY
SPECIES THAT USES
LOGICAL THINKING AS A TOOL...



...BUT BY PASSING ON AND
BUILDING ON KNOWLEDGE,
WE HAVE DEVELOPED
SUCH ADVANCED TOOLS...



...THAT WE ARE SUPERIOR
TO ANY OTHER ANIMAL
IN OUR TECHNOLOGY!





THERE ARE THREE KINDS
OF SCIENTISTS:

GATHERERS



GATHERERS are occupied
with gathering and
arranging
FACTS
and **DATA**

THINKERS



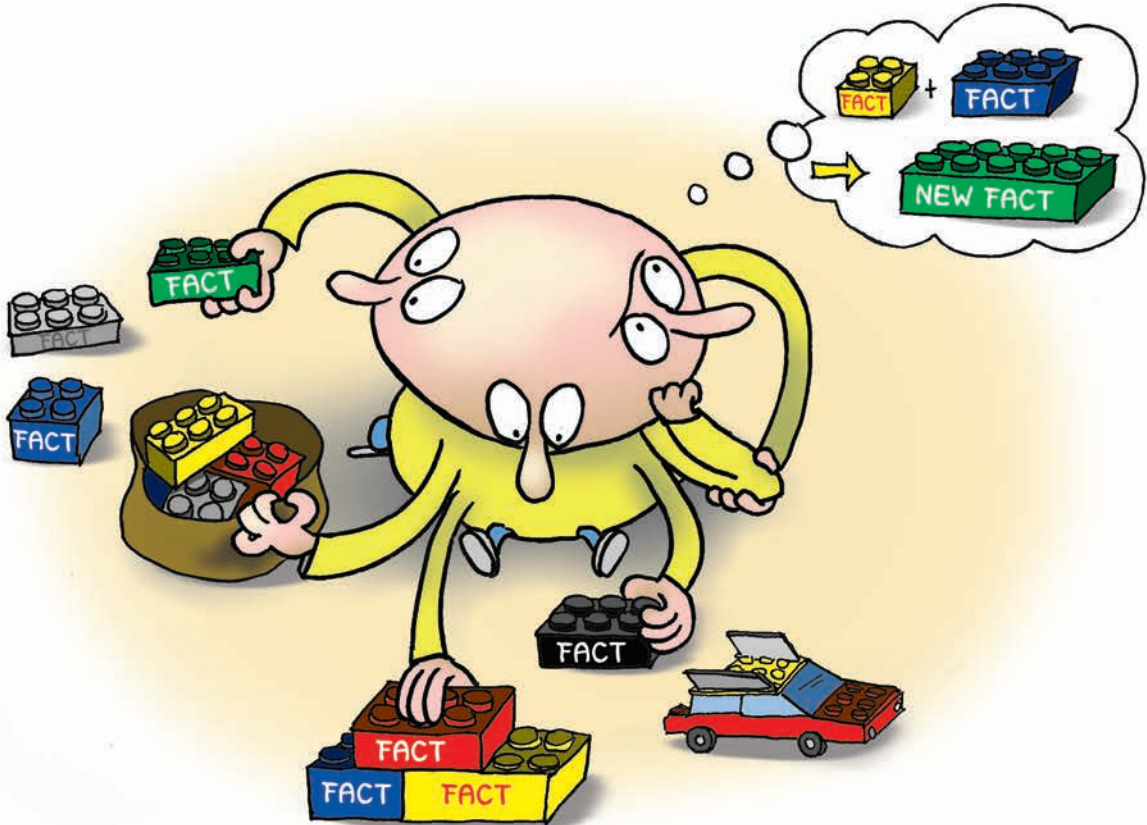
THINKERS are occupied with
logical reasoning, linking
facts; formulating
THEORIES

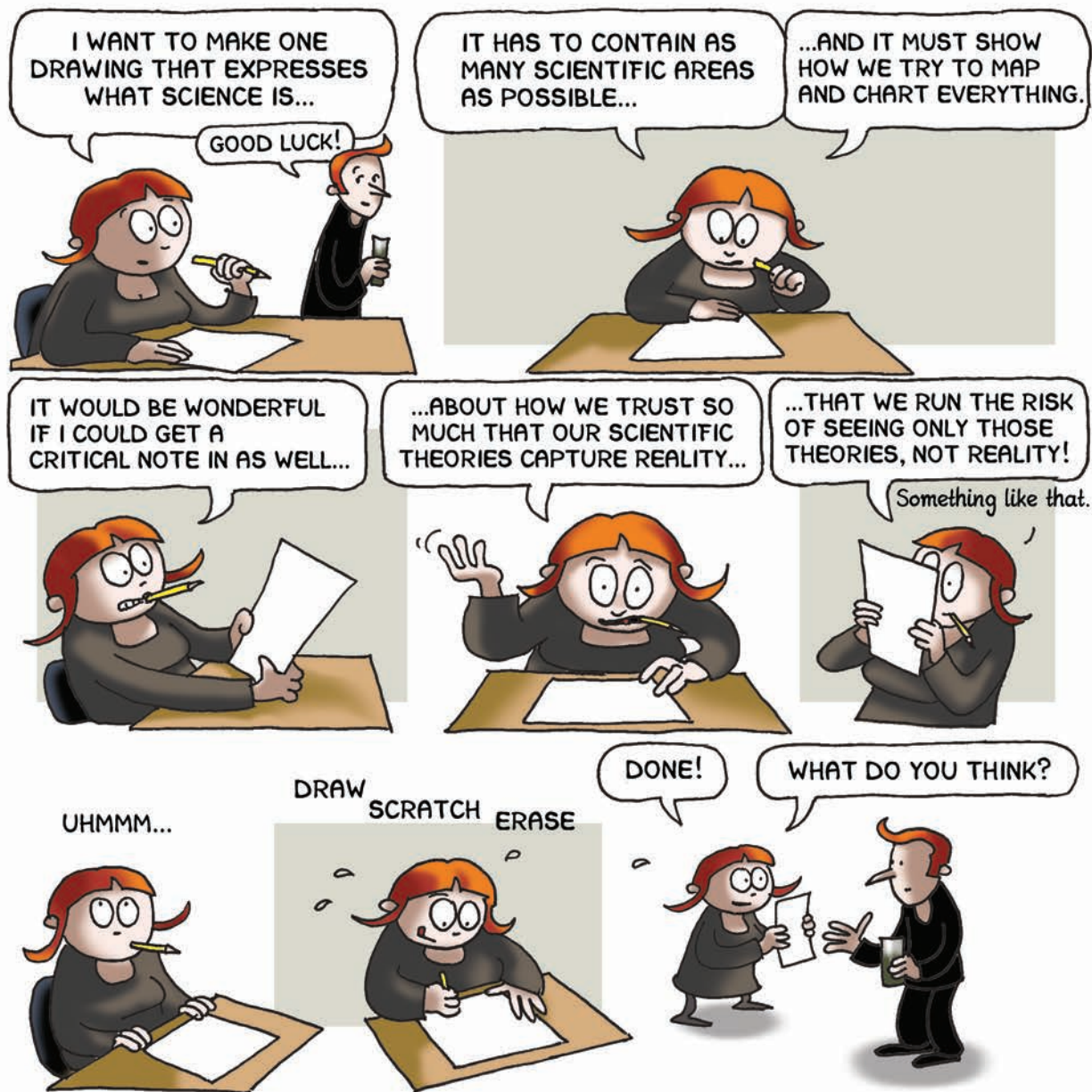
TINKERERS

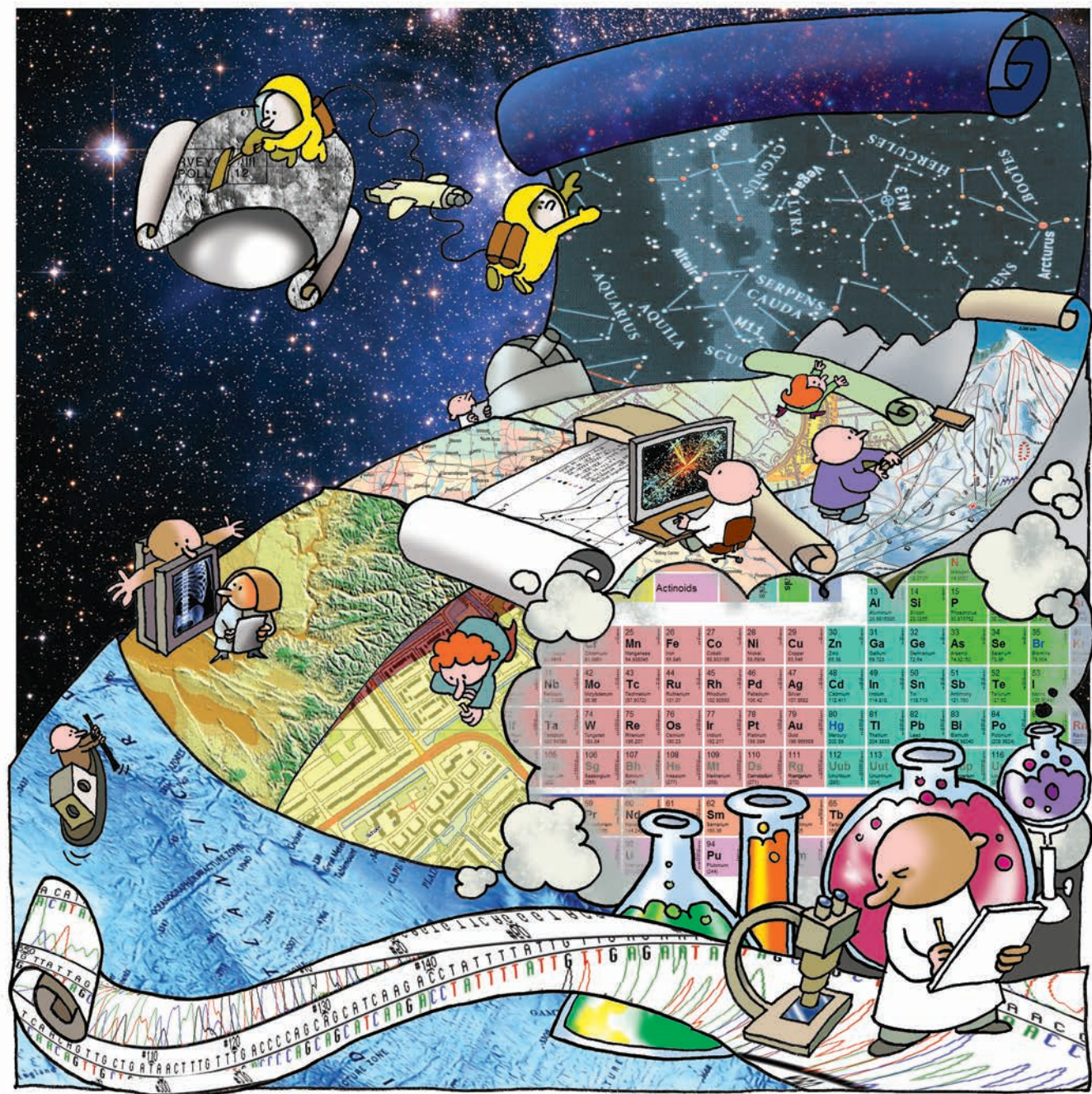


TINKERERS are occupied with
setting up **EXPERIMENTS** to
verify theories;
APPLYING scientific insights
in **TECHNOLOGIES**

A GOOD SCIENTIST IS A BIT OF ALL THREE:
GATHERER, THINKER, AND TINKERER!







HMM. I THINK SCIENCE
IS MORE LIKE
GATHERING PIECES
OF A PUZZLE...

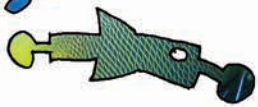
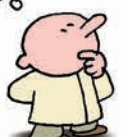


...AND FINDING OUT
HOW THESE PIECES
FIT TOGETHER...



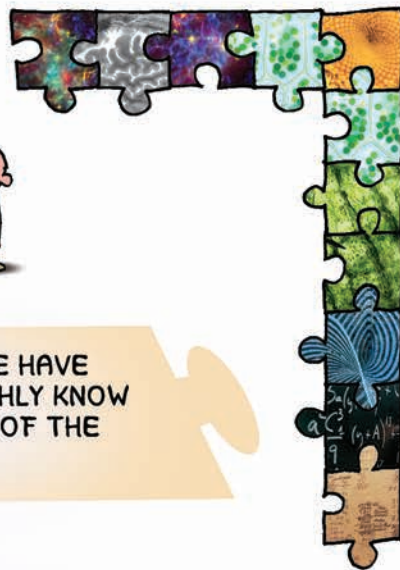
...AND IMAGINING WHAT
THE REST OF THE PUZZLE
MIGHT LOOK LIKE...

...BECAUSE WE'LL NEVER BE ABLE
TO FIND ALL THE PIECES -
SOME OF THEM ARE TOO SMALL,
OTHERS TOO BIG, OR TOO FAR AWAY...



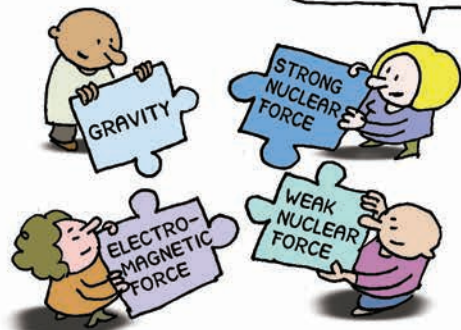


BUT WE CAN **SPECULATE**
ON THE BASIS OF THE
PIECES WE HAVE...



WHEN WE LINK THESE
FOUR PIECES TOGETHER...

...WE ARE DONE!



...SOME THINK THAT WE HAVE
ENOUGH PIECES TO ROUGHLY KNOW
THE DIMENSION OF ALL OF THE
PUZZLE...



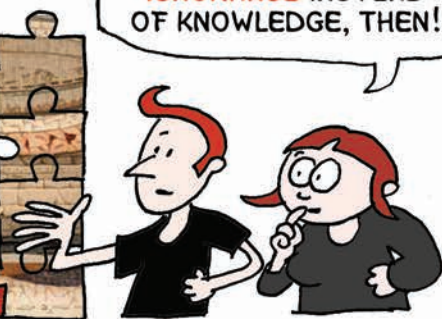
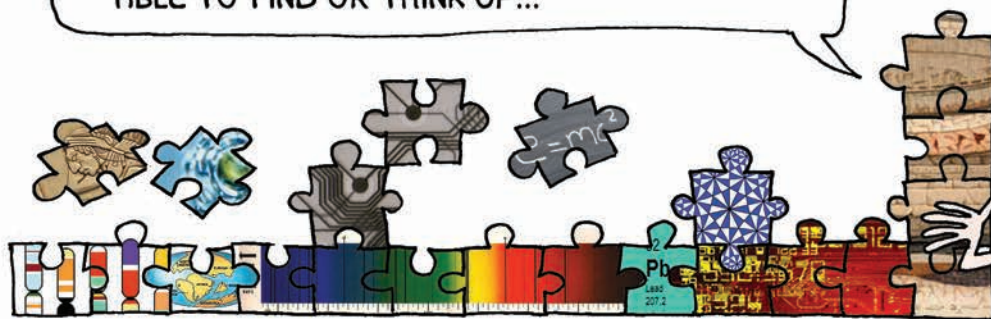
...OTHERS DOUBT IF THE PIECES WE
HAVE ARE EVEN ALL OF THE SAME PUZZLE -
MAYBE THERE EXIST SEVERAL
PUZZLES AT THE SAME TIME!



THAT MANY
CORNERS?

...AND NO ONE KNOWS FOR SURE HOW MANY
PIECES THERE ARE AND HOW MANY WE ARE
ABLE TO FIND OR THINK UP...

MAYBE WE SHOULD
CALL IT GATHERING
IGNORANCE INSTEAD
OF KNOWLEDGE, THEN!



THERE. AND NOW WE PROCEED WITH
THE HISTORY OF SCIENCE...



...STARTING WITH THE ANCIENT GREEKS!



ARE YOU
CRAZY?!

SCIENCE WAS GOING ON LONG BEFORE THE GREEKS!



What about the
BABYLONIANS?
The EGYPTIANS?
The MAYANS?
Not to mention
the CHINESE?!

WHERE DID
SCIENCE START?

THE **MAYANS** IN CENTRAL
AMERICA HAD COMPLEX SYSTEMS
OF ASTRONOMY, COSMOLOGY AND
MATHEMATICS - IN 1000 B.C.!

MESOPOTAMIA IS CALLED THE CRADLE OF WESTERN
CIVILIZATION! THE SUMERIANS AND BABYLONIANS WERE
SKILLED IN IRRIGATION, ASTRONOMY AND MATHEMATICS
AS EARLY AS 4000 B.C.!

THE **CHINESE** WERE HIGHLY ADVANCED
IN MEDICINE, ASTRONOMY, MATH AND
SEISMOLOGY - AROUND 2000 B.C.!



THE **INCAS** IN SOUTH AMERICA
HAD A THRIVING CULTURE
FROM 2000 B.C., WITH EXPERT
KNOWLEDGE OF ENGINEERING,
HYDRAULICS, ASTRONOMY
AND MEDICINE!

AND WHAT ABOUT THE
DISCOVERY OF FIRE?
THAT MUST HAVE TAKEN
PLACE IN **AFRICA**, SOME
800,000 YEARS AGO!

THE **EGYPTIANS** BUILT THEIR
PYRAMIDS AROUND 2500 B.C.,
DISPLAYING GREAT KNOWLEDGE
OF GEOMETRY, ENGINEERING
AND ASTRONOMY!

YOU MIGHT AS WELL SAY
THAT SCIENCE IS AS OLD AS
HUMANITY ITSELF!

OKAY - BUT I STILL WANT TO
START IN ANCIENT GREECE.



WHY?!



BECAUSE THE GREEK MOLDED
THE SYSTEM OF SCIENCE WHICH
WE STILL PRACTISE TODAY...

... A SYSTEM OF **OBJECTIVE INQUIRY**
AND **LOGICAL THINKING!**



Their way of thinking
and research is the
BASIS of our modern
scientific method!



THEN YOU MIGHT JUST AS WELL CALL IT THE BEGINNING OF MODERN SCIENCE...

...FINE...



...modern
WESTERN
science to
be precise...



THE BEGINNING OF
MODERN WESTERN
SCIENCE



ANCIENT GREECE

THIS IS WHAT THE WORLD
LOOKED LIKE IN **500 B.C.!**

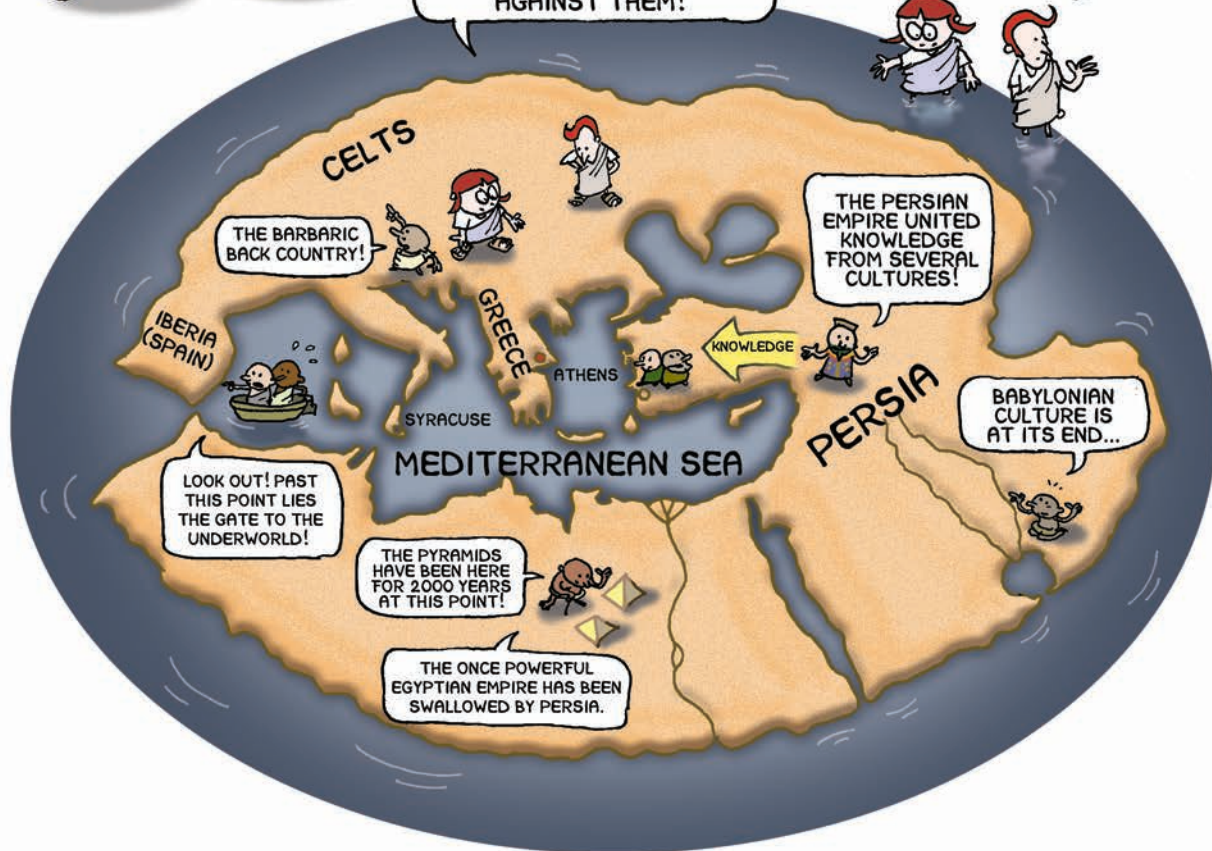
YOU MEAN: THIS IS HOW FAR CIVILIZATIONS
AROUND THE MEDITERRANEAN SEA HAD
MAPPED THE KNOWN WORLD BY THEN.



GREECE WAS MORE OR
LESS A REMOTE PROVINCE
OF THE GREAT PERSIAN
EMPIRE - EXCEPT WHEN
THEY WERE FIGHTING
AGAINST THEM!

THE LAND WAS
SURROUNDED
BY OCEAN...

WHAT LAY BEYOND
WAS UNKNOWN!



THE BARBARIC
BACK COUNTRY!

IBERIA
(SPAIN)

LOOK OUT! PAST
THIS POINT LIES
THE GATE TO THE
UNDERWORLD!

SYRACUSE

MEDITERRANEAN SEA

GREECE

ATHENS

THE PYRAMIDS
HAVE BEEN HERE
FOR 2000 YEARS
AT THIS POINT!

THE ONCE POWERFUL
EGYPTIAN EMPIRE HAS BEEN
SWALLOWED BY PERSIA.

THE PERSIAN
EMPIRE UNITED
KNOWLEDGE
FROM SEVERAL
CULTURES!

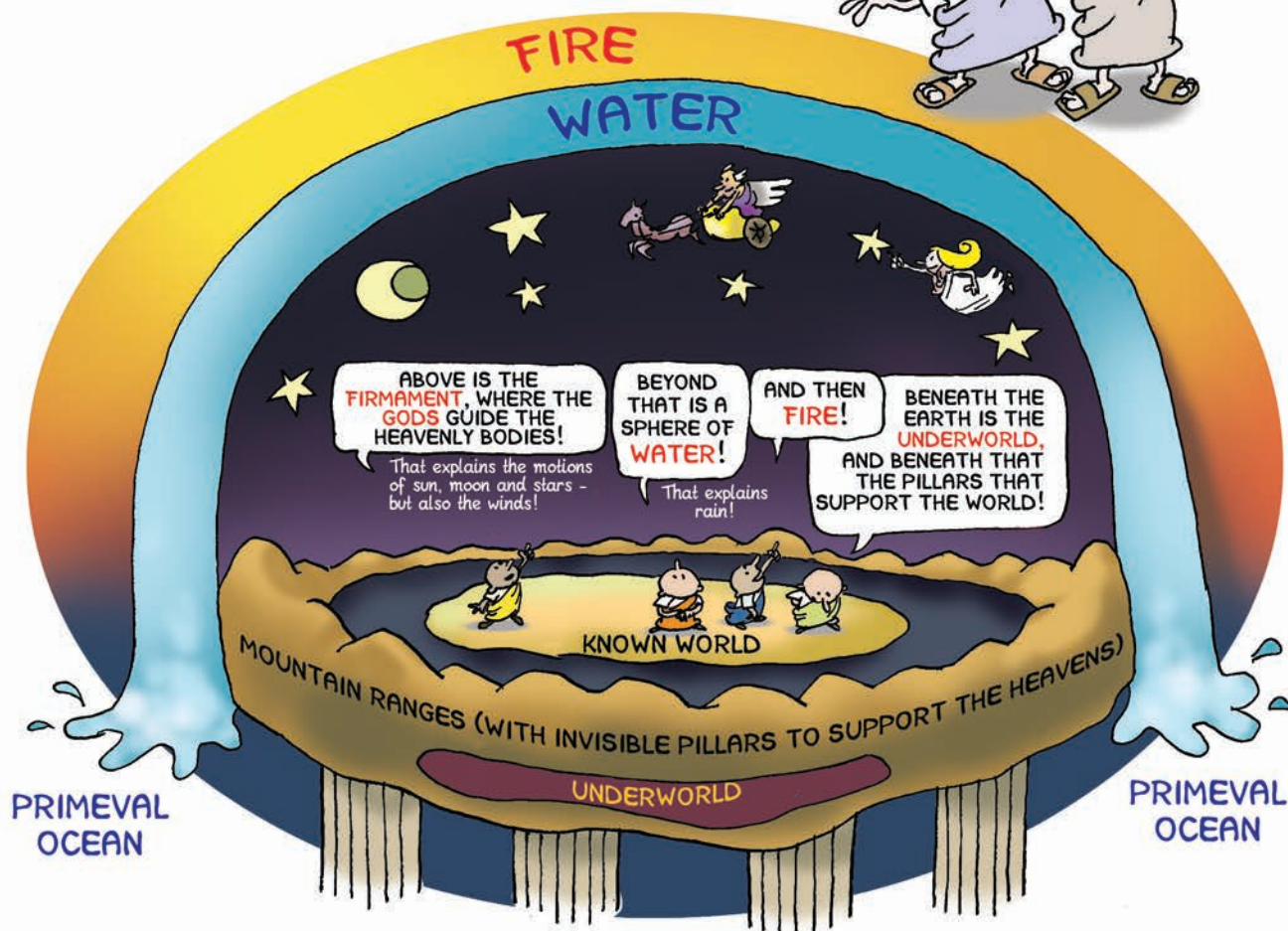
KNOWLEDGE

PERSIA

BABYLONIAN
CULTURE IS
AT ITS END...

AND THIS IS WHAT THE
COSMOS LOOKED LIKE!

YOU MEAN: THIS IS THE **COSMOLOGICAL**
AND MYTHOLOGICAL WORLDVIEW HELD
BY ANCIENT GREEK SOCIETY!



ABOVE IS THE
FIRMAMENT, WHERE THE
GODS GUIDE THE
HEAVENLY BODIES!

That explains the motions
of sun, moon and stars -
but also the winds!

BEYOND
THAT IS A
SPHERE OF
WATER!

That explains
rain!

AND THEN
FIRE!

BENEATH THE
EARTH IS THE
UNDERWORLD,
AND BENEATH THAT
THE PILLARS THAT
SUPPORT THE WORLD!

THALES OF MILETUS

THEY CALL ME THE "FATHER OF SCIENCE" !

I PROPOSE THAT, IN THINKING ABOUT NATURAL PHENOMENA, WE **DISREGARD** THE MYTHICAL WORLD OF THE GODS!

Nothing wrong with gods, but there is no place for them in **NATURAL PHILOSOPHY** !



I'M LOOKING FOR A **NATURAL CAUSE** BEHIND ALL THINGS.

EVERYTHING IS **WATER**

EVERYTHING DERIVES FROM THIS **FIRST PRINCIPLE**:

After rain on a dry plain, plants start growing out of nothing!

WATER comes in many forms: solid, liquid, gas - and if you make it even thinner it becomes **AIR**, I think.

WATER surrounds all of the known earth: land must have come out of water, like sand gathering in a bucket of swirling water.

"EVERYTHING IS WATER"?!

THAT'S WHY THEY
CALL HIM THE
FATHER OF SCIENCE...?!

NOT BECAUSE OF THAT, BUT BECAUSE:

- HE WISHED TO EXPLAIN NATURAL PHENOMENA FROM **ONE BASIC PRINCIPLE**
- HE EXCLUDED THE **GODS** FROM THE PURSUIT OF SCIENTIFIC KNOWLEDGE
- HE BASED HIS CONCLUSIONS ON **FACTS** AND **LOGICAL ARGUMENTS**
- WITH THAT, HE CREATED A METHOD FOR **OTHER** PHILOSOPHERS

SUCH AS:



ANAXIMANDER



I'M ALSO
LOOKING FOR
A **FIRST
PRINCIPLE**.

I DON'T
THINK IT'S
WATER...

...BUT AN **ULTIMATE SUBSTANCE** THAT
CAUSES ALL MATTER, INCLUDING
OPPOSITES LIKE WATER AND FIRE!
SOMETHING **INFINITE, INDIVISIBLE**
AND **INVISIBLE** - I CALL IT
APEIRON.

HEY!

SOUNDS A BIT
LIKE ATOMS!

OR DARK MATTER!

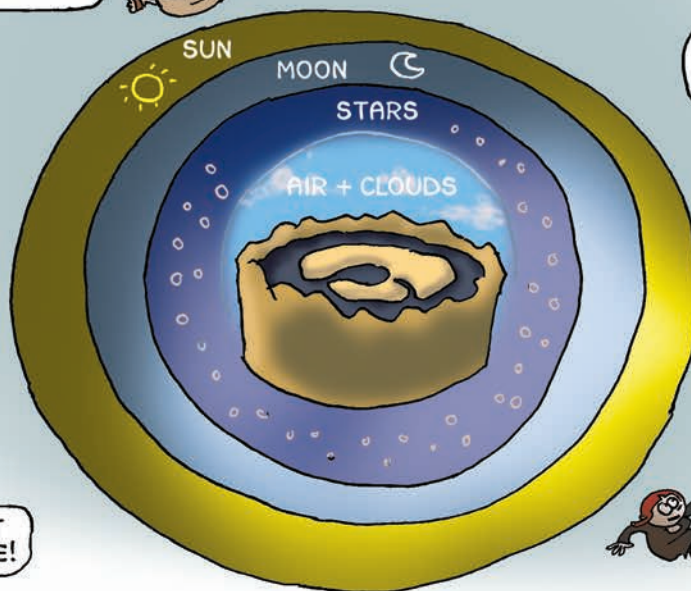
I ALSO HAVE MY OWN
PHILOSOPHY ABOUT
COSMOLOGY!

EARTH IS A **CYLINDER**, FLOATING IN SPACE, WITH
SUN, MOON AND STARS CIRCLING AROUND IT!



EARTH
IS THE
CENTER
OF THE
UNIVERSE!

THAT'S WHY IT
STAYS IN PLACE!



THE EARTH WAS FLUID
IN THE PAST.

FISH CAME OUT
OF WATER
VAPOR!

ALL THE OTHER
ANIMALS,
INCLUDING MAN,
HAVE DEVELOPED
FROM FISH.

Hey! That's a kind of
Theory of Evolution!



WHY DO THESE
OLD GREEKS CALL
THEMSELVES
PHILOSOPHERS...?

WEREN'T THEY
SCIENTISTS?

NATURAL PHILOSOPHERS WAS THE NAME
FOR PEOPLE WHO WERE INVOLVED WITH
THE STUDY OF NATURAL PHENOMENA.

THEY WERE SCHOOLED IN
EVERY DISCIPLINE: PHYSICS,
ASTRONOMY, BIOLOGY,
MATHEMATICS...



PYTHAGORAS



I AM MAINLY KNOWN FOR MY THEOREM: $A^2 + B^2 = C^2$

IN OTHER WORDS:



"IN ANY RIGHT-ANGLED TRIANGLE, THE SQUARE OF THE LENGTH OF SIDE C IS EQUAL TO THE SUM OF THE SQUARES OF SIDE A AND B."

ACTUALLY, THIS THEOREM IS NOT MINE: THE BABYLONIANS KNEW IT ALREADY AROUND 2000 B.C.

BUT I WAS THE FIRST TO MATHEMATICALLY PROVE IT!



WHAT MOST PEOPLE DON'T KNOW ABOUT ME, IS THAT I FOUNDED A **RELIGIOUS CULT** IN CROTONA, IN SOUTH ITALY.

IT WAS BASED ON THE IDEA THAT REALITY IS REALLY MATHEMATICAL:

ALL IS NUMBER!

1 = UNITY
2 = WOMAN
3 = MAN
4 = JUSTICE

5 = 2 + 3 = WOMAN + MAN
= MARRIAGE

6 = 3 + 2 + 1 = CREATION

→ 10 = 4 + 3 + 2 + 1
= UNIVERSE
holy number

He can also play the LYRE beautifully!

Don't tell anyone about our secrets!

WOW!

HE SHOULD HAVE SEEN **THE MATRIX**! IN THAT MOVIE, THE WORLD IS MADE OF ONES AND ZEROS!

π
"MATHEMATIKOI"

A RELIGION
BASED ON
MATHEMATICS?

NOWADAYS,
RELIGION AND SCIENCE ARE
EACH OTHER'S OPPOSITE!

YES, THE RELATIONSHIP
BETWEEN RELIGION AND
SCIENCE HAS CHANGED A
LOT OVER THE CENTURIES.



ARCHIMEDES



ACTUALLY, I WAS A KIND OF AN **ALL-ROUND INVENTOR!**

I MADE
WAR
MACHINES

CRANES

PULLEYS

AND THE FAMOUS
ARCHIMEDES' SCREW, FOR
TRANSPORTING WATER!

LIKE THIS ONE:



"THE CLAW"
FOR
SINKING
ENEMY
SHIPS



EVERYONE KNOWS ME FOR MY
FAMOUS EXCLAMATION:

EUREKA! ("I HAVE FOUND IT!")

BUT WHERE
DOES THAT
REFER TO?

KING HIERON
OF SYRACUSE HAD
ORDERED A GOLDEN
CROWN, TO OFFER TO
THE GODS...

I DON'T TRUST
THAT SMITH.

ARCHIMEDES!

FIND OUT IF THIS
CROWN IS REALLY
PURE GOLD!

BUT WITHOUT
DAMAGING IT!

Ge ? ★

I'LL TAKE A BATH FIRST...



MY BODY
DISPLACES
THE WATER...

EUREKA! EUREKA!

IMMERSE A PIECE OF
GOLD WITH THE **SAME**
WEIGHT IN WATER -
MEASURE HOW MUCH
WATER IS DISPLACED...

...THEN IMMERSE
THE CROWN - IF IT
DISPLACES A **DIFFERENT**
AMOUNT OF WATER,
IT'S NOT PURE GOLD!

-Very clever!
Now please
put on some
pants!

P.S.:

THE
SMITH
HAD
INDEED
CHEATED
AND WAS
PUNISHED.

THEY CALL ARCHIMEDES
THE "FATHER OF
MATHEMATICS"!

AND EUCLID, WHO
LIVED AROUND THE
SAME TIME, IS CALLED
"THE FATHER OF
GEOMETRY"!



EUCLID



MY BOOK **ELEMENTS** IS STILL USED TODAY BY STUDENTS OF MATHEMATICS!

IN HERE I DESCRIBED THE **FIVE BASIC PROPOSITIONS OF GEOMETRY**.

THESE ARE ALSO CALLED **AXIOMS**!
AXIOMS ARE PROPOSITIONS THAT CAN NOT BE PROVEN, BUT ARE ACCEPTED AS SELF-EVIDENTLY TRUE.

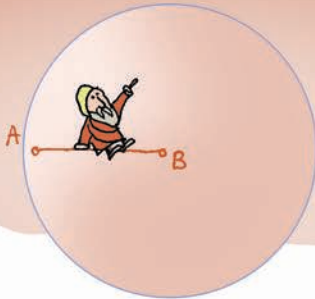
- 1 THE SHORTEST CONNECTION BETWEEN TWO POINTS IS A STRAIGHT LINE.



- 2 A STRAIGHT LINE CAN BE PROLONGED AND IT WILL STAY A STRAIGHT LINE INDEFINITELY.



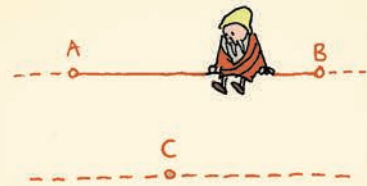
- 3 ANY STRAIGHT LINE CAN BE THE RADIUS OF A CIRCLE.



- 4 ALL RIGHT ANGLES ARE EQUAL.



- 5 ONLY ONE LINE CAN BE DRAWN THROUGH A POINT PARALLEL TO ANOTHER LINE.



WELL DUH! ISN'T THAT LOGICAL?

EUCLID'S FIVE AXIOMS NOT ONLY PROVIDED A BASE FOR GEOMETRY, BUT ALSO FOR LOGIC!



LOGIC =
COMBINING THINGS YOU KNOW
IN SUCH A WAY THAT YOU
FIND OUT THINGS YOU DIDN'T KNOW

LOGIC IS THE FOUNDATION OF MATHEMATICS. AND MATH IS THE FOUNDATION OF SCIENCE.

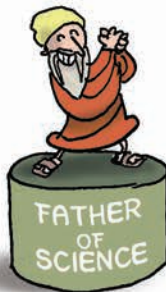
Pretty ironic then
that logic is founded
on propositions
that are
INHERENTLY
UNPROVABLE!



THIS IS WHY EUCLID IS
ALSO CALLED THE
FATHER OF SCIENCE !

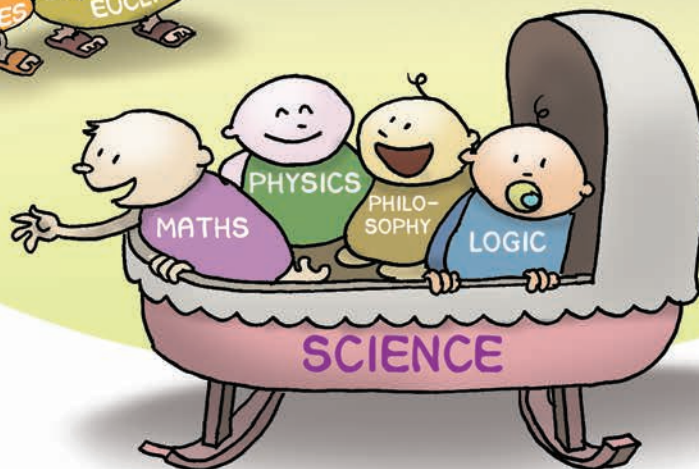
**HIM
TOO
?!**

HOW MANY
FATHERS DOES
SCIENCE HAVE?



WELL, "FATHERS" IS JUST A NAME
WE PINNED ON THE OLD GREEKS
IN HINDSIGHT...

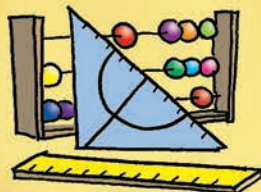
THE MOST IMPORTANT THING IS THAT
THEY LIVED AT THE TIME OF THE
BIRTH OF THE VAST FIELD OF
EXPLORATION WE NOW CALL **SCIENCE**!



MATHEMATICS



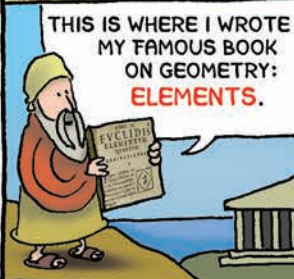
HISTORY OF MATH



THE OLDEST MATHEMATICAL DOCUMENTS DATE BACK TO 3000 B.C. AND WERE FOUND IN **BABYLONIA**.



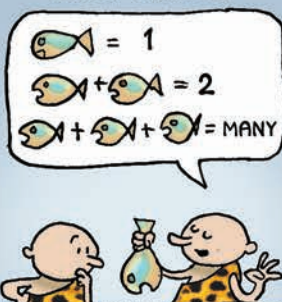
IN THE THIRD CENTURY B.C. THE CENTER OF MATH SHIFTED TO THE **MUSAEUM OF ALEXANDRIA**.



THIS IS WHERE I WROTE MY FAMOUS BOOK ON GEOMETRY: **ELEMENTS**.

WHERE DID MATHEMATICS START?

IN COMMERCE?



BABYLONIAN MATH WAS **SEXAGESIMAL** - BASED ON THE NUMBER 60.

IN OBSERVING THE STARS?



THE ANCIENT GREEKS REFINED MATH WITH **LOGIC**.

IN ARCHITECTURE?



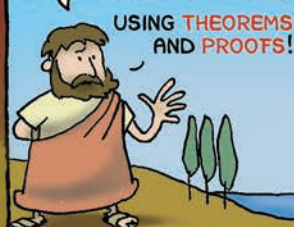
IN THE FOURTH CENTURY B.C. **PLATO'S ACADEMY** IN ATHENS WAS THE CENTER OF THE MATHEMATICAL WORLD.



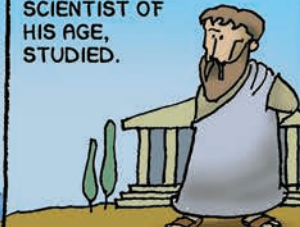
THIS IS STILL REFLECTED IN THE WAY WE MEASURE TIME AND ANGLES.

I INTRODUCED **MATH-EMATICAL REASONING!**

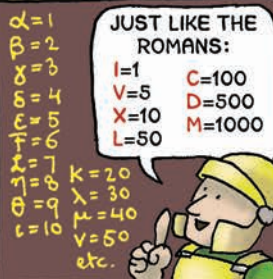
USING **THEOREMS** AND **PROOFS!**



THIS IS WHERE **ARISTOTLE**, THE GREATEST SCIENTIST OF HIS AGE, STUDIED.



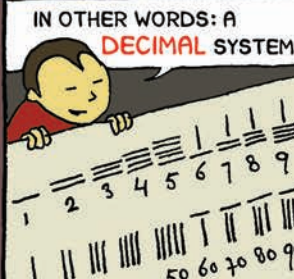
THE GREEK DID NOT USE THE NUMERALS WE KNOW TODAY, BUT **LETTERS** TO DENOTE NUMBERS.



JUST LIKE THE ROMANS:
 $\alpha=1$
 $\beta=2$
 $\gamma=3$
 $\delta=4$
 $\epsilon=5$
 $\zeta=6$
 $\eta=7$
 $\theta=8$
 $\iota=9$
 $\kappa=10$
 $\lambda=20$
 $\mu=30$
 $\nu=40$
 $\xi=50$
 etc.

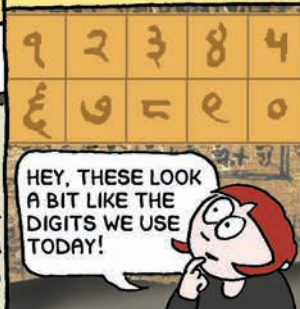
$I=1$
 $V=5$
 $X=10$
 $L=50$
 $C=100$
 $D=500$
 $M=1000$

IN THE MEANTIME THE CHINESE DEVELOPED THEIR OWN SYSTEM, BASED ON THE NUMBER 10.



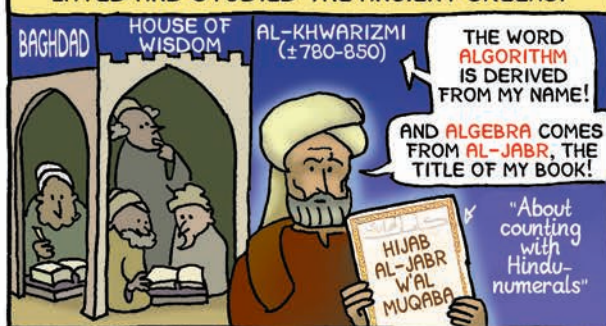
IN OTHER WORDS: A **DECIMAL** SYSTEM.

IN INDIA, DISCRETE SYMBOLS WERE USED FOR THE NUMERALS 0 TO 9.



HEY, THESE LOOK A BIT LIKE THE DIGITS WE USE TODAY!

FROM THE EIGHTH CENTURY A.D., **ISLAMIC CULTURE** BLOOMED - MUSLIM SCHOLARS TRANSLATED AND STUDIED THE ANCIENT GREEKS.



IN THE **CHRISTIAN CULTURE OF WESTERN EUROPE**, THE MOTIVE THAT DROVE SCIENCE WAS STUDYING GOD'S PERFECT DESIGN.



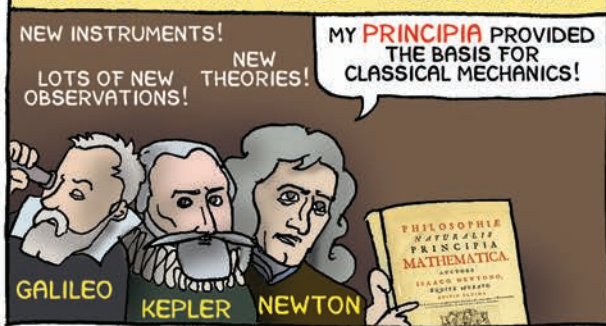
FROM THE 13TH CENTURY, THE 'HINDU ARABIC NUMERALS' **0 TO 9** CAME INTO GENERAL USE IN THE WEST.



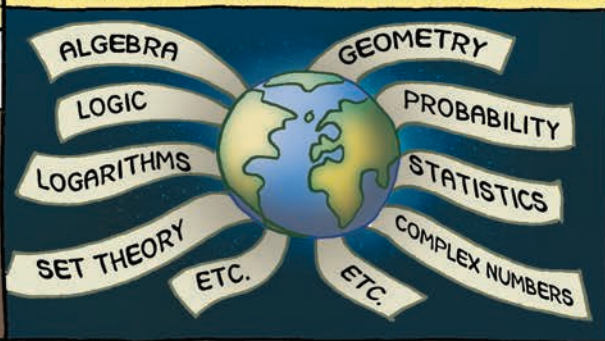
DURING THE **RENAISSANCE**, MATH WAS MAINLY USED IN COMMERCE.



DURING THE **SCIENTIFIC REVOLUTION** IN THE 16TH AND 17TH CENTURY THERE WAS PROGRESS IN MANY FIELDS - INCLUDING MATH.



MATHEMATICS BECAME MORE AND MORE INTERNATIONAL AND DEVELOPED LOTS OF SUBAREAS.

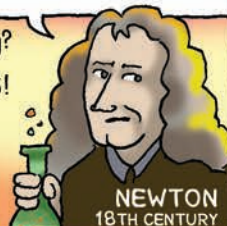


UNTIL THE 19TH CENTURY, THERE WAS NO DISTINCTION BETWEEN **MATH** AND **PHYSICS**.

WE STUDY NATURE, AND "THE BOOK OF NATURE IS WRITTEN IN MATHEMATICAL LANGUAGE."

I MAY BE A PROFESSOR OF MATH, BUT I'M ALSO INVOLVED WITH THERMODYNAMICS, OPTICS, THEOLOGY, ASTROLOGY AND ALCHEMY!

Astrology? Alchemy? But those are PSEUDO-SCIENCES!



OVER THE CENTURIES, MATHEMATICS HAS BECOME MORE ABSTRACT AND ALSO STUDIED IN ITS OWN RIGHT.

EVEN MORE SUBAREAS! ABSTRACT ALGEBRA! FUNCTION ANALYSIS! NUMBER THEORY!

BUT IS THIS KIND OF MATH STILL THE **LANGUAGE OF NATURE**? DOES IT HAVE A CONNECTION WITH REALITY?



THIS ABSTRACTNESS LAUNCHED A HOT DEBATE ABOUT THE **FUNDAMENTS OF MATHEMATICS**.

SCIENCE IS BASED ON MATHEMATICS, AND MATH IS BASED ON LOGIC - BUT **IS LOGIC AS WATERTIGHT AS IT SEEMS?**

RUSSELL'S PARADOX: A BARBER SHAVES ONLY THOSE MEN WHO DON'T SHAVE THEMSELVES - BUT DOES THAT MEAN HE SHAVES HIMSELF, OR NOT?

IF I SHAVE MYSELF, I'M NOT SHAVED BY THE BARBER!

BUT I AM THE BARBER! ARGH! I'M GOING CRAZY!



HOWEVER, THERE'S NO DEBATING THE PLENTIFUL **MATHEMATICAL PATTERNS** FOUND IN NATURE!



MATH CAN EVOKE A RANGE OF FIERCE EMOTIONS - FROM **PURE AESTHETIC ECSTASY**...

MATH IS **ART**!

SEE HOW BEAUTIFUL?

$$e^{i\pi} + 1 = 0$$

GORGEOUS! I CALL IT **OUR JEWEL**!



...TO DEEPLY ROOTED **DISGUST** AND **FRUSTRATION**.

YUCK, MATH!

I NEVER GET IT!

WHY CAN'T THEY SEE HOW GREAT THIS SUBJECT IS?

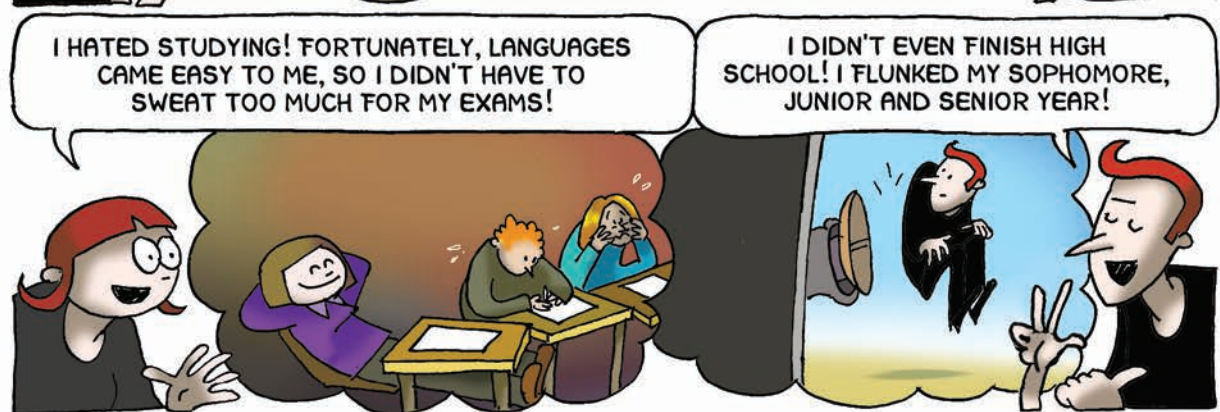
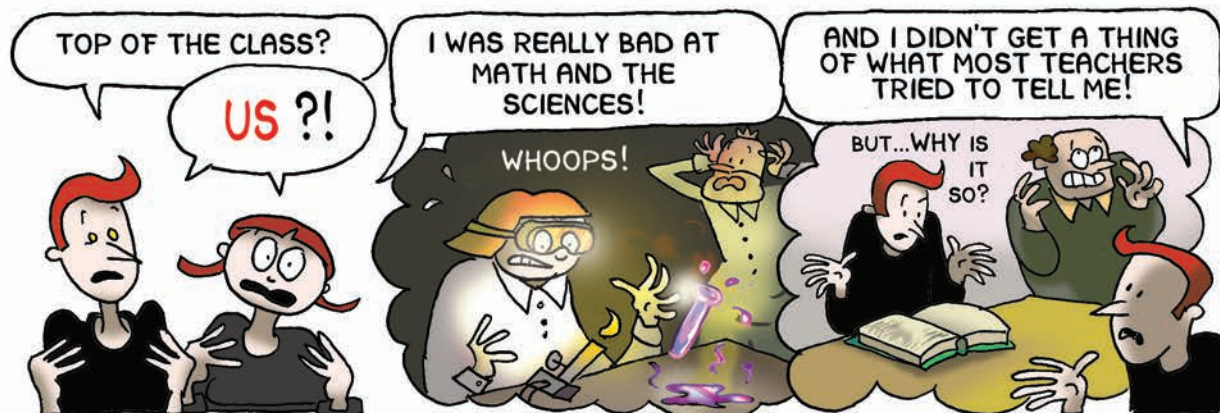




WELL, WELL, THE TWO OF
YOU ARE A REAL PAIR OF
EGGHEADS, AREN'T YOU?

YOU PROBABLY WERE TOP
OF YOUR CLASS AT SCHOOL?





I WAS 22 WHEN I STARTED TO DISCOVER WHAT I LIKED TO STUDY FOR **MYSELF**!

HEY, A BOOK ABOUT
STEPHEN HAWKING!

"...for then we would
know the mind of god..."

A SCIENTIST WHO TALKS
ABOUT RELIGION?
HOW INTRIGUING!

THIS IS GREAT! I'M
LEARNING STUFF WITHOUT
THE PRESSURE OF EXAMS!



AND I STARTED LOOKING UP THINGS IN THE **LIBRARY** THAT I DIDN'T LEARN IN SCHOOL!

BUT **WHY** ARE
THINGS LIKE
THAT...?

WELL, YOU'LL
JUST HAVE TO
ASSUME THEM!

I DON'T LIKE
ASSUMPTIONS!

FRACTALS
AND CHAOS

A BRIEF
HISTORY
OF TIME

GÖDEL, ESCHER, BACH:
AN ANNOTATED EDITION

THE QURAN

SILENCE!



IN MY EXPERIENCE, **LEARNING**
HAS VERY LITTLE TO DO WITH
WHAT GOES ON IN SCHOOLS!

IT'S MUCH MORE IMPORTANT
TO BE **CURIOUS** THAN TO BE
THE BEST IN YOUR CLASS!

TEACHERS SHOULD BE
ABLE TO IMPART
ENTHUSIASM!

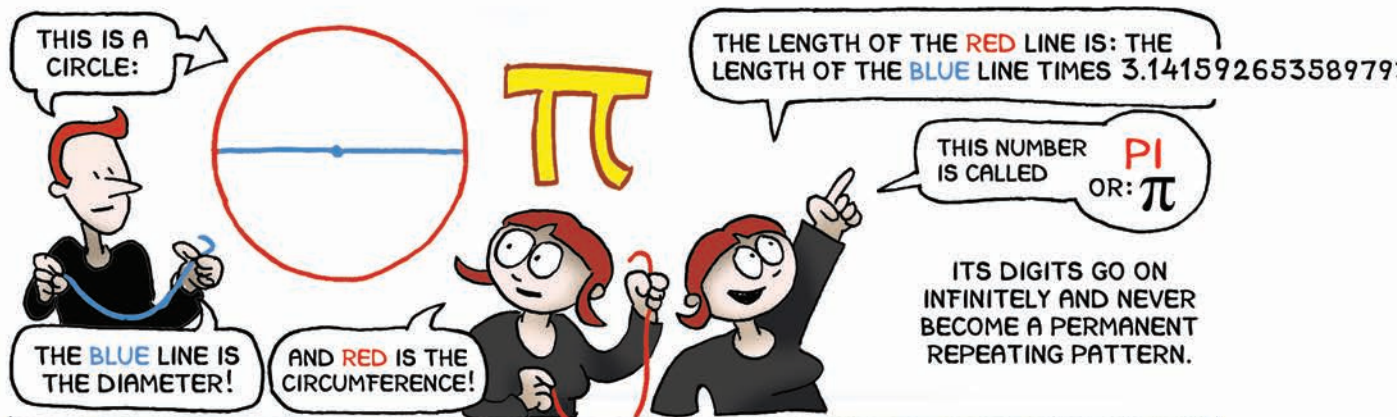
NOT JUST
KNOWLEDGE!





FOUR
FASCINATING
MATHEMATICAL
PHENOMENA





MATHEMATICIANS HAVE BEEN INTRIGUED BY PI FOR CENTURIES - THE SEARCH FOR ADDITIONAL DIGITS WAS AN IMPORTANT INCENTIVE IN THE DEVELOPMENT OF THE COMPUTER.



PI ALSO INSPIRED NUMEROUS ARTISTIC WORKS.

"NOW I WILL A RHYME CONSTRUCT, BY CHOSEN WORDS THE YOUNG INSTRUCT. CUNNINGLY DEvised ENDEAVOUR, CON IT AND REMEMBER EVER. WIDTHS IN CIRCLE HERE YOU SEE, SKETCHED OUT IN STRANGE OBSCURITY."



MNEMONIC TO MEMORIZE THE FIRST 31 DIGITS OF PI.

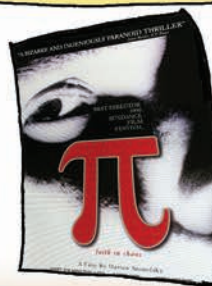
(COUNT THE NUMBER OF LETTERS IN EACH WORD)

Sweet and gentle sensitive man
With an obsessive nature and deep fascination
For numbers
And a complete infatuation with the calculation
Of pi

Oh he love, he love, he love
He does love his numbers
And they run, they run, they run him
In a great big circle
In a circle of infinity

FROM THE ALBUM
AERIAL (2005)

KATE BUSH



AMERICAN SCIENCE-FICTION MOVIE
BY DARREN ARONOFSKY (1998)

INFINITY

INFINITELY FASCINATING!

WHAT IS INFINITY? IS IT A PURELY PHILOSOPHICAL IDEA...?

...OR CAN WE CONSIDER IT AS A **NUMBER** WHICH HAS SOME SPECIAL PROPERTIES?

IT'S WRITTEN AS: ∞

$$\begin{aligned}\infty + 1 &= \infty \\ -\infty < x < \infty\end{aligned}$$

IS SPACE INFINITE?



DOES THAT MEAN THERE IS AN INFINITE NUMBER OF INHABITED PLANETS LIKE OUR EARTH?

COSMOLOGISTS

GEORG CANTOR
(1845-1918)



AUGUST MOEBIUS
(1790-1868)



PHILOSOPHERS

MATHEMATICIANS

IN 1858, I DISCOVERED THIS **MOEBIUS-STRIP!** IT HAS AN INFINITE SURFACE!



MAKE YOUR OWN MOEBIUS STRIP!

TAKE A RECT-ANGULAR PIECE OF PAPER

GLUE A TO A AND B TO B



THE SET CONTAINING ALL WHOLE NUMBERS IS INFINITE...

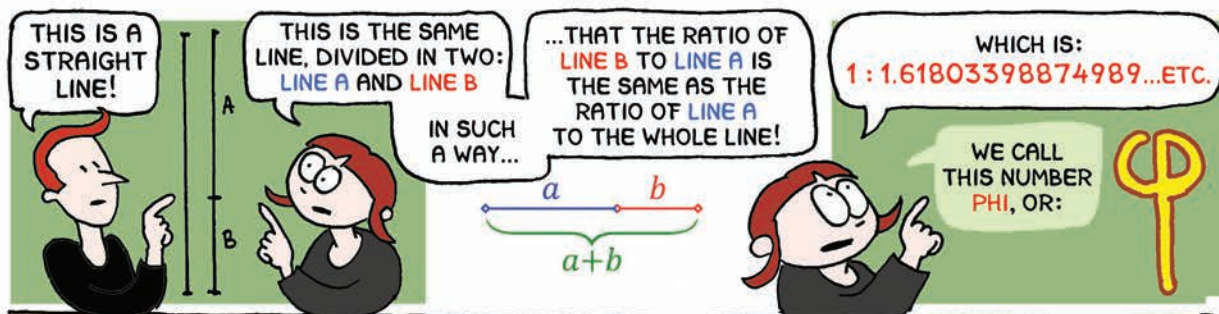
THE SET CONTAINING ALL MULTIPLES OF TEN IS ALSO INFINITE...

YET THERE EXIST MORE WHOLE NUMBERS THAN MULTIPLES OF TEN!

SO: CAN ONE INFINITY BE **SMALLER** THAN ANOTHER?

CANTOR ENDED UP IN A MENTAL HOSPITAL!
COMTEMPLATING INFINITY IS NOT WITHOUT DANGER!



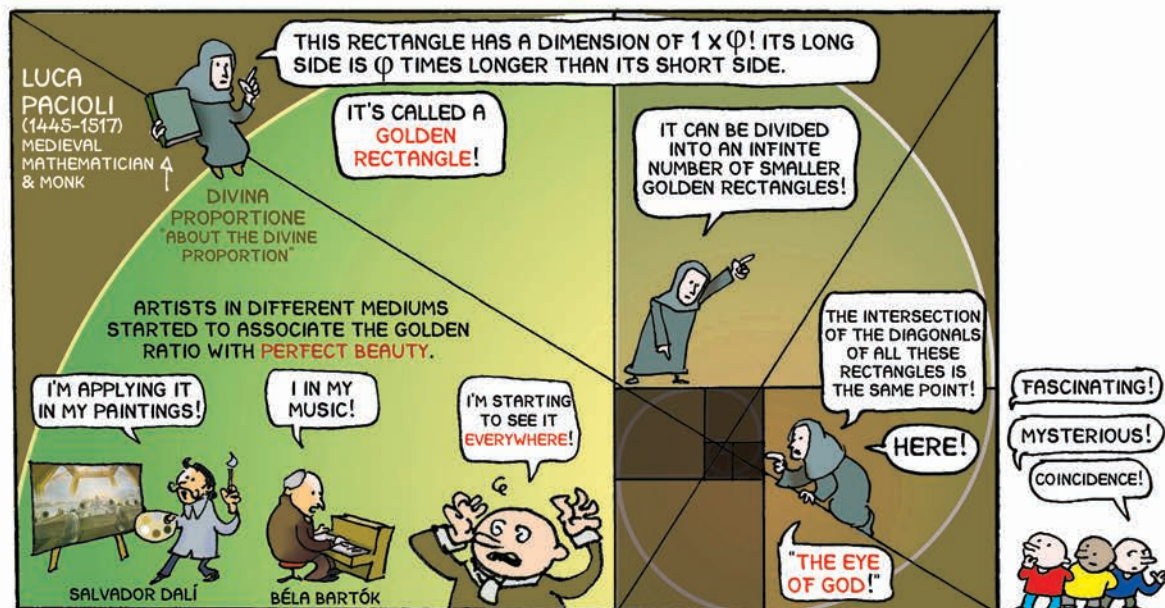


THIS RATIO HAS SOME PARTICULAR PROPERTIES, AND CAN BE FOUND FREQUENTLY IN NATURE:



THE RATIO $1:\Phi$
IS ALSO CALLED

THE GOLDEN RATIO



THE NUMBER **ZERO** IS USED IN TWO WAYS: AS **PART** OF ANOTHER NUMBER - LIKE 2013 OR 1.06...

...OR AS AN **INDEPENDENT** NUMBER.



ZERO

MY BOOK IS THE OLDEST KNOWN TEXT ABOUT ZERO AS AN INDEPENDENT NUMBER. I STATED:

ZERO **PLUS** A **POSITIVE** NUMBER IS **POSITIVE**.
ZERO **PLUS** A **NEGATIVE** NUMBER IS **NEGATIVE**.
ZERO **PLUS** ZERO IS ZERO.

ZERO **MINUS** A **POSITIVE** NUMBER IS **NEGATIVE**.
ZERO **MINUS** A **NEGATIVE** NUMBER IS **POSITIVE**.
ZERO **MINUS** ZERO IS ZERO.

A NUMBER **MULTIPLIED** BY ZERO IS ZERO.
A NUMBER **DIVIDED** BY ZERO IS... ERM...

I THINK THAT WHEN YOU **DIVIDE BY ZERO**, THE OUTCOME IS **INFINITY**.

HM. IT GETS TRICKY WHEN YOU START **DIVIDING BY ZERO**.

$$x/0 = \infty$$

$$0 \times \infty = x$$

NO NO NO !!!
IF THAT WERE TRUE, THEN ZERO **TIMES** INFINITY WOULD BE **ANY NUMBER!** AND THAT MAKES NO SENSE!

THEREFORE:
YOU SIMPLY CAN'T DIVIDE BY ZERO!

WHAT IS IT THAT MAKES ZERO SO SPECIAL?



BRAHMAGUPTA
(INDIA, 7TH CENTURY)



BHASKARA
(INDIA, 12TH CENTURY)



GEORGE BERKELEY
(IRELAND/ENGLAND, 18TH CENTURY)

BUT... HOW ABOUT **ZERO DIVIDED BY ZERO**? A NUMBER DIVIDED BY ITSELF IS ALWAYS 1, ISN'T IT?

$$0/0 = 1 ?$$

Or doesn't that apply to zero?

Is it even a real number then?





THE MOST IMPORTANT
AND MOST VERSATILE
SCIENTIST OF ANCIENT
GREECE WAS

ARISTOTLE

I STUDIED EVERYTHING THAT WAS KNOWN
IN MY TIME - FROM BIOLOGY TO PHILOSOPHY,
FROM MATHEMATICS TO POETRY.

SCIENCE WAS A VERY BROAD
SUBJECT TO ME. I DIVIDED IT
INTO **THREE SUBAREAS**:



PRACTICAL SCIENCE
DEALS WITH HUMAN ACTIONS
SUCH AS ETHICS AND POLITICS

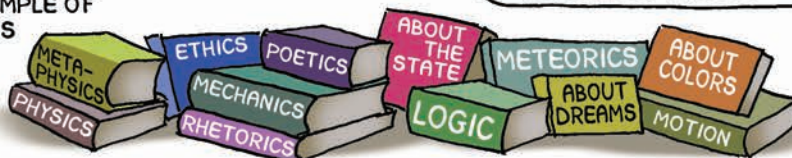


POETIC / PRODUCTIVE SCIENCE
INCLUDES DISCIPLINES OF A CREATIVE
NATURE, SUCH AS POETRY, LITERATURE,
FINE ARTS - BUT ALSO ALCHEMY



THEORETICAL SCIENCE
IS CONCERNED WITH FINDING TRUTH
AND INCLUDES PHYSICS, MATH -
BUT ALSO PHILOSOPHY AND THEOLOGY

A SMALL SAMPLE OF
ARISTOTLE'S
WORKS:



AND THEN THERE IS **LOGIC**,
WHICH IS THE FOUNDATION
FOR ALL OF THESE!





ARISTOTLE IS SAID TO HAVE LAID THE FOUNDATION FOR THE SCIENTIFIC METHOD

BUT WHAT DOES
THAT MEAN?



MY TEACHER PLATO ASSUMED THAT **ULTIMATE REALITY**
WAS TO BE FOUND IN THE **REALM OF IDEAS**.

IT'S NO USE TO LINGER
TOO MUCH ON OUR
PERCEPTION OF THIS
TANGIBLE REALITY.

EVERYTHING WE SEE
AND FEEL IS MERELY
A **SHADOW**...

...OF THE WORLD OF
UNCHANGABLE
IDEAS THAT EXISTS
BEYOND OUR
VISIBLE REALITY!



BODIES DIVERSITY
TRANSCIENCE



SOULS

ULTIMATE
LIGHT OF
REALITY

UNITY

INTRANSCIENCE

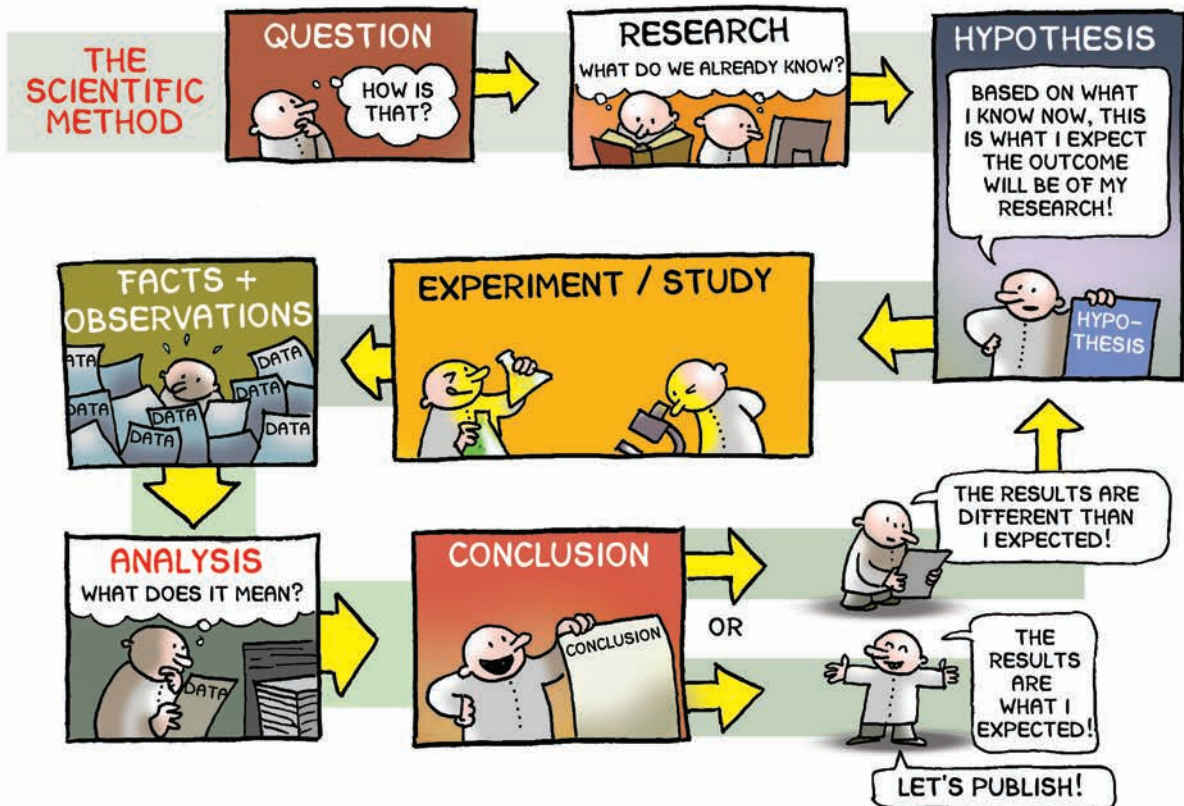
I HAVE A
DIFFERENT
VIEW:

THE WORLD CONSISTS OF THINGS THAT ARE CONSTANTLY **CHANGING**
- IT IS BY STUDYING THOSE CHANGES THAT WE DISCOVER THE
UNDERLYING **CONSTANTS**!

AND IT IS BY STUDYING
ASPECTS OF THINGS THAT
WE GAIN UNDERSTANDING
OF THEIR **ESSENCE**!



ULTIMATE REALITY IS NOT
OUTSIDE OUR WORLD, BUT
INSIDE EVERYTHING!



LOGIC PLAYS AN IMPORTANT ROLE IN THE SCIENTIFIC METHOD!



I DESCRIBED TWO WAYS OF **LOGICAL REASONING**:

DEDUCTION

- ALL HUMANS ARE MORTAL.
- ARISTOTLE IS HUMAN.

SO

ARISTOTLE IS MORTAL.

INDUCTION

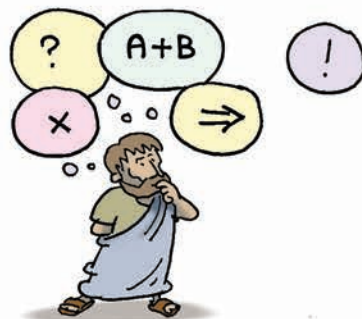
- I SEE A WHITE SWAN.
- I SEE ANOTHER WHITE SWAN.
- I SEE ANOTHER WHITE SWAN.
- I SEE ANOTHER WHITE SWAN.
- ETC.

SO

ALL SWANS ARE WHITE.

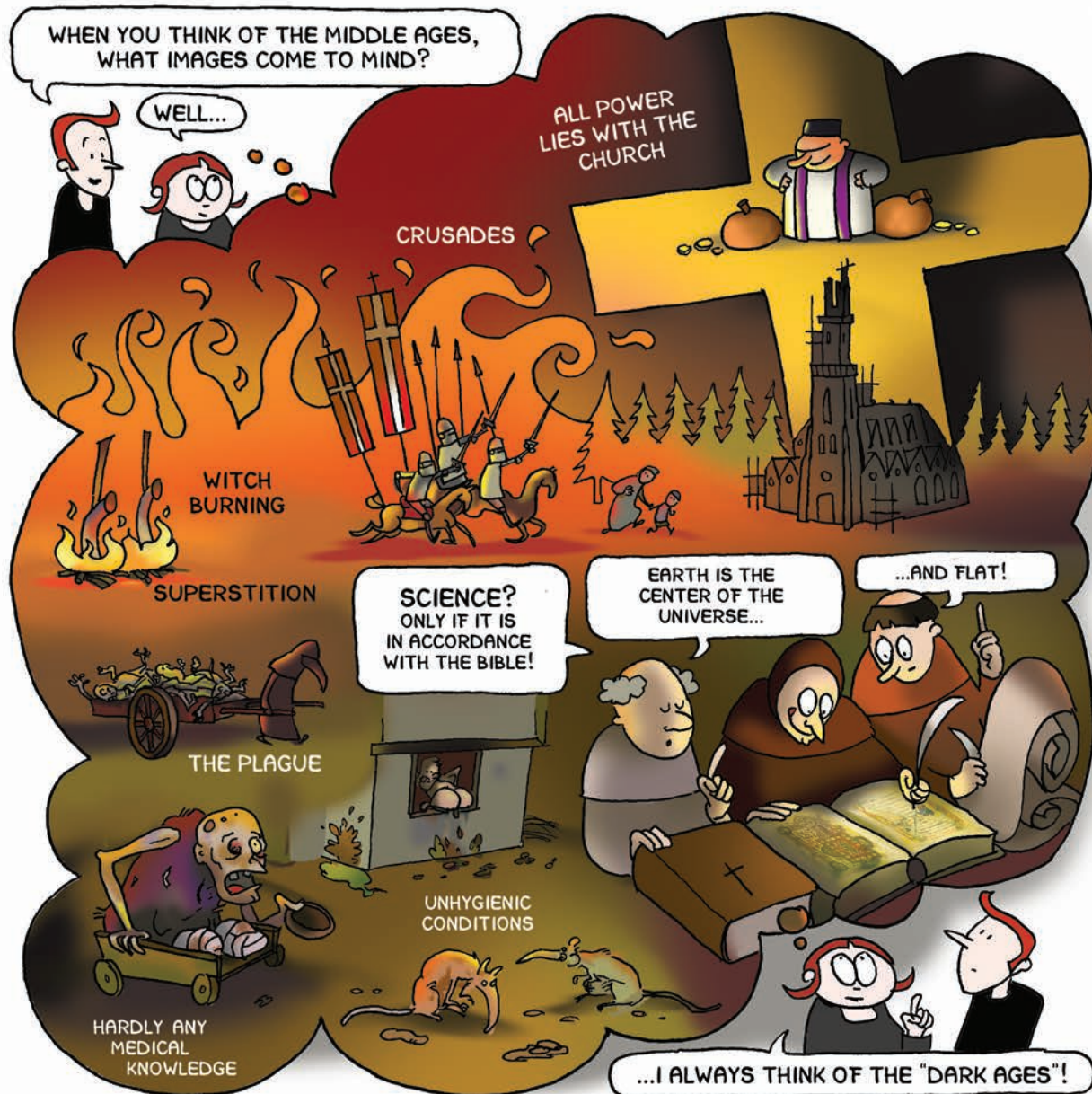
THIS HOLDS UNTIL I SEE A COLORED SWAN!





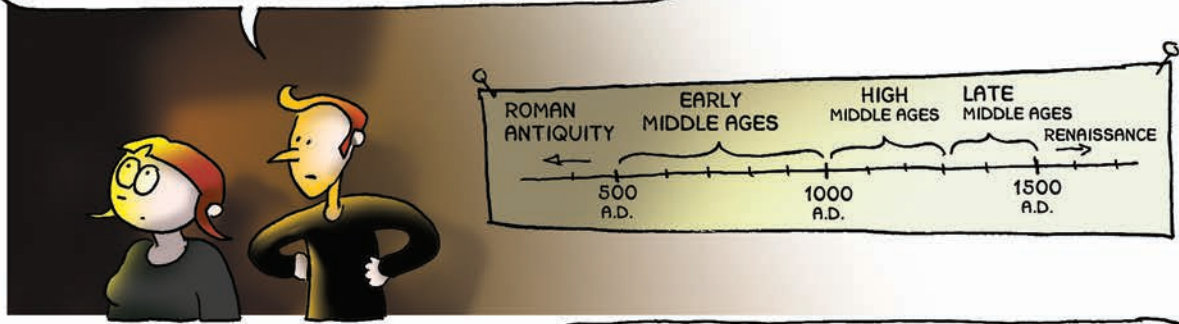
SCIENCE IN THE MIDDLE AGES





THOSE IMAGES ONLY HOLD TRUE FOR
THE **FIRST PART** OF THE MIDDLE AGES!

FROM 500 TO 1000!



AND THEN ONLY FOR THE
WESTERN PART OF EUROPE!

France,
Germany,
England...

THE EAST DEVELOPED DIFFERENTLY!
THERE THE **MUSLIM CULTURE** PROSPERED!

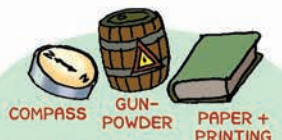


THE MIDDLE AGES WERE SO MUCH MORE
THAN JUST SUPERSTITION AND DISEASE!

THEY WERE TIMES OF DISCOVERIES
AND RE-DISCOVERIES! OF PRACTICAL
INVENTIONS AND BEAUTIFUL RELIGIOUS
ART AND CULTURE!



THE MIDDLE AGES AT A GLANCE



THESE ALREADY EXISTED IN CHINA (BUT HAD NOT REACHED THE WEST YET)

FALL OF THE ROMAN EMPIRE



476

POVERTY AND UNSAFETY IN MANY PARTS OF EUROPE

EDUCATION? WE'RE HAPPY TO FIND SOME FOOD!



500

BEGINNING OF ISLAM IN THE MIDDLE EAST



622

ISLAMIC EXPANSION



SIEGE OF CONSTANTINOPLE

GREEK FIRE



673

STIRRUPS



I WON'T FALL OFF MY HORSE AGAIN!

VIKING INVASIONS 8TH-10TH CENTURY



IRISH MONKS DISCOVER ICELAND AND THE SHETLANDS, AMONG OTHERS

SCIENCE MEANS TO US: FIGURING OUT GOD'S DESIGN OF HIS CREATION, THROUGH LOGIC AND EXPERIMENT!

INTERESTING! LET'S TRANSLATE THESE INTO LATIN!

I TRANSLATED WORKS OF ARISTOTLE AND ANNOTATED THEM!

CROSSBOW



TOO DANGEROUS! I FORBID IT! except against the infidels!

CONQUER JERUSALEM?!

YOU MEAN: RECONQUER!

CRUSADES



UNIVERSITIES IN EUROPE



DOMINICANS

1216

THOMAS AQUINAS

ARISTOTLE AVERROES 1126-1198

POPE INNOCENT II

1139

BOLOGNA

PARIS

OXFORD

WINDMILLS



SPECTACLES



COMPASS



SPINNING WHEEL



TRADE AND DISCOVERY VOYAGES

WE ARE TRADING WITH THE EAST!

ALL THE WAY TO INDIA!

I TRAVELLED THROUGHOUT ALL OF ASIA: FROM BEIJING TO SINGAPORE!

HURRAY!

FINALLY WE SEE SOME...

...PROGRESS!

YOU'RE LATE!

HERBS

SPICES

SILK ROAD

MARCO POLO 1254-1324

CHARLEMAGNE PROMOTED SCIENCE AND EDUCATION

SCHOOLS WERE FOUNDED IN MONASTERIES



EDUCATION FOR ALL! FREE!

even for a few women!

GRAMMAR
LOGIC
RHETORIC
(TRIVIUM)

AND BIBLE LESSONS OF COURSE!

GEOMETRY
ARITHMETIC
ASTRONOMY
MUSIC
(QUADRIVIVUM)

MEANWHILE, IN MUSLIM AREAS...

WE'RE WAY AHEAD OF YOU!

WE HAVE PAPER!

WE HAVE UNIVERSITIES!

WE ARE STUDYING THE GREEKS!

WE CONDUCT SCIENCE BASED ON LOGIC AND EXPERIMENT!

800

CRUSADES

THE CHRISTIANS ARE ATTACKING!

THEY ARE TRYING TO CONQUER JERUSALEM!

I WAS THE FOUNDER OF OPTOMETRY!

What's that I see?

I DISCOVERED THE DIFFERENCE BETWEEN SMALLPOX AND THE MEASLES! & KEROSENE!

I ARRANGED CHEMICAL ELEMENTS!

I POPULARIZED THE USE OF INDIAN NUMERALS!

AL-HAYTHAM (ALHAZEN) 965-1040

AL-QANUN FI AL-TIBB

IBN-SINA (AVICENNA) 980-1037

AL-RAZI 865-952

AL-KHWARIZMI

JABIR IBN HAYYAN ±721-815

1096

THE BLACK DEATH

WHAT IS THIS?!

A SOUVENIR FROM CHINA...

I DON'T FEEL SO GOOD...

WHY DOESN'T GOD SAVE US?

ER...

OOOPS!

THIS ILLNESS UNDERMINES THE POWER OF THE CHURCH!

PRINTING PRESS



1492: COLUMBUS DISCOVERS AMERICA

NOW WE CAN PASS ON KNOWLEDGE SO MUCH EASIER!

LEONARDO DA VINCI

WITH ME, A NEW ERA BEGAN: THE RE-BIRTH OF THE CLASSICAL ARTS!

THE RENAISSANCE

THE PLAGUE KILLED A THIRD OF THE POPULATION

1350

1436

1500

THE MEDIEVAL WORLDVIEW

PEOPLE THOUGHT THE
UNIVERSE LOOKED LIKE THIS:



PTOLEMY
GREEK ASTRONOMER
87-150 A.D.



THIS VIEW IS A SYNTHESIS OF THE
MODEL I DEvised IN THE SECOND
CENTURY...

...AND
CHRISTIAN
DOCTRINE!



MEDIEVAL MONK →

ALL STARS
AND PLANETS
ROTATE IN
THEIR
APPOINTED
SPHERES!

BUT WHO OR WHAT
STARTED THEIR
MOVEMENT?

THAT WOULD BE
ME, OF COURSE! IN
CHRISTIANITY,
AT LEAST.

WE DON'T
KNOW EXACTLY,
BUT WE CALL
IT THE

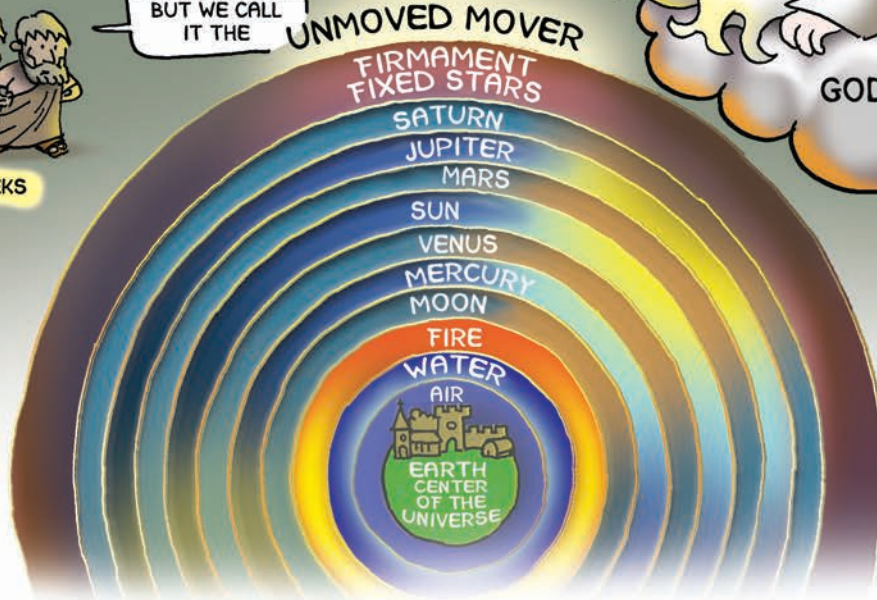
UNMOVED MOVER



ANCIENT GREEKS



GOD



IN THE MIDDLE AGES IT WAS THOUGHT THAT THE UNIVERSE WAS MADE OUT OF FIVE BASIC ELEMENTS: **EARTH, WATER, AIR, FIRE...**

ALL THINGS ARE MADE OUT OF A COMBINATION OF FOUR ELEMENTS!

TAKE THIS STICK FOR EXAMPLE...

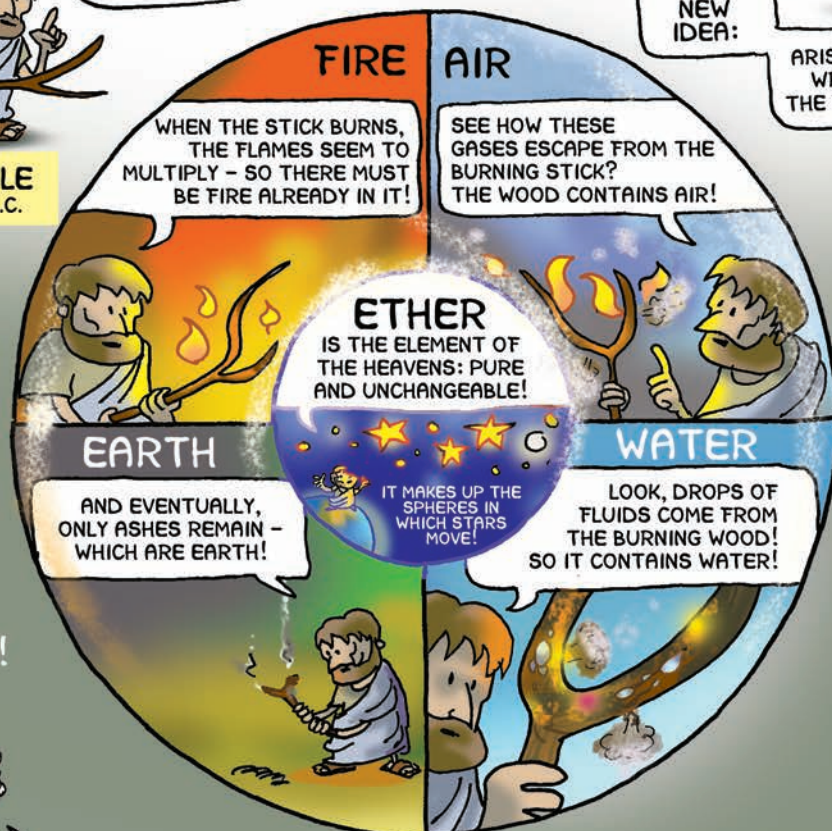


ARISTOTLE
384-322 B.C.

...AND **ETHER**.

THIS WAS NOT A NEW IDEA:

ARISTOTLE HAD ALREADY WRITTEN ABOUT IT IN THE FOURTH CENTURY B.C.



NOTE!



'ETHER' HAS MORE MEANINGS! IT IS ALSO A KIND OF ANESTHETIC GAS AND AN OUTDATED CONCEPT IN THEORIES OF ELECTROMAGNETIC WAVES. BUT ON THIS PAGE, ETHER IS DESCRIBED IN ITS DEFINITION AS ONE OF THE **CLASSICAL ELEMENTS**.

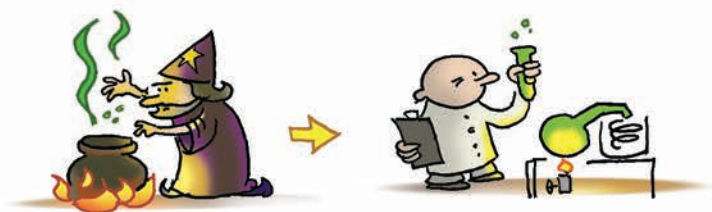
THE FIVE ELEMENTS MAKE A NICE NATURAL
LEAD-IN TO A CHAPTER ABOUT **CHEMISTRY**!

GREAT!

BUT IN THE MIDDLE AGES IT
WASN'T CALLED CHEMISTRY YET!
IT WAS **ALCHEMY** THEN!



CHEMISTRY



CHEMISTRY IS...

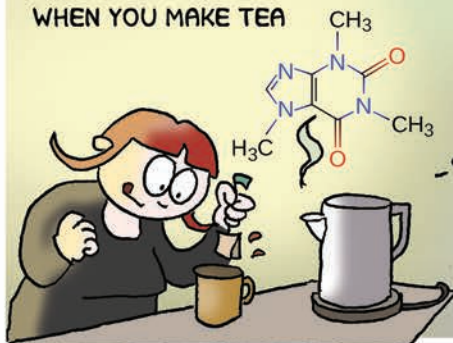


"A SCIENCE THAT DEALS WITH THE COMPOSITION, STRUCTURE AND PROPERTIES OF SUBSTANCES AND WITH THE TRANSFORMATIONS THAT THEY UNDERGO."

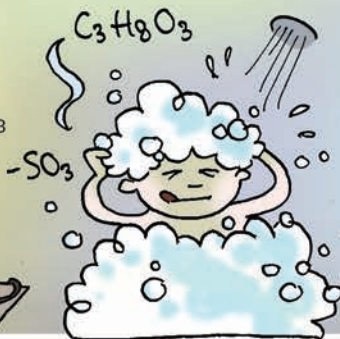
SO CHEMISTRY IS TRULY **ALL AROUND US!**



WHEN YOU MAKE TEA



WHEN YOU WASH YOUR HAIR

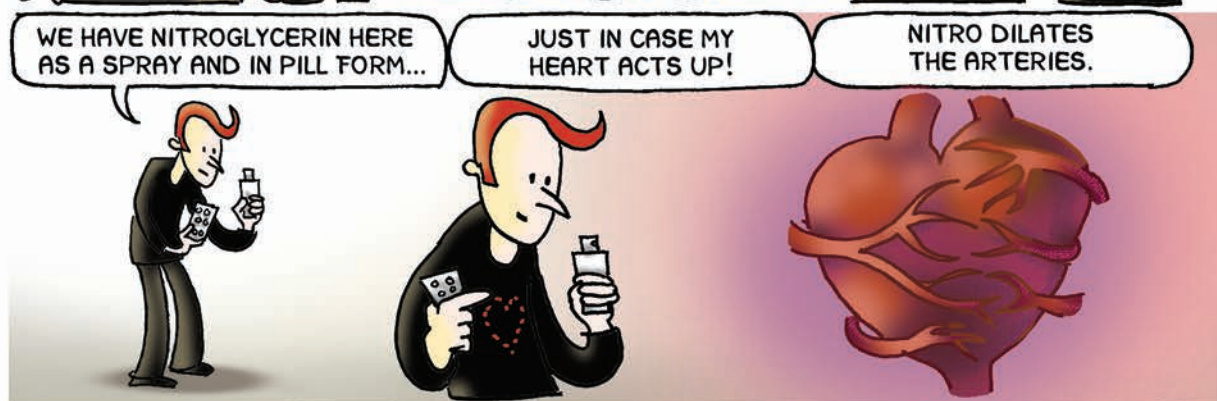
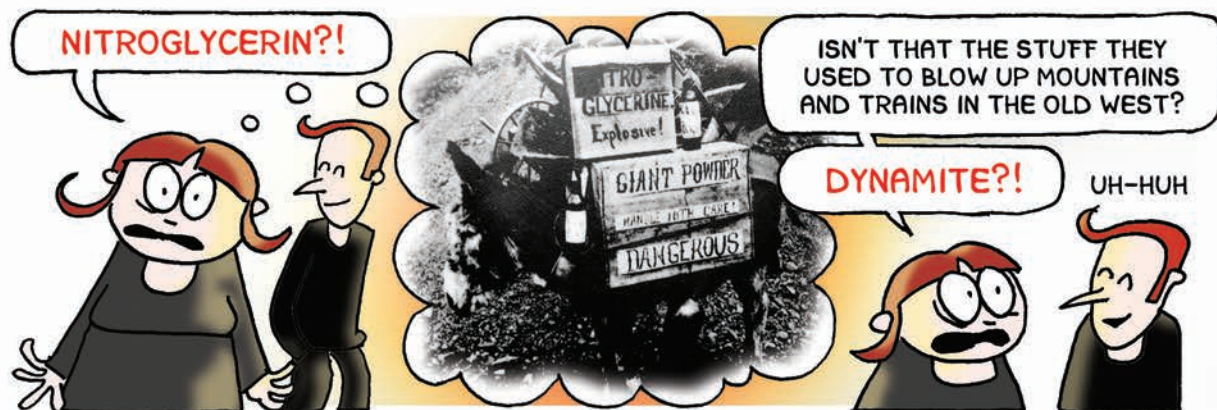


WHEN YOU BREATHE



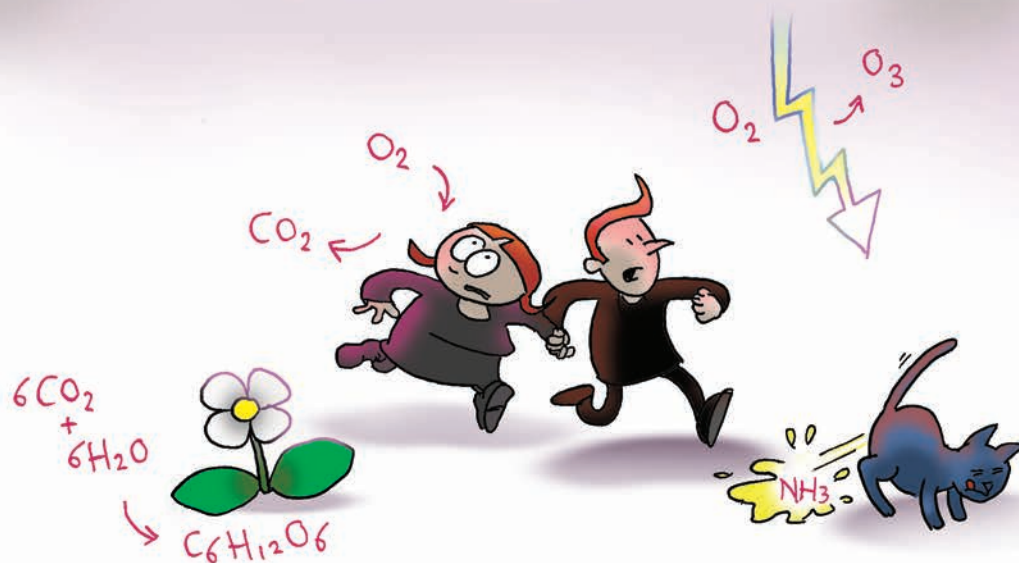
OUR HOME IS FULL OF ALL KINDS OF DANGEROUS CHEMICAL SUBSTANCES!







CHEMISTRY
IS
ALL AROUND
US



HISTORY OF CHEMISTRY



WHEN DID CHEMISTRY START?

WITH THE
DISCOVERY OF FIRE?

DYEING
CLOTHES?

SMELTING
METAL?

WITH
COOKING?

COPPER + TIN
= BRONZE

TIME FOR THE
BRONZE AGE!



EARLY IN HUMAN HISTORY PEOPLE STARTED TO STUDY SUBSTANCES AND THEIR PROPERTIES.

THEY DISTINGUISHED BASIC ELEMENTS AND BASIC PROPERTIES.

WATER EVAPORATES INTO STEAM, FREEZES INTO ICE - YET IT IS STILL THE SAME SUBSTANCE!

IN ESSENCE, IT IS MADE OUT OF UNCHANGEABLE PARTICLES!

I CALL THEM
ATOMS!

α -τομος =
NON-CUTTABLE



EVERYTHING EXISTS OUT OF ONE OR MORE OF THESE FOUR ELEMENTS!

AND THEN THERE'S THE FIFTH ELEMENT: ETHER, WHICH HAS NO PROPERTIES.

AND EVERYTHING POSSESSES AT LEAST ONE OF THESE PROPERTIES!



PRECIOUS METALS WERE DISCOVERED, SUCH AS GOLD.

THE SEARCH FOR THE RECIPE OF GOLD LED TO ALCHEMY, THE PRECURSOR TO CHEMISTRY.

LIKE!!!
WANT!!!

MAYBE WE CAN MAKE GOLD OURSELVES, FROM OTHER, CHEAPER METALS!

LET'S TRY!



MAYBE WE CAN "CURE" BASE METALS, SUCH AS LEAD, SO THEY BECOME PRECIOUS, LIKE GOLD!

ALCHEMY IS NOT SCIENCE!

IT'S MYST-
ICISM!

WE ARE SEARCHING FOR THE **PHILOSOPHER'S STONE**, WHICH WILL ENABLE US NOT ONLY TO MAKE GOLD, BUT ALSO THE **ELIXIR OF LIFE!**



MUSLIM SCHOLARS WERE THE FIRST TO PRACTICE ALCHEMY IN A RATIONAL MANNER.

WORK IN A **LABORATORY!**
WRITE EVERYTHING DOWN!



JABIR IBN HAYYAN
A.K.A. GEBER
IRAQ, 721-815

ARE YOU MAD?!

YOU SHOULD BE MYSTERIOUS ABOUT IT! OR ELSE EVERYONE WILL START DOING IT!



EUROPEAN ALCHEMISTS
12TH-15TH CENTURY

IN THE **RENAISSANCE** PERIOD AFTER THE MIDDLE AGES, ALCHEMY MADE PROGRESS.

I PRACTICED ALCHEMY TO FIND **MEDICINE!**



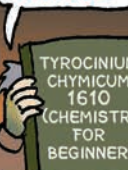
PARACELSUS
1493-1541
SWITZERLAND

I APPLIED MYSELF TO **MINERALOGY!**



GEORG AGRICOLA
1494-1555
GERMANY

I WROTE THE FIRST **CHEMISTRY MANUAL!**



JEAN BEGUIN
1550-1620
FRANCE

I STRESSED THE IMPORTANCE OF **EXPERIMENTS!**



ROBERT BOYLE
1627-1691
IRELAND/ENGLAND

CHEMISTRY IN THE MODERN SENSE STARTED IN THE EIGHTEENTH CENTURY.

THANKS TO THIS MAN: **ANTOINE LAVOISIER!**



WHAT A CURIOUS PAINTING!

ALWAYS MAKE CAREFUL **MEASUREMENTS!**

THAT'S HOW I FOUND MY FAMOUS LAW:

IN A **CHEMICAL REACTION**, MATTER IS NEITHER CREATED NOR DESTROYED.

ANTOINE LAVOISIER
1743-1794
FRANCE

I ALSO DISCOVERED THAT **WATER** AND **AIR** ARE NOT ELEMENTS!

WATER = HYDROGEN + OXYGEN

AIR = OXYGEN + NITROGEN



AND I DISPROVED **PHLOGISTON!**

ELEMENT THAT WAS SAID TO EXPLAIN EXPLOSIONS

HOT ISSUES IN THAT TIME WERE THE DEBATES ABOUT **VITALISM** AND **ATOMISM**.

ORGANIC MATTER CAN NOT COME FROM INORGANIC MATTER!

YES IT CAN!

ALL MATTER CONSISTS OF **ATOMS!**

EVERY ELEMENT HAS ITS OWN ATOM WITH UNIQUE PROPERTIES!

Only **LIFE** can bring forth **LIFE MATTER!**

I JUST MADE **UREA** IN MY LABORATORY!



BERZELIUS
1779-1848
SWEDEN



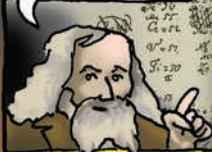
FRIEDRICH WÖHLER
1800-1882
GERMANY



JOHN DALTON
1760-1844
ENGLAND

AND ALSO THE MATTER OF **HOW MANY ELEMENTS** THERE ARE AND HOW TO ARRANGE THEM.

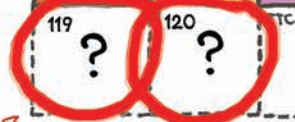
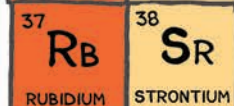
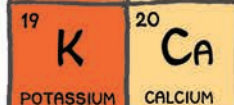
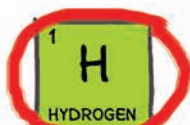
IN 1869, 63 ELEMENTS WERE KNOWN, AND I ARRANGED THEM IN A TABLE BASED ON THEIR ATOMIC WEIGHT: THE **PERIODIC TABLE!**



DIMITRI MENDELEEV
1834-1907
RUSSIA

	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII	Group IX
1	H								
2	Li	Be							
3	Na	Mg	Al	Si	P	S	Cl	Ar	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Cobalt, Nickel, Copper, Zinc, Gallium, Germanium, Arsenic, Selenium, Bromine, Krypton
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rhodium, Palladium, Silver, Cadmium, Indium, Tin, Antimony, Tellurium, Iodine, Xenon
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Platinum, Gold, Mercury, Thallium, Lead, Bismuth, Polonium, Astatine, Radon
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hf	
8									
9									
10									
11									
12									

THE PERIODIC TABLE



THESE ELEMENTS HAVE NOT BEEN MADE YET!

BUT THEY'LL PROBABLY EXIST BY THE TIME YOU READ THIS!

I DISCOVERED THAT, WHEN YOU ARRANGE ELEMENTS ACCORDING TO THEIR ATOMIC WEIGHT...



DIMITRI MENDELEEV
1834-1907
RUSSIA

...CERTAIN PROPERTIES REPEAT THEMSELVES!

RECURRING IN SO-CALLED **PERIODS**!

DID YOU KNOW THAT THE EARTH IS ONE-THIRD IRON?



THIS WAS ONE OF THE ELEMENTS THAT WAS NOT YET DISCOVERED IN MY TIME - MY TABLE PREDICTED IT!



21 Sc SCANDIUM	22 Ti TITANIUM	23 V VANADIUM	24 Cr CHROMIUM	25 Mn MANGANESE	26 Fe IRON	27 Co COBALT
39 Y YTTRIUM	40 Zr ZIRCONIUM	41 Nb NIOBIUM	42 Mo MOLYBDENUM	43 Tc TECHNETIUM	44 Ru RUTHENIUM	45 Rh RHODIUM
57-70	71 Lu LUTETIUM	72 Hf HAFNIUM	73 Ta TANTALUM	74 W TUNGSTEN	75 Re RHENIUM	76 Os OSMIUM
77 Ir IRIDIUM	78 Pt PLATINUM	79 Au GOLD	80 Hg MERCURY	81 Tl THALLIUM	82 Pb LEAD	83 Bi BISMUTH
89-102	103 Lr LAWRENCIUM	104 Rf RUTHERFORDIUM	105 Db DUBNIUM	106 Sg SEABORGIUM	107 Bh BOHRNIUM	108 Hs HASSIUM
109 Mt MEITNERIUM	110 Ds DARMSTADTIUM	111 Rg ROSGONIUM	112 Cn CAROLINIUM	113 Nh NIHONIUM	114 Fl FLEROVIUM	115 Mc MOSCOVIUM

LANTHANIDS

57 La LANTHANUM	58 Ce CERIUM	59 Pr PRASEODYMIUM	60 Nd NEODYMIUM	61 Pm PROMETHIUM	62 Sm SAMARIUM	63 Eu EUROPIUM
89 Ac ACTINIUM	90 Th THORIUM	91 Pa PROTACTINIUM	92 U URANIUM	93 Np NEPTUNIUM	94 Pu PLUTONIUM	95 Am AMERICIUM

ACTINOIDS

ELEMENTS IN THE SAME VERTICAL ROW ARE CALLED A **GROUP** AND SHARE SIMILAR CHEMICAL PROPERTIES!

LIKE COPPER, SILVER & GOLD!

95% OF THE HUMAN BODY IS MADE OUT OF **CARBON, NITROGEN AND OXYGEN!**

Oops! THESE ARE THE **NOBLE GASES!**

ELEMENTS IN THE SAME VERTICAL ROW ARE CALLED A **GROUP** AND SHARE SIMILAR CHEMICAL PROPERTIES!

LIKE
COPPER,
SILVER &
GOLD!

							2 He HELIUM		
				5 B BORON	6 C CARBON	7 N NITROGEN	8 O OXYGEN	9 F FLUORINE	10 Ne NEON
				13 Al ALUMINUM	14 Si SILICON	15 P PHOSPHORUS	16 S SULFUR	17 Cl CHLORINE	18 Ar ARGON
27 Co COBALT	28 Ni NICKEL	29 Cu COPPER	30 Zn ZINC	31 Ga GALLIUM	32 Ge GERMANIUM	33 As ARSENIC	34 Se SELENIUM	35 Br BROMINE	36 Kr KRYPTON
45 Rh RHODIUM	46 Pd PALLADIUM	47 Ag SILVER	48 Cd CADMIUM	49 In INDIUM	50 Sn TIN	51 Sb ANTIMONY	52 Te TELLURIUM	53 I IODINE	54 Xe XENON
77 Ir IRIDIUM	78 Pt PLATINUM	79 Au GOLD	80 Hg MERCURY	81 Tl THALLIUM	82 Pb LEAD	83 Bi BISMUTH	84 Po POLONIUM	85 At ASTATINE	86 Rn RADON
109 Mt MEITNERIUM	110 Ds DARMSTADIUM	111 Rg ROENTGENIUM	112 Cn COPERNICIUM	113 Uut UNUNTRIUM	114 Fl FLEROVIUM	115 Uup UNUNPENTIUM	116 Lv LIVERMORIUM	117 Uus UNUNSEPTIUM	118 Uuo UNUNOCTIUM

 = RADIOACTIVE

94 OF THE KNOWN ELEMENTS OCCUR **NATURALLY** ON EARTH!

THE OTHERS ARE MADE **ARTIFICIALLY** IN EXPERIMENTS WITH RADIOACTIVITY!

SOME OF THEM EXIST ONLY FOR A FRACTION OF A SECOND BEFORE THEY DECAY INTO OTHER ELEMENTS.

64 Gd GADOLINIUM	65 Tb TERBIUM	66 Dy DYSPROSIUM	67 Ho HOLMIUM	68 Er ERBIUM	69 Tm THULIUM	70 Yb YTTERBIUM
96 Cm CURIUM	97 Bk BERKELIUM	98 Cf CALIFORNIUM	99 Es EINSTEINIUM	100 Fm FERMIUM	101 Md MENDELEVIUM	102 No NOBELIUM

IN THE TWENTIETH CENTURY, THE UNDERSTANDING OF THE **STRUCTURE OF ATOMS** RAPIDLY INCREASED.

AN ATOM CONSISTS OF A **NUCLEUS** WITH POSITIVELY CHARGED **PROTONS** IN IT, AND AROUND IT A SHELL WITH NEGATIVELY CHARGED **ELECTRONS** !

THOSE ELECTRONS CIRCLE AROUND THE NUCLEUS IN FIXED ORBITS !

HEY! THE NUMBER OF PROTONS IN THE NUCLEUS DICTATES THE PLACE OF AN ELEMENT ON THE PERIODIC TABLE - NOT THE WEIGHT OF THE ATOM !

IN THE NUCLEUS WE ALSO FIND **NEUTRONS**, WITH NO ELECTRICAL CHARGE!



THIS IS, FOR INSTANCE, HELIUM! IT HAS ATOMIC NUMBER 2!

RUTHERFORD
1871-1937
NW-ZEALAND/ENGLAND

NIELS BOHR
1885-1962
DENMARK

HENRY MOSELEY
1887-1915
ENGLAND

JAMES CHADWICK
1891-1974
ENGLAND

SINCE THEN, CHEMISTRY HAS BRANCHED OUT IN A GREAT NUMBER OF SUBAREAS.

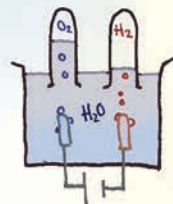
LIKE **NUCLEAR CHEMISTRY**

BIOCHEMISTRY

ELECTROCHEMISTRY

ENVIRONMENTAL CHEMISTRY

NUCLEAR CHEMISTRY STARTED WITH OUR DISCOVERY OF **RADIO-ACTIVITY**, IN 1896!



WHAT IS THE EFFECT OF HUMAN ACTIONS ON THE BIOSPHERE?



BECQUEREL
1852-1908
FRANCE

MARIE & PIERRE CURIE
1867-1934 1859-1906
POLAND FRANCE

STUDIES THE STRUCTURE OF DNA, AMONG OTHERS.

EXAMINES THE RELATIONSHIP BETWEEN ELECTRICAL AND CHEMICAL PROCESSES.

AND MANY OTHERS.

CHEMICAL KNOWLEDGE HAS BEEN APPLIED TO ALMOST EVERYTHING AROUND US!

FUEL

AGRICULTURE

CLEANING

MEDICINE



SO...

TO MAKE
A QUICK
SUMMARY...

...IN MY
OWN
WORDS...



CHEMISTRY IS: THE ART OF PLAYING AROUND WITH SUBSTANCES!

AND WHAT DO SUBSTANCES CONSIST OF?

WE USED TO THINK IT WAS FOUR ELEMENTS: FIRE, WATER, AIR AND EARTH!

& ETHER!

FIVE!



ANCIENT GREEKS CENTURIES B.C.

WE DISCOVERED MOLECULES!

AND HOW THEY ARE MADE OUT OF DIFFERENT ATOMS!

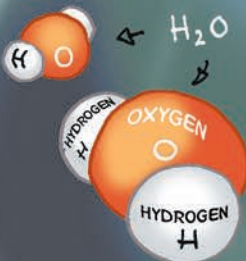
EVERY ELEMENT HAS ITS OWN SPECIFIC ATOM!

NOTE!

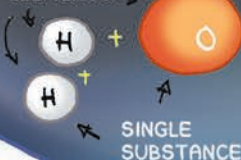
THE MEANING OF 'ELEMENT' HAS SHIFTED OVER TIME!

IT IS NOW: A SUBSTANCE CONSISTING OF ONE KIND OF ATOM!

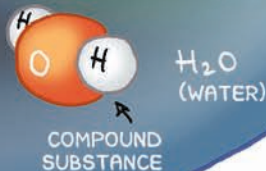
LAVOISIER 18TH CENTURY



ELEMENTS



=



H₂O (WATER)

ABOUT A CENTURY AGO, WE DISCOVERED THAT ATOMS THEMSELVES CONSIST OF EVEN SMALLER PARTS: **ELECTRONS**, **PROTONS** AND **NEUTRONS**!

NUMBER 8 ON THE PERIODIC TABLE, SO IT HAS 8 PROTONS IN THE NUCLEUS AND THEREFORE ATOMIC NUMBER 8.

THIS IS AN
OXYGEN
ATOM

THE CONTENTS
OF THE **NUCLEUS** DETERMINE
THE PROPERTIES OF
AN ELEMENT!

ELECTRONS ARE NEGATIVELY
CHARGED PARTICLES THAT
ROTATE AROUND THE NUCLEUS!

THE NUCLEUS
CONTAINS
POSITIVELY CHARGED
PROTONS...

...AND **NEUTRONS**, THAT
HAVE NO ELECTRICAL
CHARGE - USUALLY THERE
ARE AS MANY NEUTRONS
AS THERE ARE PROTONS.

THERE ARE AS MANY
ELECTRONS
AS THERE ARE **PROTONS**!

PLAYING AROUND WITH ELECTRONS,
PROTONS AND NEUTRONS IS
STRICTLY SPEAKING NOT CALLED
CHEMISTRY, BUT **PARTICLE PHYSICS**!

YES,
MAKE THINGS EVEN
MORE COMPLEX,
WHY DON'T YOU?!



RUTHERFORD
EARLY 20TH CENTURY



HOW DO WE KNOW ALL THAT STUFF ANYWAY? ATOMS ARE TOO SMALL TO BE SEEN!

BY **INDIRECT OBSERVATION!** BY ANALYZING THE BEHAVIOR OF SUBSTANCES IN CHEMICAL PROCESSES!

EXPERIMENT, OBSERVATION AND LOGIC!

WE HAVE ALSO LEARNED A LOT ABOUT THE STRUCTURE OF ATOMS BY BOMBARDING THEM WITH SMALLER PARTICLES AND SEEING HOW THEY ARE DEFLECTED - OR NOT.

BOMBARDING?

FOR INSTANCE, WITH AN ELECTRON GUN!

FIRE AWAY AND SEE WHAT HAPPENS!

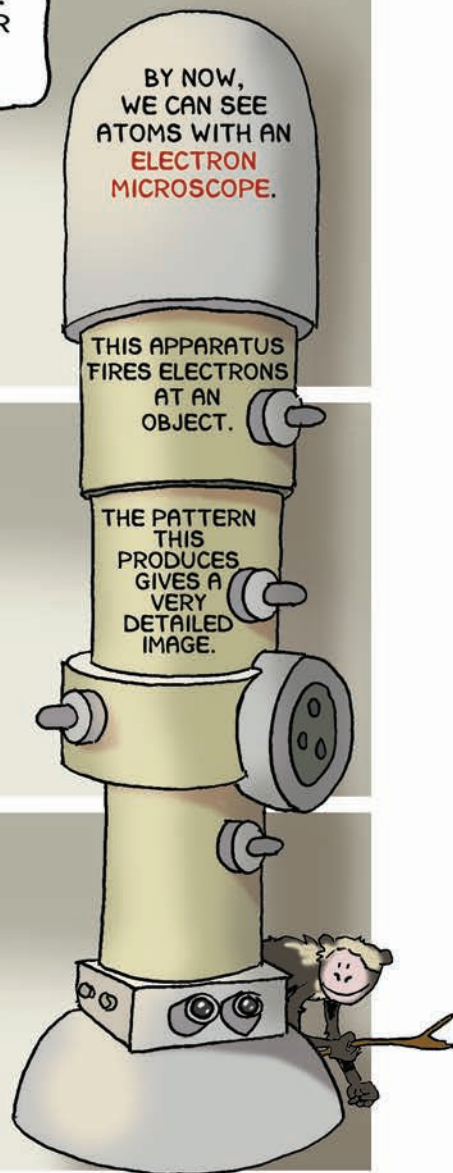
THAT SOUNDS A BIT LIKE A MONKEY POKING AROUND WITH A STICK!

YES, BUT A VERY SMART MONKEY WITH A TECHNOLOGICALLY ADVANCED STICK!

BY NOW, WE CAN SEE ATOMS WITH AN **ELECTRON MICROSCOPE.**

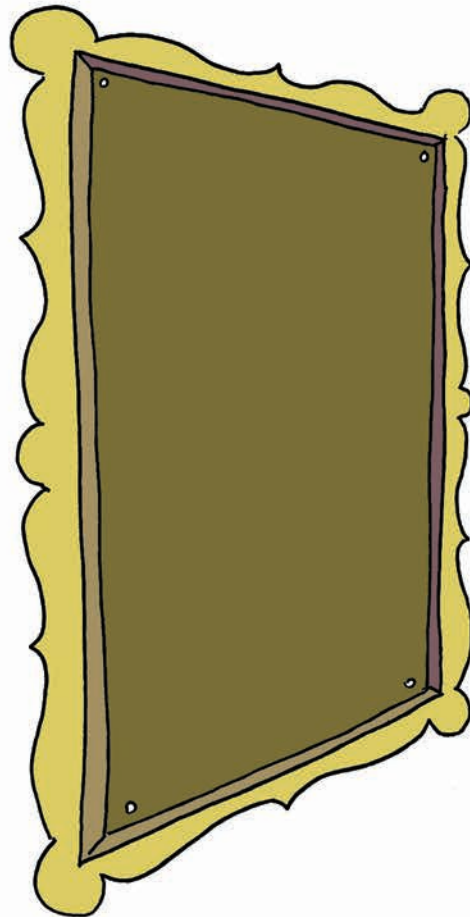
THIS APPARATUS FIRES ELECTRONS AT AN OBJECT.

THE PATTERN THIS PRODUCES GIVES A VERY DETAILED IMAGE.



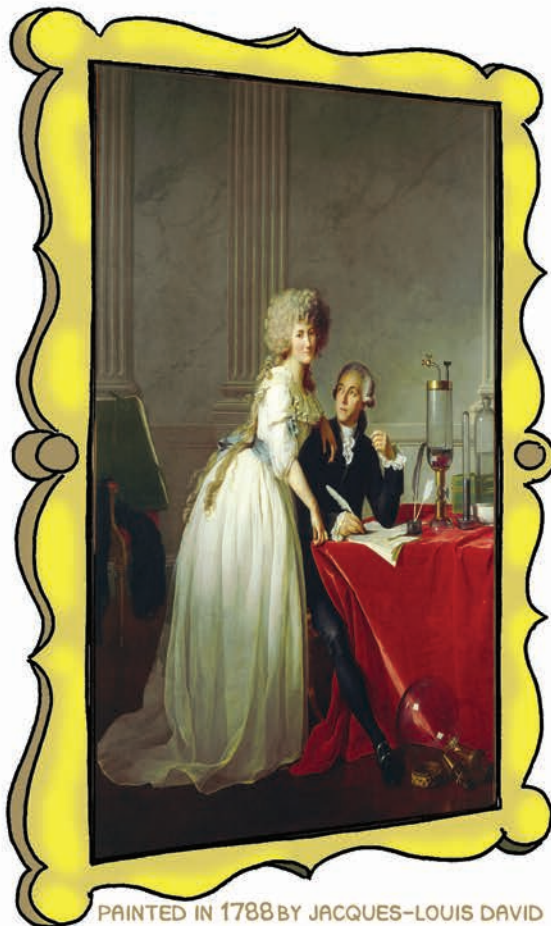
MRS.
SCIENTIST

WHAT A
REMARKABLE
PAINTING!



IT IS CALLED:
ANTOINE LAVOISIER
AND HIS WIFE!

BUT LOOK AT THAT COMPOSITION!



PAINTED IN 1788 BY JACQUES-LOUIS DAVID

SHE IS THE ONE WHO IS
DEPICTED IN THE CENTER,
IN A GORGEOUS DRESS,
CATCHING THE LIGHT...

...WHILE **HE** IS ONLY PARTIALLY
DEPICTED, IN DARK CLOTHES,
LITERALLY IN HER SHADOW!

AND LOOK AT THE WAY HE
LOOKS UP AT HER!
WITH SUCH SERVILE
ANTICIPATION!



THAT COMPOSITION
CAN'T BE ACCIDENTAL!

The Lavoisiers commissioned
this painting themselves!

THIS PAINTING SAYS: IT IS NOT **HE**, BUT **SHE** WHO IS
THE BRILLIANT SCIENTIST OF THE TWO!

Look at these
details!



MARIE LAVOISIER WAS A VERY INTELLIGENT WOMAN:
SHE TRANSLATED BOOKS ABOUT CHEMISTRY AND
ANNOTATED THEM, SHE CORRESPONDED WITH
OTHER SCIENTISTS...

...AND SHE ASSISTED HER HUSBAND
IN HIS LABORATORY!

LOOK! THIS IS
A DRAWING
SHE MADE!



IT MIGHT MAKE YOU WONDER
ABOUT THE ROLE OF WOMEN
IN SCIENCE!

HOW MANY WOMEN HAVE MADE
THEIR MARK IN SCIENCE
WITHOUT IT EVER BEING
RECORDED IN HISTORY?

BRILLIANT,
BUT
INVISIBLE?



FROM ANTIQUITY, A FEW NAMES OF FEMALE SCIENTISTS HAVE SURVIVED.



I WAS **CHIEF PHYSICIAN** IN ANCIENT EGYPT!

BEFORE THE PYRAMIDS WERE BUILT!

MERITH PTAH
±2700 B.C.
EGYPT



I WAS THE WIFE OF **PYTHAGORAS**, AND A MATHEMATICIAN MYSELF!

$P^2 + t^2 = \heartsuit^2$

THEANO
6TH CENTURY B.C.
GREECE



I WAS AN ALCHEMIST AND INVENTED THE **BAIN MARIE**!

THAT IS: THE GRADUAL HEATING OF SUBSTANCES BY PUTTING THEM IN A PAN OF WATER AND BOILING IT!

MARY THE PROPHETESS
BETWEEN 1ST AND 3RD CENTURY
SYRIA (?)



I WAS **HEAD OF THE PLATONIST SCHOOL** IN ALEXANDRIA!

I TAUGHT MATHEMATICS, PHILOSOPHY AND ASTRONOMY!

HYPATIA OF ALEXANDRIA
±350-415
EGYPT

IN THE MIDDLE AGES, SCHOLARLY WOMEN FOUND THEIR PLACE IN MONASTERIES.



I WAS A **BENEDICTINE ABBESS**!

MYSTIC, HEALER, COMPOSER, AUTHOR...

AMONG OTHERS OF THIS BOOK ABOUT PHYSICS:

PHYSICA

HILDEGARD OF BINGEN
1098-1179
GERMANY



CL. S. RIPIERT. C.

ALMA MATER STUDIORUM
A.D. 1088


I WAS ACQUAINTED WITH POPES AND WIDELY RESPECTED!

AROUND THIS TIME, THE FIRST UNIVERSITIES WERE FOUNDED, BUT WOMEN WERE NOT WELCOME HERE...

EXCEPT WITH US IN **BOLOGNA, ITALY**!

TO STUDY, THAT IS, NOT TO TEACH OF COURSE!


THE SIXTEENTH AND SEVENTEENTH CENTURIES SAW THE SCIENTIFIC REVOLUTION. WOMEN HAD LITTLE OPPORTUNITY TO BE PART OF IT, BUT THERE WERE A FEW NONETHELESS.



IT HELPS IF YOU'RE AN **ARISTOCRAT**, LIKE ME!

PHILOSOPHER OF SCIENCE & AUTHOR

MARGARET CAVENDISH
1623-1673
ENGLAND




OR IF YOU HAVE A **FATHER** WHO'S A TEACHER, LIKE I DID! AND A **HUSBAND** WHO SHARES YOUR INTERESTS!

ASTRONOMER

FIRST WOMAN TO DISCOVER A COMET

MARIA WINKELMANN
1670-1720
GERMANY



OR IF YOU LIVE IN **GERMANY**, WHERE 14% OF ALL ASTRONOMERS WERE WOMEN!

ENTOMOLOGIST & ILLUSTRATOR

MARIA SIBYLLA MERIAN
1647-1717
GERMANY

IN THE EIGHTEENTH CENTURY, MANY WERE INSPIRED BY NEWTON'S DISCOVERIES.

I TRANSLATED NEWTON'S WORKS INTO FRENCH!

AND WAS THE LOVER OF FAMOUS AUTHOR VOLTAIRE

"DU CHÂTELET IS A GREAT MAN WHOSE ONLY FAULT IS BEING A WOMAN"!

I TAUGHT NEWTON'S NEW PHYSICS AT THE UNIVERSITY OF BOLOGNA!

AND THEREFORE I'M THE WORLD'S FIRST FEMALE PROFESSOR!

I DISCOVERED TEN NEW HEAVENLY BODIES WITH THE TELESCOPE NEWTON INVENTED!



ÉMILIE DU CHÂTELET
1706 - 1749
FRANCE



LAURA BASSI
1711 - 1778
ITALY



CAROLINE HERSCHEL
1750 - 1848
GERMANY/ENGLAND

IN THE NINETEENTH CENTURY, NEW AREAS OPENED UP - ALSO TO A FEW WOMEN.

MAGNETISM!

PALEONTOLOGY!

COMPUTER SCIENCE!

NAUTICAL ASTRONOMY!

STATISTICS!

I WAS THE WORLD'S FIRST COMPUTER PROGRAMMER!

IT EXISTED ALREADY, BUT NOW MUCH FINER INSTRUMENTS ARE AVAILABLE!

I USED STATISTICS TO REFORM THE BRITISH HEALTH CARE SYSTEM!



MARY SOMERVILLE
1780 - 1872
SCOTLAND



MARY ANNING
1799 - 1847
ENGLAND



ADA LOVELACE
1815 - 1852
ENGLAND



MARIA MITCHELL
1818 - 1889
AMERICA



FLORENCE NIGHTINGALE
1820 - 1910
ENGLAND

THANKS TO THE WOMEN'S LIBERATION MOVEMENT IN THE TWENTIETH CENTURY, WOMEN STARTED TO PARTICIPATE MORE IN MANY FIELDS OF SCIENTIFIC RESEARCH.

I WAS THE FIRST WOMAN TO WIN A NOBEL PRIZE!

IN 1903!

AND ANOTHER IN 1911!

AND SO DID MY DAUGHTER IRENE!

I GOT ONE IN 1935!

I WAS THE FIRST AMERICAN WOMAN TO GET ONE, IN 1947!

IN BIO-CHEMICS!

→ SINCE THEN, TWELVE MORE WOMEN IN SCIENCE RECEIVED A NOBEL PRIZE - THE MOST RECENT RECIPIENTS (AT THE TIME OF MAKING THIS BOOK)

WE GOT ONE IN 2009!



MARIE CURIE
1867 - 1934
POLAND/FRANCE



IRENE JOLIOT-CURIE
1897 - 1956
FRANCE

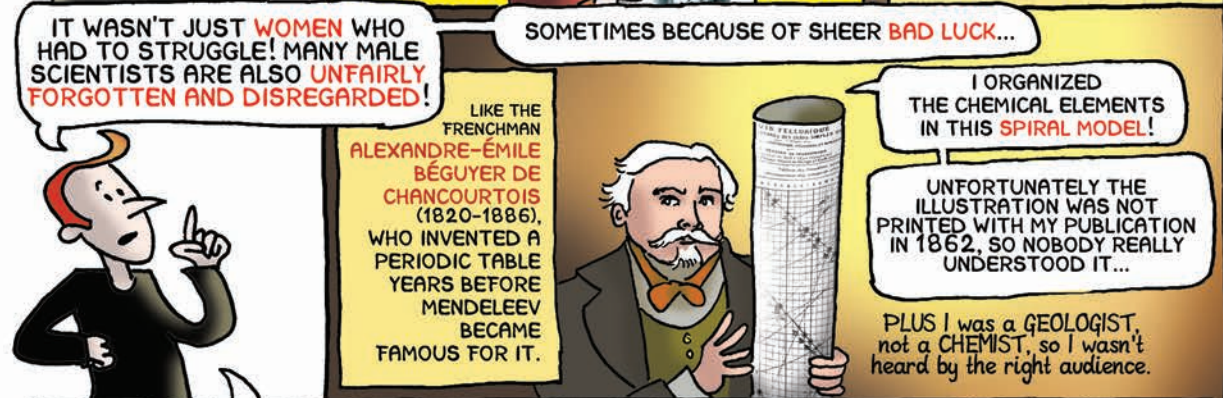
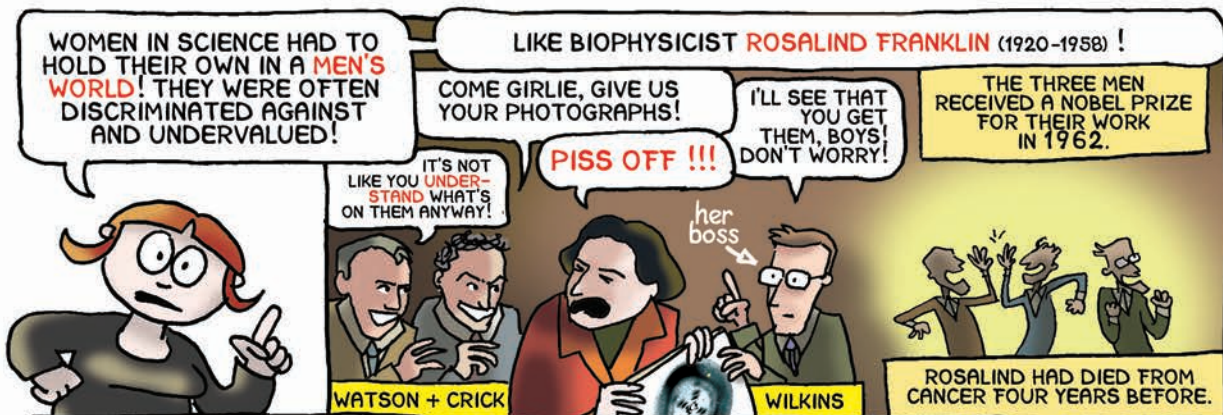


GERTY CORI
1896 - 1957
AMERICA



ELIZABETH BLACKBURN
b. 1948
AUSTRALIA/AMERICA

CAROL GREIDER
b. 1961
AMERICA



THE MOST POIGNANT STORY IS PERHAPS THAT OF **GIDEON MANTELL** (1790-1852)

MANTELL WAS A
BRITISH DOCTOR,
GEOLOGIST AND
PALEONTOLOGIST.
HE DISCOVERED
THE FIRST

DINOSAUR.

(WHICH HE CALLED
IGUANODON.)

THESE FOSSIL TEETH DON'T BELONG TO ANY
ANIMAL WE KNOW - IT MUST HAVE BEEN SOME
KIND OF **GIANT REPTILE** !

No way! They
belong to some kind
of FISH!

Or a RHINO!

Hmmm...

REV.
BUCK-
LAND

CUVIER

OWEN

PROMINENT GEOLOGISTS

IN HIS EAGERNESS TO GET
RECOGNITION FOR HIS DISCOVERY, HE
WENT INTO HUGE AMOUNTS OF DEBT.

IN 1841 HE HAD
AN ACCIDENT THAT
SHATTERED HIS SPINE.

HE COMMITTED SUICIDE IN 1852.

I'M
LOSING MY
PRACTICE

AND I
HAVE TO SELL
MY COLLECTION
OF FOSSILS

AND RICHARD
OWEN IS ALWAYS
HARASSING ME!

AND
MY WIFE

I WANT
TO CLAIM HIS
DISCOVERY
AS ONE OF
MINE !!!

UNSOLD
BOOKS

IGUANODON



AND I GAVE DINOSAURS
THEIR NAME !!!

And I put
Mantell's deformed spine
on display
in my museum!

MUHAHA

OWEN

IN MEMORIAM
GIDEON MANTELL
A MEDIOCRE
SCIENTIST

YOU'D THINK THAT THE PRACTICE
OF SCIENCE IS PURELY RATIONAL,
OBJECTIVE AND LOGICAL -
IN OTHER WORDS: **FAIR**!

WELL, IT'S STILL A **HUMAN** ENDEAVOR...

...A FIELD FULL OF EGOS,
JEALOUSY, POWER GAMES,
RIVALRY, ACCIDENTS
AND JUST BAD LUCK !



THERE ARE SO MANY MORE COMPELLING
STORIES TO TELL ABOUT THE WOMEN
IN THIS CHAPTER!

THERE'S NO SPACE
TO DO THAT, BUT...

HERE ARE A FEW INTERESTING
FACTS TO UNRAVEL
YOURSELF!



SHE WAS **FOUR FEET** TALL &
LIVED TO THE AGE OF **98**.

SHE WAS MURDERED
BY A MOB OF
ANGRY CITIZENS.

SHE WROTE ONE OF THE
FIRST **SCIENCE FICTION**
NOVELS, IN 1668.



**HYPATIA OF
ALEXANDRIA**



MARGARET CAVENDISH
SCIENCE PHILOSOPHER

SHE WAS HIT BY
LIGHTNING WHEN SHE
WAS A TODDLER.



ADA LOVELACE
MATHEMATICIAN

SHE WAS THE
DAUGHTER OF THE
FAMOUS POET
LORD BYRON.



FLORENCE NIGHTINGALE
PHYSICIAN

SHE GREW UP IN A
QUAKER COMMUNITY.



MARIA MITCHELL
ASTRONOMER



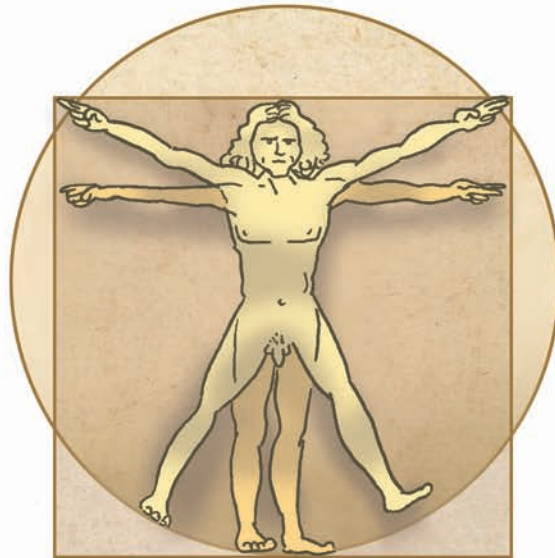
CAROLINE HERSCHEL
ASTRONOMER

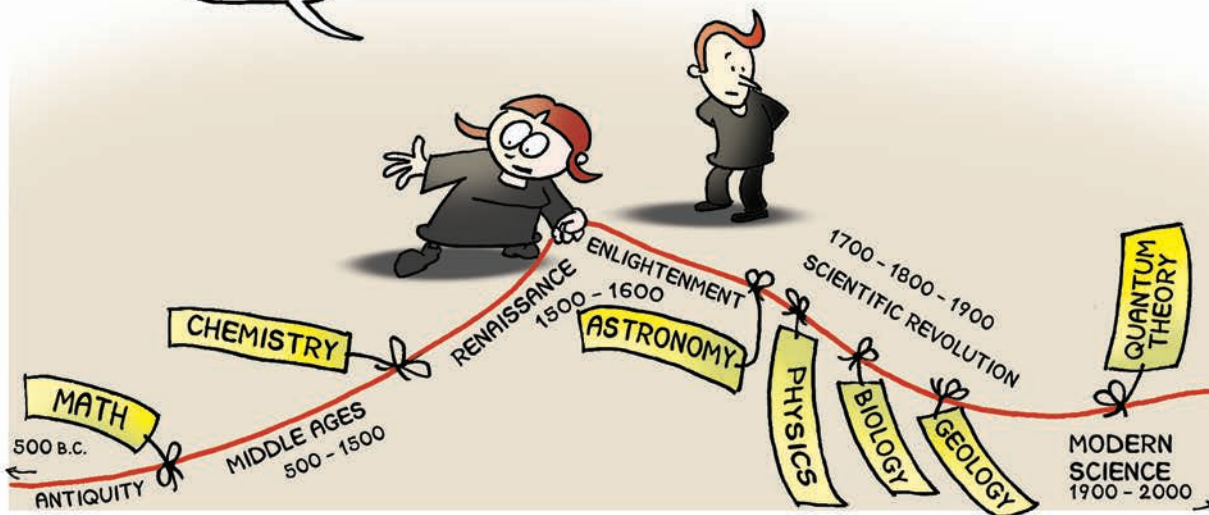
SHE WITNESSED THE HORRORS
OF THE **CRIMEAN WAR**.



MARY ANNING
PALEONTOLOGIST

THE RENAISSANCE





THE RENAISSANCE IS
EMBODIED BY ONE MAN:

LEONARDO DA VINCI

1452 - 1519
ITALY



MULTI-TALENTED GENIUS!

RENAISSANCE
MEANS
REBIRTH!

THIS TIME EXPERIENCED THE **REBIRTH**
OF THE KNOWLEDGE OF ANTIQUITY
IN THE ARTS AND SCIENCES!

I MASTERED THEM ALL
AND ADDED MY OWN
CREATIVE TALENT TO THEM!

HE MAKES SUCH
DETAILED
ANATOMICAL
DRAWINGS...

LOOKS LIKE
WITCHERY!

SHOULDN'T WE PERSECUTE?

NO, HIS TALENT IS
OBVIOUSLY
GOD-GIVEN...

BUT HE HAS
TO STOP DOING
ANATOMY!

LOOK, HE MADE A CART THAT
RIDES BY ITSELF!
IT GOES 36 YARDS!

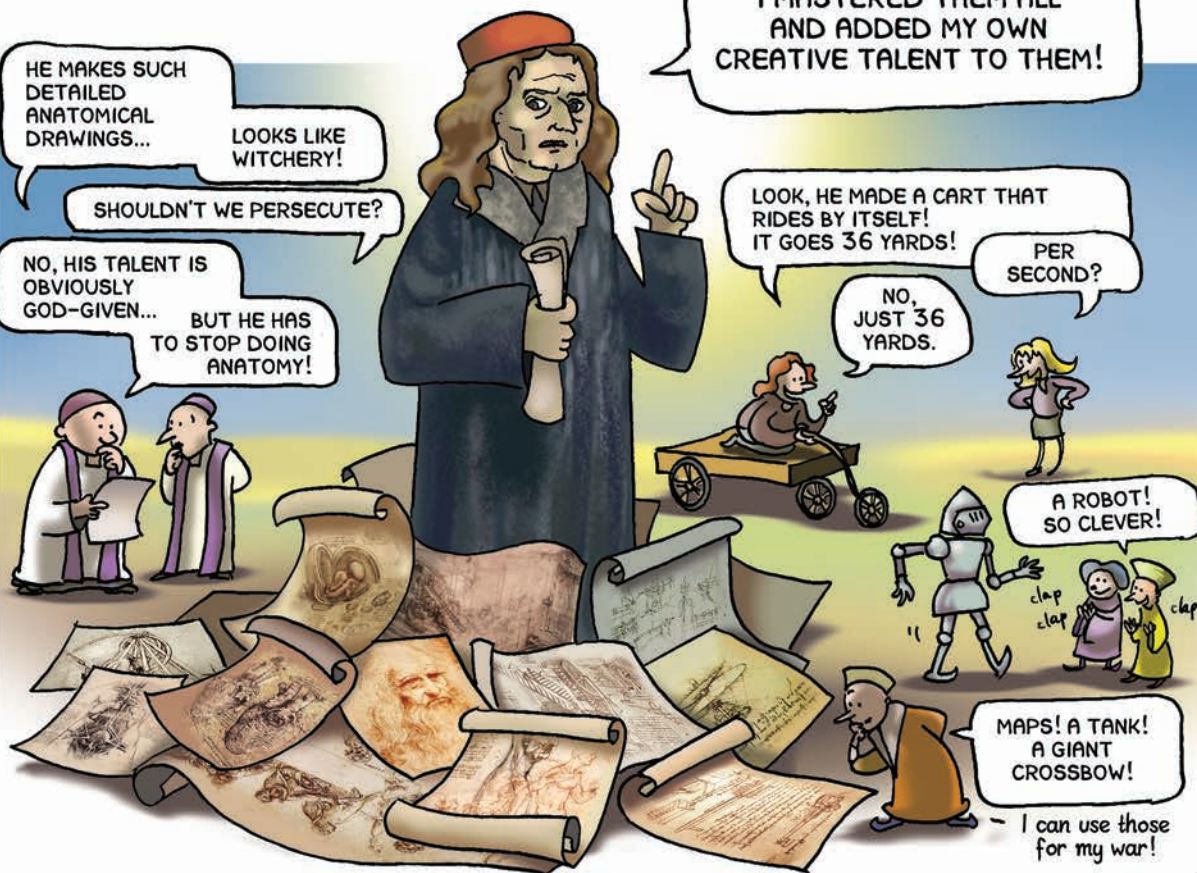
PER
SECOND?

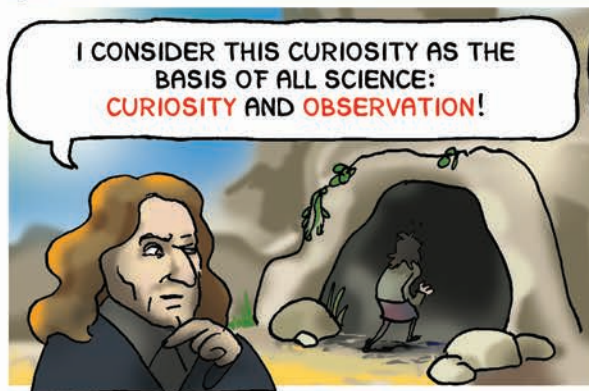
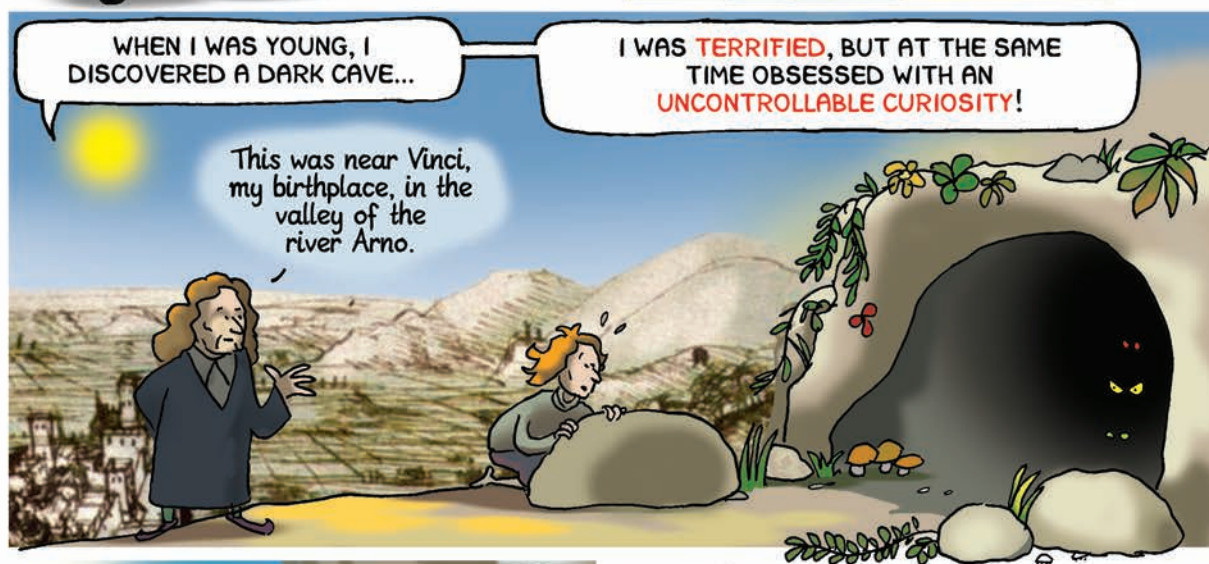
NO,
JUST 36
YARDS.

A ROBOT!
SO CLEVER!

MAPS! A TANK!
A GIANT
CROSSBOW!

I can use those
for my war!



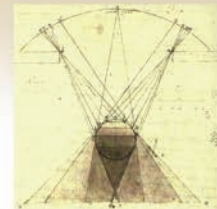


USING THIS METHOD, I STUDIED PRACTICALLY **EVERYTHING** I CAME ACROSS!

I DISSECTED **BODIES** TO
SEE HOW HUMANS
FUNCTION ON THE INSIDE.



I ANALYZED BIRDS IN
FLIGHT AND EVEN BUILT
FLYING MACHINES.



I STUDIED THE
BEHAVIOR OF **LIGHT**
AND SHADOW.

I MADE DRAWINGS
OF EVERYTHING!

AND MEANWHILE, I EARNED MY KEEP BY BEING
EMPLOYED BY RICH, POWERFUL PEOPLE!

HE'S A
GENIUS!

YES, I
COLLECT
TALENT!

CRAFTY
BOY!



DE MEDICI

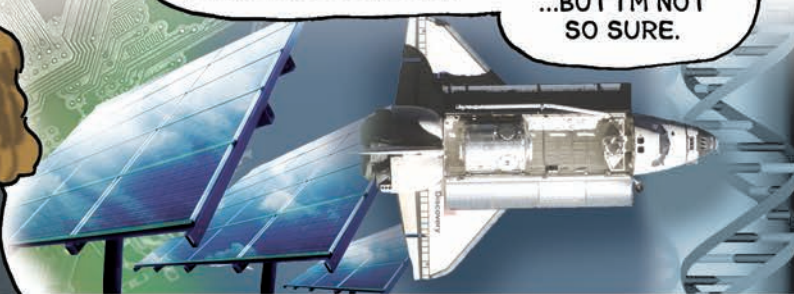


DUKE OF MILAN

LOTS OF MY NOTEBOOKS WERE ONLY
MADE PUBLIC AFTER MY DEATH.

PEOPLE SAY SOMETIMES THAT I WOULD HAVE
BEEN BETTER SUITED TO THE NINETEENTH OR
TWENTIETH CENTURY...

...BUT I'M NOT
SO SURE.



IN MY TIME, I COULD PURSUE ALL KINDS OF INTERESTS AND DISCIPLINES, ALL AT MY OWN PACE...



...IN YOUR MODERN TIME YOU'RE ONLY CONSIDERED A SCIENTIST IF YOU STICK TO ONE SUBJECT!



ARTIST,
INVENTOR
AND SCIENTIST?

SMELLS LIKE
A CONFLICT OF
INTEREST!

Or insanity even!



I COULD DABBLE IN ALL SORTS OF THINGS AND TAKE TIME TO INVENT AND EXPERIMENT...

ALL AT THE
SAME TIME!

SOME COMMISSIONS
TOOK ME YEARS! OR
I DIDN'T FINISH
THEM AT ALL!



A MODERN SCIENTIST IS EXPECTED TO FREQUENTLY PUBLISH IN RENOWNED SCIENCE MAGAZINES!

IS YOUR ARTICLE
FINISHED YET?

IS IT SUFFICIENTLY
CONTROVERSIAL?
ABOUT A
HOT TOPIC,
I HOPE?



BUT LEONARDO - DON'T YOU THINK YOUR TALENTS AND PROGRESSIVE IDEAS WOULD BE MUCH MORE APPRECIATED IN OUR TIME?

APPRECIATED?!

HA!



IN MY TIME I WAS FINANCIALLY
DEPENDENT ON THE MONEY AND
INTEREST OF THOSE IN **POWER**...

SCIENCE IS DRIVEN BY
POWER INTERESTS!



DO YOU KNOW HOW
MANY WAR MACHINES
I WAS ORDERED
TO INVENT?

THAT'S NO
DIFFERENT IN
YOUR TIME!

BY PEOPLE WHO
WANT **WEAPONS**

AND **MONEY**

AND **GADGETS!**

ELECTRIC CARS! MUCH BETTER
FOR THE ENVIRONMENT!

NOT NOW!

OR WE WON'T
MAKE **OUR** MONEY
ON OIL ANYMORE!



BUSINESS PEOPLE

NUCLEAR POWER! THERE'S SO MUCH
WE COULD DO WITH THAT!

YOU'D BETTER
START BY MAKING
A **BOMB!**

BEFORE THE
ENEMY INVENTS
ONE!



POLITICIANS



SCIENTISTS

YOU CAN'T STOP SCIENTIFIC PROGRESS.
HUMAN CURIOSITY SIMPLY WON'T BE **CONTAINED**...

NOT TO MENTION
HUMAN GREED AND
HUNGER FOR POWER!



I LEARNED THAT WHEN
I WAS STILL A CHILD.



...BUT SOMETIMES
I WONDER...

...IF THAT FEELING
OF **TERROR**...

...WASN'T A MUCH MORE
SENSIBLE INSTINCT?



THE SCIENTIFIC REVOLUTION



THE SCIENTIFIC DEVELOPMENTS THAT TOOK PLACE IN WESTERN EUROPE
IN THE SIXTEENTH, SEVENTEENTH AND EIGHTEENTH CENTURY ARE CALLED
THE SCIENTIFIC REVOLUTION !

IT WAS AN
EXPLOSION OF
NEW IDEAS AND
INVENTIONS!



ANATOMY



GRAVITY



ATOMISM



PRINTING
PRESS

HUMANISM
(Man is most
important)



HELIOCENTRISM (earth revolves around the sun)



INCREASINGLY
BETTER INSTRUMENTS
(most importantly
telescopes)



NEW?
NOT REALLY!



ALL OF THESE IDEAS WERE
ALREADY IN EXISTENCE...

BUT AT THIS TIME THEY STARTED TO GAIN
GROUND ON PREVAILING BELIEFS, ESPECIALLY
BELIEFS BASED ON IDEAS BY **ARISTOTLE**.

➤ MODERN PHILOSOPHERS OF SCIENCE



IDEAS OF ARISTOTLE

4TH CENTURY B.C.

THE UNIVERSE IS **GEOCENTRIC**.

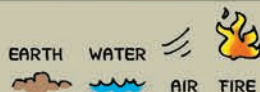
EVERYTHING
REVOLVES
AROUND THE
EARTH!



AS I EXPLAINED IN THIS
BOOK I WROTE IN THE
2ND CENTURY!

PTOLEMY (87 - 150 A.D.)

ALL EARTHLY SUBSTANCES ARE MADE OUT OF
FOUR ELEMENTS.



HEAVENLY SUBSTANCE
IS MADE OF ETHER!



MOTION IS CAUSED BY OBJECTS SEEKING THEIR
NATURAL PLACE.

EARTH
TO
EARTH



AIR
TO
AIR

ANATOMY: THE BODY CONTAINS FOUR
TYPES OF BODILY FLUID.

BLOOD

YELLOW
BILE

SLIME

BLACK BILE

GALEN (2ND CENTURY)



IDEAS OF THE CHURCH

THEOCENTRISM

GOD IS
CENTRAL !



AND THE CHURCH OF
ROME REPRESENTS
HIM ON EARTH!

THE CHURCH HOLDS ALL POWER

NEW IDEAS

IN THE 16TH, 17TH AND 18TH CENTURY

OUR PLANETARY SYSTEM IS **HELIOCENTRIC**.

WE REVOLVE
AROUND THE
SUN!



COPERNICUS KEPLER GALILEO

We said so
3000 years
ago already!



INDIAN
SAGES

ALL MATTER CONSISTS OF **ATOMS.**

THAT'S WHAT
I SAID IN THE
4TH CENTURY
B.C. ALREADY!



DEMOCRITUS DALTON

I EXPANDED
THIS IDEA IN
THE 18TH
CENTURY!

MOTION IS CAUSED BY
OBJECTS EXERTING FORCES ON EACH OTHER.

LIKE
GRAVITY!



NEWTON

THE EARTH
ATTRACTS
OBJECTS!

ANATOMY: THE BODY IS SUSTAINED BY
BLOOD CIRCULATION.

GALEN'S
WORK
IS FAULTY!



VESALIUS

I DEMONSTRATE
THIS BY EXTENSIVE
ANATOMICAL
RESEARCH!

NEW MOVEMENTS

IN THE 16TH, 17TH AND 18TH CENTURY

HUMANISM

MAN IS THE
MEASURE OF
ALL THINGS!



THE ROMAN
CHURCH ABUSES
ITS POWER!

REFORMATION

ONE OF THE MOST IMPORTANT NAMES OF THE SCIENTIFIC REVOLUTION IS THAT OF
GALILEO GALILEI (1564-1642, ITALY)

ISN'T THAT THE GUY WHO
DISCOVERED THAT THE
EARTH REVOLVES AROUND
THE SUN?

AND WHO GOT INTO
A FIGHT WITH THE
CHURCH OVER THIS?

KIND OF, YES.

HERE'S GALILEO'S STORY:

GALILEO WAS
ACTUALLY **NOT**
THE ONE TO
DISCOVER THE
EARTH REVOLVES
AROUND THE SUN
- THIS IDEA WAS
PUBLISHED IN A
BOOK BY
COPERNICUS,
IN 1543...

ON THE
REVOLUTIONS
OF THE
CELESTIAL
SPHERES
COPERNICUS
GERMANY 1543

21 YEARS BEFORE
GALILEO
WAS BORN!

GALILEO WAS A PROFESSOR
OF ASTRONOMY AT THE
UNIVERSITY OF **PADUA**,
ITALY.

ONE DAY HE FOUND A TELESCOPE
AT A STREET MARKET.

MADE IN HOLLAND - A CHILD'S TOY,
BUT I CAN MODIFY AND IMPROVE IT!

COPERNICUS
WAS RIGHT!

ROME, 1616

COPERNICUS
CAN'T POSSIBLY BE
RIGHT, YOU HEAR?!

READ
THE
BIBLE!

WE'LL GIVE YOU AN ADMONITION, GALILEO!
YOU CAN NO LONGER PUBLICLY
DEFEND THAT THEORY!

OKAY!

Psalm 93:1
indeed, the world is
established, firm
and secure.

1 Chronicles 16:30
Tremble before him, all the earth!
The world is firmly established; it cannot be moved.

Psalm 96:10
The world is firmly established,
it cannot be moved;

JESUITS
ORDER OF MONKS
WHO HELD POWER AND
LED THE INQUISITION

GALILEO LAY LOW UNTIL A NEW POPE WAS ELECTED. THIS ONE WAS A FRIEND OF HIS.



IN 1632 GALILEO'S BOOK 'DIALOGUE CONCERNING THE TWO CHIEF WORLD SYSTEMS' WAS PUBLISHED.



DID YOU REALLY READ IT? HE MAKES FUN OF YOU!

HE NAMED THE PERSON REPRESENTING YOUR VIEW 'SIMPLICIO'...

WHAT KIND OF POPE ARE YOU?

I WON'T RISK MY JOB FOR THIS!

'SIMPLETON'!



IN 1633 GALILEO HAD TO DEFEND HIMSELF AT A COMMITTEE OF THE INQUISITION.



GALILEO REMAINED UNDER HOUSE ARREST UNTIL HIS DEATH IN 1642, AGED 77.

BUT I WAS TOTALLY WILLING TO COLLABORATE WITH THE CHURCH!

IT'S NOT FAIR!



IT TOOK UNTIL 1992 BEFORE THE CHURCH OFFICIALLY APOLOGIZED FOR GALILEO'S TREATMENT.

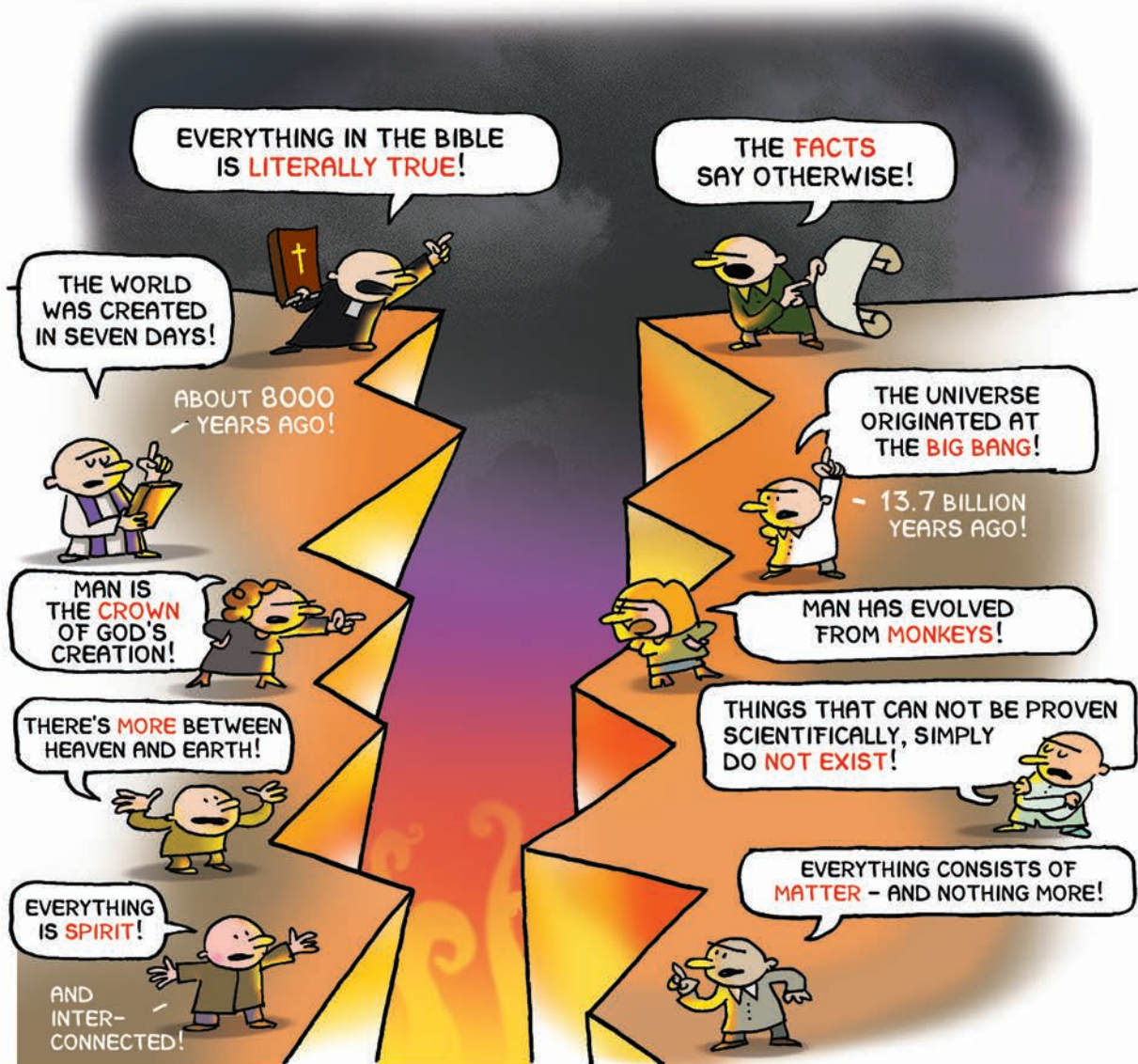
THE MIDDLE FINGER OF GALILEO'S RIGHT HAND

WAS PRESERVED AND DISPLAYED AS A RELIC IN THE 18TH CENTURY.

IT CAN STILL BE SEEN IN THE GALILEO MUSEUM IN FLORENCE.



SINCE THAT TIME, THERE HAS BEEN A RIFT BETWEEN SCIENCE AND RELIGION.



SOMETIMES IT'S
JUST LIKE A
FAILED MARRIAGE...

...IN WHICH BOTH PARTIES
KEEP BOTHERING EACH OTHER
FOR YEARS AFTER,
EACH TRYING TO OUT-ARGUE
THE OTHER.



UNBELIEVABLE
JERK!

IRRATIONAL
BITCH!



THE
RELATIONSHIP
BETWEEN
SCIENCE
&
RELIGION



TELL ME: WHAT EXACTLY HAPPENED BETWEEN YOU TWO?



Well...



A LONG TIME AGO...

SEE
THAT?

THE SUN, MOON AND STARS
ALL REVOLVE AROUND US!



WELL...

I THINK, WHEN YOU LOOK CLOSE,
THAT IT'S THE EARTH
THAT REVOLVES
AROUND THE SUN!

NO WAY!



LOOK AT THESE
CALCULATIONS!

It's real!



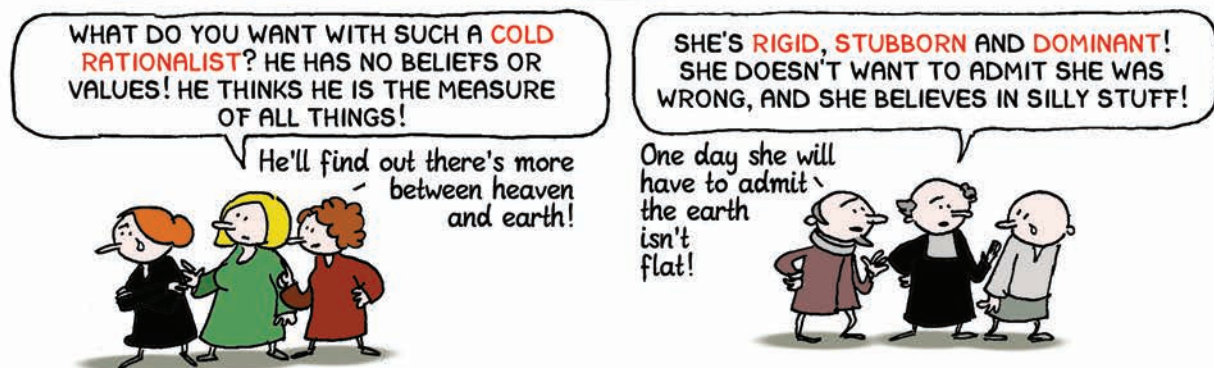
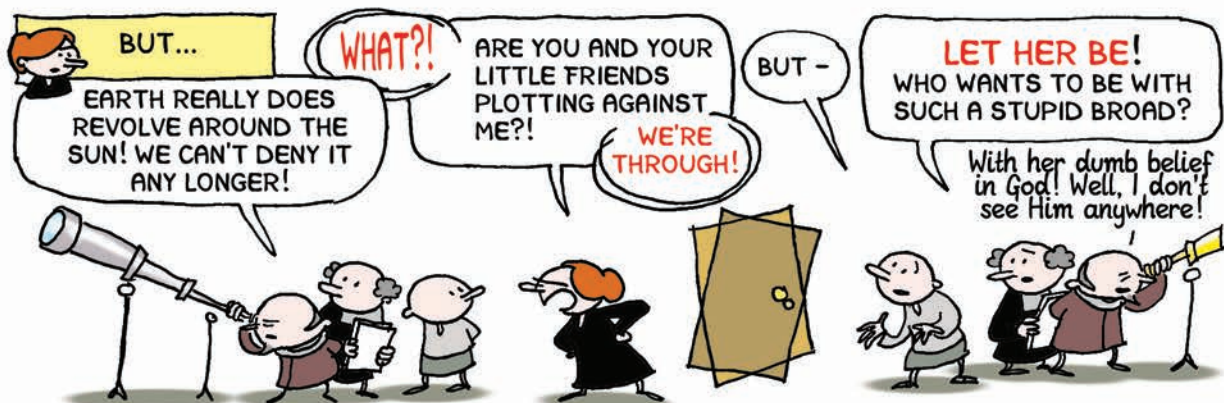
I DON'T CARE IF IT'S REAL
OR NOT, YOU SHOULD JUST
ALWAYS CONCUR WITH ME!



God has created a
hierarchy and His
power on earth
is vested in
the Church!

OKAY - THE EARTH IS THE
CENTER. HAVE IT YOUR WAY.





THE AGE OF THE EARTH
IS 4.6 BILLION YEARS!

AND HUMANS HAVE EVOLVED
FROM MONKEYS, DID YOU KNOW?

And religion can be
psychologically explained
as Fear of Death!



LA
✓ LA LA LA LAAA
I can't
HEAR YOU !!!



THE WORLD IS REALLY
A BIG **MACHINE**!

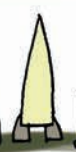
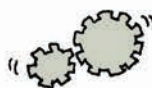
Everything is governed
by cause and effect!

OUR RATIONALITY MAKES US
MASTERS OF CREATION!

Cool and
objective!

LOOK AT ALL THIS
PROGRESS !

PROGRESS...?



WHOOPS! **QUANTUM THEORY** SUGGESTS THAT
REALITY IS MUCH **MORE COMPLEX** THAN WE THOUGHT!

We aren't objective
observers at all!

Not everything can
be predicted!

Everything is
interconnected!



* see p. 167



THE EARTH IS NOT A MACHINE,
IT'S A **LIVING ORGANISM** !

Our actions
have
consequences!

Maybe we should think
about our responsibility
as part of that.



HER PRESUMPTIONS ABOUT LIFE CAN'T BE PROVEN, BUT THEY DO GIVE HER VALUES THAT WE SCIENTISTS MIGHT NEED AS WELL.

I HAVE BEEN ARROGANT. I NO LONGER WANT TO IMPOSE MY WILL ON OTHERS. I WANT TO PROPAGATE A SPIRIT OF OPENNESS, DIALOGUE AND UNDERSTANDING.



AFTER ALL, WE DO LIVE TOGETHER ON THIS FRAGILE PLANET FOR WHICH ALL OF US ARE RESPONSIBLE!

MAYBE THERE ARE STILL SOME THINGS WE HAVE IN COMMON!



WE'D LIKE TO GIVE IT ANOTHER TRY!

NOT IN THE OLD WAY

BUT IN THE WAY WE WERE INTENDED: ENJOYING AND ADMIRING LIFE TOGETHER!

...in which only one of us could be right...



Isn't everything wondrous?
So diverse and complex!

And we're part of it!
Isn't that special?





I THINK THIS RIFT HAS BEEN GREATLY EXAGGERATED -
EMBELLISHED BY PRESS, POLITICIANS AND A FEW FUNDAMENTALISTS.
IN REALITY, SCIENCE AND RELIGION CAN CO-EXIST JUST FINE.

ESPECIALLY WHEN YOU DEFINE
RELIGION AS AN INDIVIDUAL'S
SPIRITUAL PATH

AND SCIENCE AS AN
EXPRESSION OF THE CURIOSITY
OF THE HUMAN SPIRIT

LITERALLY !

NONSENSE!

BIBLE COMMENTATORS HAVE TREATED
THE BOOK AS LITERARY, MYSTIC
TEXTS SINCE THE FIRST CENTURY!

NOT AS A
HISTORY BOOK!
IF YOU SEE IT AS
LITERAL, YOU
ARE SELLING
IT SHORT!

SCIENCE PROVES THAT
THERE IS NO GOD!

NONSENSE !

SCIENTIFIC RESEARCH
LIMITS ITSELF TO
PHYSICAL REALITY!

SPIRITUALITY
IS SOMETHING
DIFFERENT!

RELIGIOUS
FUNDAMENTALISTS

SCIENTIFIC
FUNDAMENTALISTS

I'M A
PRIEST!

AND I BELIEVE
IN EVOLUTION!

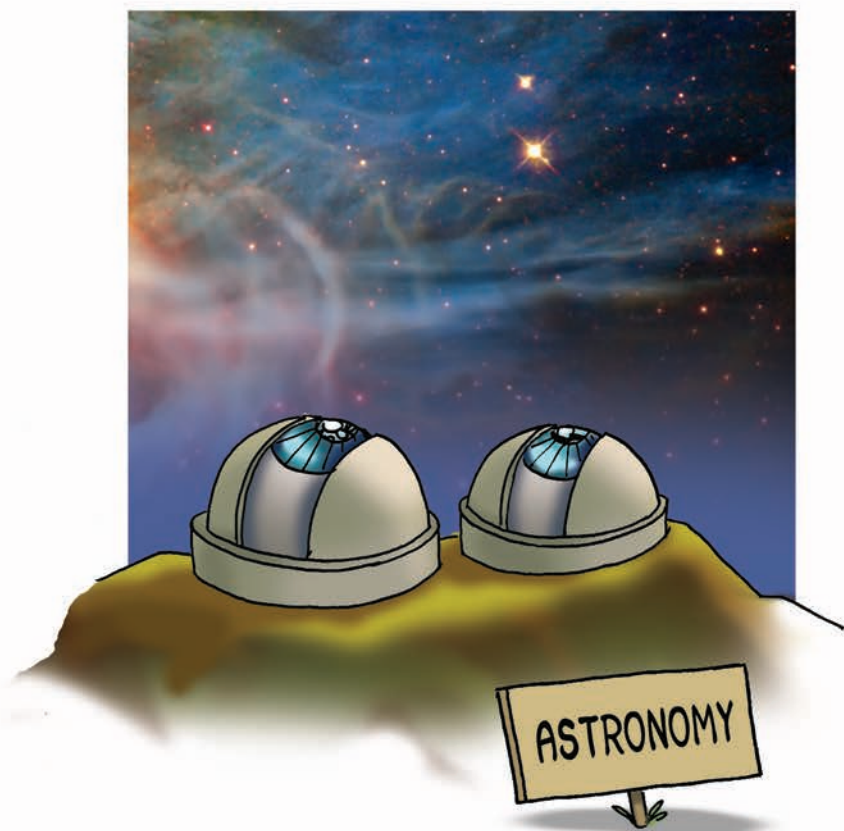
I'M A
PHYSICIST!

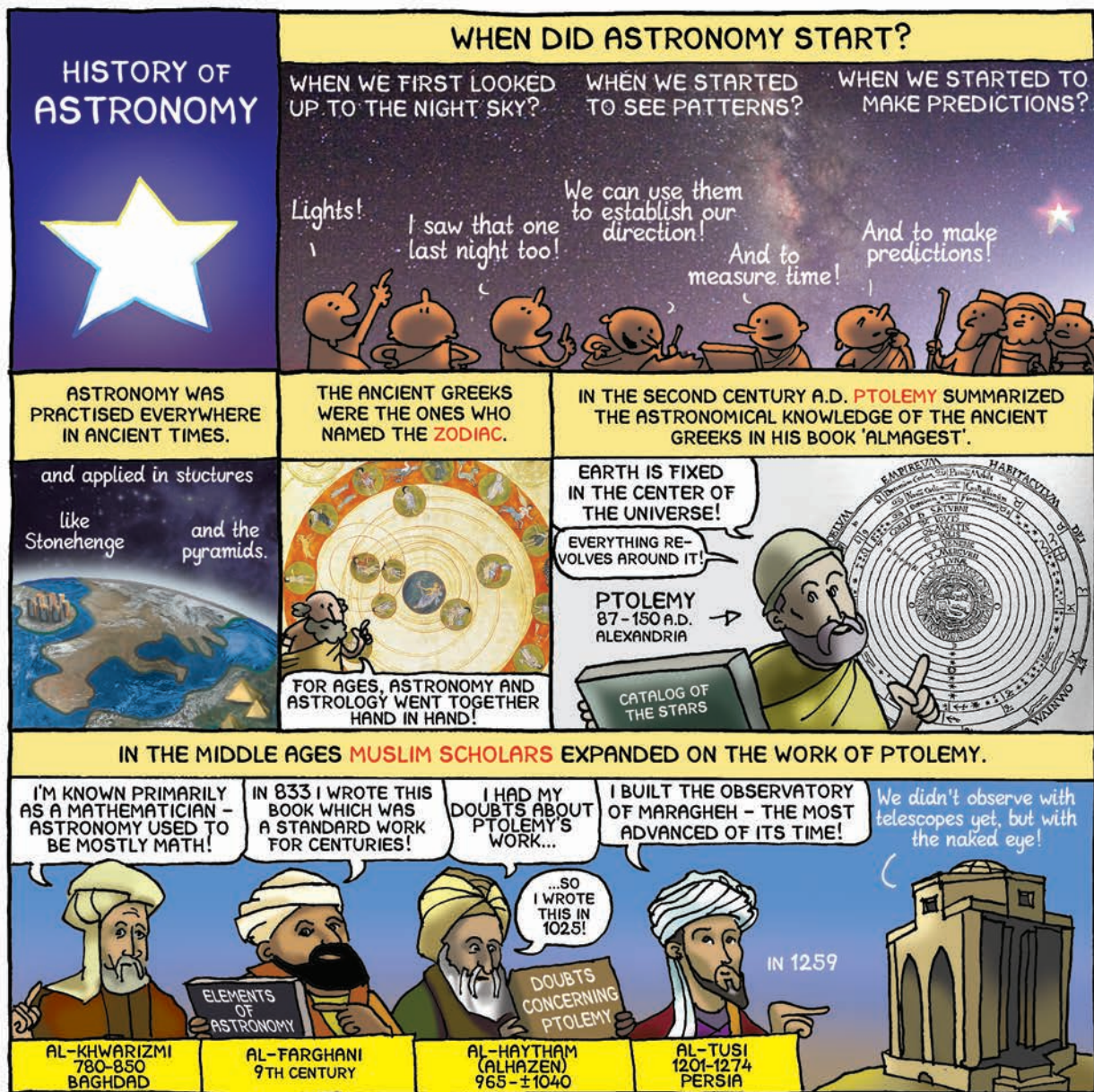
AND I GO TO
CHURCH!

I LIKE TO READ
SCIENTIFIC ARTICLES
TO MARVEL AT
CREATION!

I LIKE TO MEDITATE
WHEN I'M STUCK IN
A SCIENTIFIC
PROBLEM!

EVERYTHING IS
SO WONDROUS!





IN THE 16TH AND 17TH CENTURY, NEW ASTRONOMICAL INSIGHTS CAUSED A **REVOLUTIONARY NEW WORLDVIEW**: EARTH REVOLVES AROUND THE SUN, NOT THE OTHER WAY AROUND!

IT ALL STARTED WITH THIS BOOK OF MINE IN 1543.



NICOLAUS COPERNICUS
1473 - 1543
POLAND

I STUDIED THE SUPERNOVA THAT SUDDENLY APPEARED IN 1572! IT CONFIRMED COPERNICUS' IDEAS FOR ME!



TYCHO BRAHE
1546 - 1601
DENMARK

I USED BRAHE'S MANY OBSERVATIONS TO DERIVE 3 LAWS ON THE MOTIONS OF THE STARS!



JOHANNES KEPLER
1571 - 1630
GERMANY

I DEFENDED THE NEW IDEAS IN THE CHURCH, BUT:



GALILEO GALILEI
1564 - 1642
ITALY

SHUT UP !!!

And I made countless observations myself!

THE INVENTION OF THE **TELESCOPE** LED TO MORE OBSERVATIONS THAN EVER BEFORE!

THE MILKY WAY CONSISTS OF COUNTLESS STARS!



GALILEO
ITALY, 1610

SATURN HAS RINGS! AND A MOON!



CHRISTIAAN HUYGENS
1629 - 1695
THE NETHERLANDS

ISAAC NEWTON WAS THE FIRST TO BRING TOGETHER **ASTRONOMY AND PHYSICS**.

OBJECTS ON EARTH AND IN THE HEAVENS ALL OBEY THE SAME LAWS!

LIKE THE LAW OF GRAVITY!



ISAAC NEWTON
1642 - 1727
ENGLAND

the first reflecting telescope

IN THE 19TH CENTURY, ASTRONOMY MADE EVEN MORE PROGRESS.

DISCOVERY OF URANUS!

A WHOLE LOT OF ASTEROIDS BETWEEN MARS AND JUPITER!

DISCOVERY OF NEPTUNE!



1781

1801 - 1847

1846

INVENTION OF SPECTROSCOPY

NOW WE CAN ANALYZE THE LIGHT SPECTRUM OF THE SUN TO SEE WHAT CHEMICAL ELEMENTS IT CONTAINS!



GUSTAV KIRCHHOFF
1824 - 1887
GERMANY

HYDROGEN AND HELIUM!

ASTRONOMY BECAME WIDELY POPULAR: ASTRONOMICAL SOCIETIES WERE FOUNDED AND SPECIAL EXPEDITIONS WERE ORGANIZED.

WE'RE GOING TO HONOLULU TO SEE THE SOLAR ECLIPSE!

WE ALL SHARE OUR OBSERVATIONS!



1874

THE RAPIDLY IMPROVING TECHNOLOGY OF THE 20TH CENTURY POSED NEW QUESTIONS:

HOW BIG IS THE UNIVERSE?

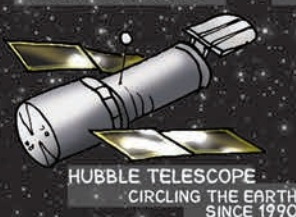
IS IT STATIC OR EXPANDING?

HOW WAS THE UNIVERSE BORN?

ARE THERE MORE PLANETS THAT CAN SUSTAIN LIFE?



IRAS
1983



HUBBLE TELESCOPE
CIRCLING THE EARTH
SINCE 1990

MARS
ROVER
EXPLORING
MARS
SINCE
2003



RADIO-ASTRONOMY
"sees" supernovas,
pulsars

INFRARED ASTRONOMY
"sees" cold objects that
don't light up, like planets

UV-ASTRONOMY
"sees" blue stars,
nebulae etc.

X-RAY ASTRONOMY
"sees" pulsars,
galaxies etc.

GAMMA-RAY ASTRONOMY
"sees" neutron stars
black holes

MANY NEW ANSWERS WERE FOUND, FOR INSTANCE ABOUT THE ORIGIN OF THE UNIVERSE.

MY THEORY OF RELATIVITY
EXPLAINED MOTION IN THE
UNIVERSE -



ALBERT EINSTEIN
1879 - 1955
GERMANY / USA

BUT I THOUGHT
THE UNIVERSE
ITSELF WAS
STATIC!

MY
**BIGGEST
BLUNDER!**

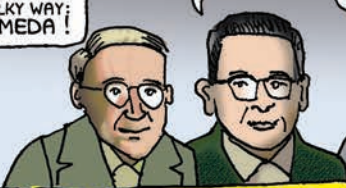
I PROVED THE UNIVERSE
IS **EXPANDING!**



EDWIN HUBBLE
1889 - 1953
USA

I ALSO DISCOVERED THE
FIRST GALAXY OUTSIDE
OUR OWN MILKY WAY:
ANDROMEDA!

WE CAME UP WITH THE
THEORY OF THE **BIG BANG!**



GAMOW & ALPHER
1904 - 1968
RUSSIA
1921 - 2007
USA

IN 1948!

IN 1964, WE FOUND THE
EVIDENCE FOR THIS THEORY!

**COSMIC
BACKGROUND
RADIATION!**



PENZIAS & WILSON
1933
GERMANY / USA
1936
USA

BY
ACCIDENT.

BUT STILL, MORE THAN ENOUGH QUESTIONS AND UNEXPLAINED PHENOMENA REMAIN!

THE MOVEMENT
OF CERTAIN
GALAXIES...

...CAN ONLY BE EXPLAINED
IF THEY ARE MUCH HEAVIER
THAN THEY SEEM TO BE
FROM OUR OBSERVATION!

THERE MUST BE
EXTRA MATTER
WE CAN'T SEE!



WE'RE CALLING IT
DARK MATTER.

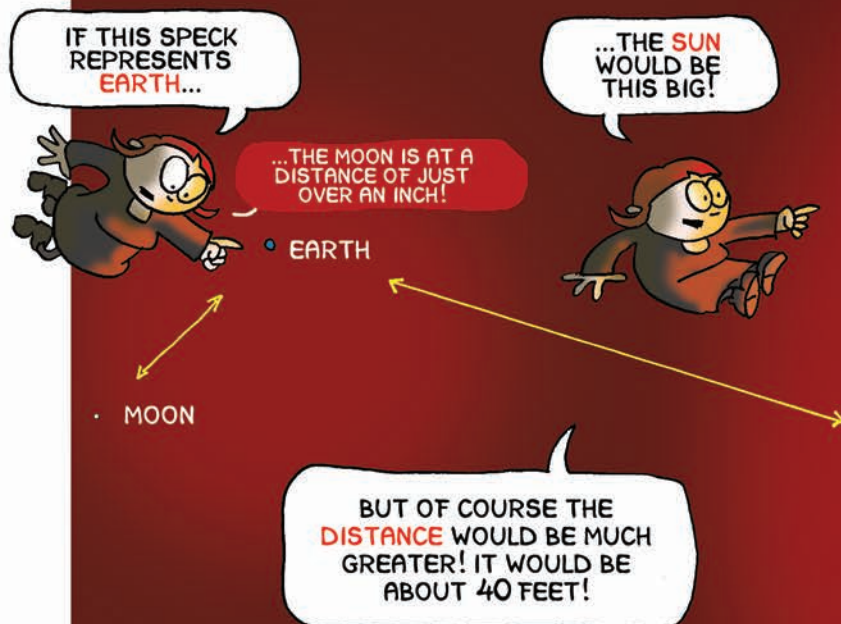
IT IS ESTIMATED THAT
23 % OF THE UNIVERSE
CONSISTS OF DARK MATTER...

...AND 74% CONSIST OF
DARK ENERGY!

I THINK THE EXCITING THING
ABOUT ASTRONOMY IS
HOW IT CHALLENGES OUR
UNDERSTANDING OF
SPACE AND **TIME**!



SPACE





THE DISTANCE TO **NEPTUNE**, THE FARTHEST PLANET
IN OUR SOLAR SYSTEM, WOULD BE HALF A MILE!



THE DISTANCE TO **PROXIMA CENTAURI**,
THE CLOSEST STAR, WOULD BE
ALMOST A THOUSAND MILES!



AND THAT WOULD BE JUST
TO OUR NEAREST NEIGHBOR
IN OUR GALAXY!

MIND-BOGGLING! -





WHEN YOU LOOK AT THE STARS, YOU'RE ACTUALLY **LOOKING BACK IN TIME**! THE SPEED OF LIGHT IS "ONLY" 186,000 MILES PER SECOND - AND SPACE IS INFINITELY BIG!

SUN
8.3 MINUTES
AGO

NEPTUNE
4.2 HOURS
FROM THE
SUN

MOON
1.25
SECONDS
AGO

JUPITER
41 MINUTES
FROM THE
SUN

OUR
GALAXY



SATURN
85
MINUTES
FROM THE SUN

PROXIMA
CENTAURI
4.3 YEARS
AGO

THE
NEAREST STAR

NORTH
STAR
432 YEARS
AGO

MAGELLANIC CLOUD
(THE NEAREST GALAXY
OUTSIDE OUR OWN)
160,000 YEARS AGO

CENTER
OF THE MILKY WAY
27,700 YEARS
AGO

ANDROMEDA GALAXY
2,540,000 YEARS AGO

THE FARTHEST STARS WE CAN SEE
WITH OUR TELESCOPES, DATE
BACK 14,000,000,000 YEARS!

Earth didn't even
EXIST
at that time!

EVEN **MORE** MIND-BOGGLING!



NEWTON



ISAAC NEWTON

ENGLAND, 1642 - 1727

WAS NOT AN AGREEABLE MAN,
BUT HE DID NOT HAVE SUCH AN AGREEABLE EARLY LIFE:



HE STUDIED AT CAMBRIDGE, WHERE HE WAS AN AVERAGE STUDENT.

IN 1666 THE UNIVERSITY CLOSED DUE TO THE PLAGUE AND NEWTON CONTINUED HIS STUDIES AT HOME.



IN 1667 HE RETURNED TO CAMBRIDGE AS A POSTGRADUATE.

HE BUILT HIS OWN LABORATORY AND MADE THE FIRST REFLECTING TELESCOPE.



NEWTON WAS A RATHER SOLITARY PERSON WHO PREFERRED WORKING ON HIS MANY PROJECTS IN PRIVATE.

WHAT'S HE DOING IN THERE?

I HATE PEEPING TOMS!

thick wall around his private garden

IN 1648 EDMOND HALLEY VISITED HIM.

PROFESSOR, I HAVE A QUESTION...

aged 27

HALLEY LATER BECAME FAMOUS FOR HIS STUDY OF HALLEY'S COMET, WHICH WAS OBSERVED IN 1681.

aged 41

KEPLER STATES THAT PLANETS MOVE IN **ELLIPSES** - BUT HOW DO WE PROVE THAT?

OH, THAT.

I CALCULATED IT ONCE, MUST BE HERE SOMEWHERE...

YOU... CALCULATED IT...?!

HMM... I CAN'T FIND IT.

WILL YOU DO YOUR CALCULATIONS AGAIN, PLEASE ?!

HMM. OKAY.

NOW THAT I'M AT IT, I MIGHT AS WELL EXPAND IT A LITTLE...

I'VE ALREADY SPENT SOME TIME THINKING ABOUT THESE THINGS, AFTER ALL...

TWO YEARS LATER

NEWTON GIVES US **UNIVERSAL LAWS** THAT EXPLAIN ALL TERRESTRIAL AND CELESTIAL MOTION! THIS FUNDAMENTALLY CHANGES THE WAY WE LOOK AT REALITY!

THERE!

GENIUS!

THE ROYAL SOCIETY

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA
AUCTORE
ISAACO NEWTONO, EQ. AGRICOL.

Optice, Geometricæ, & Astronomicæ
libri tres. Typis Thomæ Le Neve & Transilvii Jacquot
Ex Gallicana Bibliotheca Regiâ
MDCCLXXII. Londini.



HIS BOOK **PRINCIPIA** MADE NEWTON
WIDELY KNOWN AS A BRILLIANT SCIENTIST...

GOOD!

NOW I CAN CONTINUE ON THE WORK
THAT IS **REALLY** IMPORTANT!



...BUT MOST OF HIS WORK WAS ABOUT
VASTLY DIFFERENT MATTERS!



NEWTON WAS DEEPLY RELIGIOUS AND
SEARCHED THE BIBLE FOR HIDDEN MESSAGES.

EVERYBODY KEEPS PREDICTING THE END OF THE
WORLD USING BIBLICAL CALCULATIONS...

...AND THEN IT
DOESN'T COME! THEY
DISCREDIT THE BIBLE!

I'LL WORK IT OUT
ONCE AND FOR ALL!

THE APOCALYPSE
WILL DEFINITELY NOT
OCCUR BEFORE
2060!



HE WAS VERY SECRETIVE ABOUT
MOST OF THIS WORK.

WELL,
OF COURSE!

MANY PRACTICES OF
ALCHEMY ARE ILLEGAL!
AND RELIGION IS
SUCH A SENSITIVE
SUBJECT!

For instance: I'd better
not let it be publicly known
that I don't
believe in the
Holy Trinity!



LATER IN LIFE HE BECAME MASTER OF
THE MINT, A TASK HE TOOK VERY SERIOUSLY.

I HATE
COUNTERFEITERS!

I WANT THEM HANGED,
DRAWN AND QUARTERED!!!



HE WAS ALSO A MEMBER OF THE BRITISH
PARLIAMENT, BUT MADE NO
POLITICAL STATEMENTS OF NOTE.

ANY
COMMENTS? YES! CAN THE WINDOW BE CLOSED?
I HATE DRAFTS!



HE REMAINED A BACHELOR ALL HIS LIFE.
BY THE END OF IT, HE LIVED WITH HIS NIECE
AND HER HUSBAND IN WESTMINSTER.

THERE'S A LOT OF THINGS I HATE,
BUT I **LOVE** MY NIECE!



CATHERINE
BARTON
1679-1739

smart, beautiful
& admired by
many

NEWTON DIED IN HIS SLEEP ON
MARCH 31, 1727 - AGED 84.

HE LIES BURIED IN WESTMINSTER ABBEY.

HIC DEPOSITUM EST
QUOD MORTALE FUIT
ISAACI NEWTONI

NEWTON IS CONSIDERED TO BE THE FIRST AND MOST FAMOUS **MODERN SCIENTIST**.

BUT I STATE THAT NEWTON WAS NOT THE FIRST
OF THE AGE OF REASON: HE WAS THE LAST OF
THE **MAGICIANS** !



JOHN MAYNARD KEYNES
(1883-1946)

BOUGHT A STACK OF
NEWTON'S UNPUBLISHED
MANUSCRIPTS IN
1942

IT MIGHT WELL BE THAT NEWTON HAD ASPERGER
SYNDROME - A FORM OF AUTISM !



SIMON BARON-COHEN
(b. 1958)

PROFESSOR OF
DEVELOPMENTAL
PSYCHOPATHOLOGY,
EXPERT IN RESEARCHING
AUTISM

NEWTON WROTE OF HIMSELF, BY THE END OF HIS LIFE:

"I don't know what I may seem to the world, but as to myself, I seem to have been only like a boy playing on the sea-shore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."



NEWTON'S LAWS

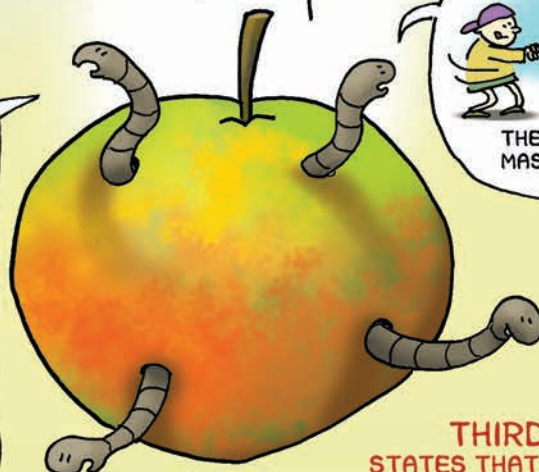
NEWTON'S FIRST LAW OF MOTION
DESCRIBES HOW AN OBJECT MOVES WHEN NO FORCE IS ACTING ON IT.

IN OTHER WORDS:



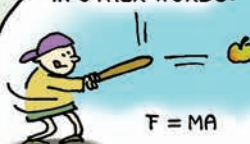
A FALLING APPLE WILL KEEP ON FALLING

...if it were falling in a **VACUUM**, that is!
In reality, this apple experiences all kinds of forces, like **FRICTION** and **GRAVITY**!



NEWTON'S SECOND LAW OF MOTION
DESCRIBES HOW FORCE AND ACCELERATION ARE RELATED.

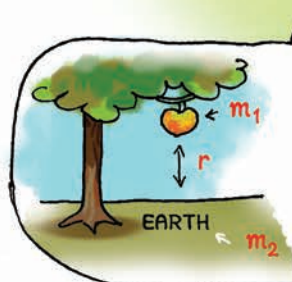
IN OTHER WORDS:



THE FORCE (F) IS EQUAL TO THE MASS (M) TIMES ACCELERATION (A).

NEWTON'S THIRD LAW OF MOTION
STATES THAT EVERY ACTION HAS AN EQUAL AND OPPOSITE REACTION.

NEWTON'S LAW OF GRAVITY $F = G \frac{m_1 m_2}{r^2}$



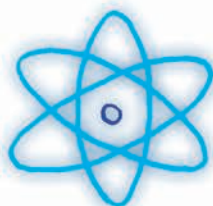
The attraction between two objects depends on their mass (m) and the square of the distance (r) between them
- and also on the so-called "gravitational constant" (G).

THE EARTH PULLS AT THE APPLE, BUT THE APPLE PULLS **JUST AS HARD** AT THE EARTH.



Earth is much heavier than the apple, that's why the motion of earth changes much less than that of the apple.

PHYSICS



HISTORY OF PHYSICS



WHEN DID PHYSICS START?

WHEN WE STARTED OBSERVING THE STARS?

WHEN WE FIRST APPLIED PHYSICAL FORCES IN EQUIPMENT?

WHEN WE STOPPED EXPLAINING NATURAL PHENOMENA IN MYTHOLOGICAL TERMS?

LIKE LEVERS

THUNDER! ZEUS IS AT IT AGAIN!

OR - HERE'S A THOUGHT - MAYBE IT'S CLOUDS COLLIDING!

THE ANCIENT GREEKS CAME UP WITH PHYSICAL THEORIES ABOUT NATURAL PHENOMENA.

THEIR IDEAS DEFINED THE GENERAL WORLD VIEW UNTIL THE END OF THE MIDDLE AGES.

WE'RE LOOKING FOR **GENERAL PRINCIPLES**!

WHAT IS MATTER MADE OF?

WHAT CAUSES CHANGE?

WHAT MOVES THE STARS?

THERE ARE **FIVE ELEMENTS**: EARTH, WATER, AIR, FIRE & ETHER.

ALL CELESTIAL MOTION IS **PERFECT** - THAT MEANS: PERFECTLY **CIRCULAR**.

MOTION ON EARTH IS **IMPERFECT**.

CELESTIAL BODIES MOVE IN ETHER!

EARTH IS THE CENTER OF THE UNIVERSE!

EARTH IS A FLAT DISK!

THAT'S WHY IT'S NO USE PERFORMING EXPERIMENTS.

PHYSICS IS MAINLY PHILOSOPHY!

IN THE SIXTEENTH CENTURY, NEW INSIGHTS CAUSED A REVOLUTIONARY NEW WORLD VIEW.

THE EARTH IS **NOT** THE **CENTER**! EARTH AND THE OTHER PLANETS REVOLVE AROUND THE SUN!

IN **ELLIPTICAL ORBITS**! NOT IN CIRCLES!

I'LL TELL YOU EVEN MORE: THEY MOVE ACCORDING TO THE **SAME LAWS** AS OBJECTS ON EARTH!

LIKE ONE BIG **MECHANICAL MACHINE**, SO TO SPEAK!

But what about the **PERFECTION** of the heavens?!

$$F = G \frac{m_1 m_2}{r^2}$$

$$F = ma$$

COPERNICUS
1473 - 1543
POLAND

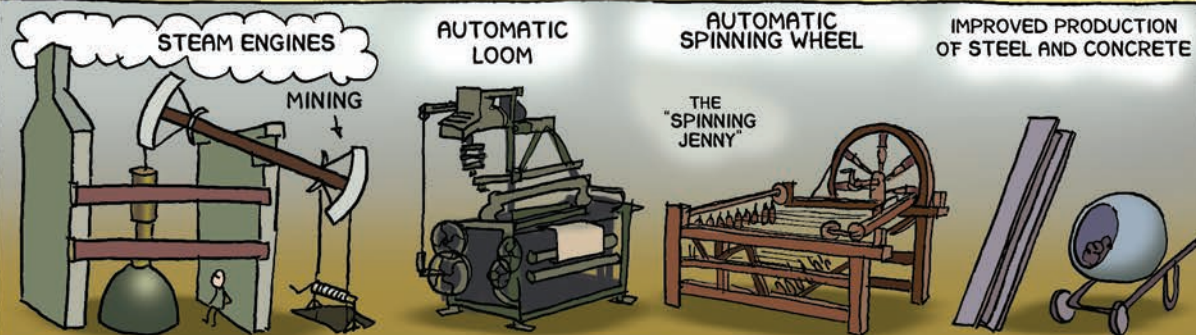
GALILEO
1564 - 1642
ITALY

KEPLER
1571 - 1630
GERMANY

NEWTON
1642 - 1727
ENGLAND

18TH CENTURY

IN THE 18TH AND 19TH CENTURY THE **INDUSTRIAL REVOLUTION** TOOK PLACE IN WESTERN EUROPE.



PHYSICAL RESEARCH FLOURISHED LIKE NEVER BEFORE! MANY SCIENTISTS FROM THIS PERIOD GAVE THEIR NAME TO UNITS AND PROCESSES THAT WE STILL USE TODAY:

<p>TEMPERATURE SCALES:</p> <p>FAHRENHEIT IS USED IN THE USA!</p>	<p>CELSIUS IS USED EVERYWHERE ELSE!</p>	<p>WATT IS A UNIT OF POWER!</p>	<p>COULOMB IS A UNIT OF ELECTRICAL CHARGE!</p>	<p>VOLT IS A UNIT OF ELECTRIC POTENTIAL!</p>	<p>DALTON IS A UNIT OF ATOMIC MASS!</p>
					
<p>D.G. FAHRENHEIT 1686 - 1763 GERMANY</p>	<p>ANDERS CELSIUS 1701 - 1744 SWEDEN</p>	<p>JAMES WATT 1736 - 1819 ENGLAND</p>	<p>C.-A. DE COULOMB 1736 - 1806 FRANCE</p>	<p>ALESSANDRO VOLTA 1745 - 1827 ITALY</p>	<p>JOHN DALTON 1766 - 1844 ENGLAND</p>
<p>AMPÈRE IS A UNIT OF ELECTRIC CURRENT!</p>	<p>FARAD IS A UNIT OF ELECTRIC CAPACITY!</p>	<p>JOULE IS A UNIT OF ENERGY!</p>	<p>PASTEURIZATION IS A PROCESS OF HEATING LIQUID FOODS, LIKE MILK.</p>	<p>I LEFT BEHIND THE NOBEL FOUNDATION WHICH AWARDS THE NOBEL PRIZES!</p>	<p>THE UNIT OF SOUND, DECIBEL, WAS NAMED AFTER ME!</p>
					
<p>A.-M. AMPÈRE 1775 - 1836 FRANCE</p>	<p>M. FARADAY 1791 - 1867 ENGLAND</p>	<p>JAMES JOULE 1818 - 1889 ENGLAND</p>	<p>LOUIS PASTEUR 1822 - 1895 FRANCE</p>	<p>ALFRED NOBEL 1833 - 1896 SWEDEN</p>	<p>ALEXANDER BELL 1847 - 1922 SCOTLAND/USA</p>

IN THE EARLY 20TH CENTURY, A RADICAL NEW BASIS WAS LAID FOR PHYSICS.

WE'RE DOING EXPERIMENTS WITH RADIATION OF HEATED OBJECTS!

ACCORDING TO OUR CALCULATIONS, EVEN A COZY FIRE WOULD PRODUCE SO MUCH RADIATION WE COULD NOT POSSIBLY SURVIVE IT!

BUT THAT'S NOT WHAT HAPPENS.

WE MUST TREAT RADIATION AS CONSISTING OF SMALL **PACKETS OF ENERGY!**
CALLED: QUANTA, SINGULAR: **QUANTUM!**

BLACK BODY

THE ULTRAVIOLET CATASTROPHE!

WHY?!

IT'S NOT PRETTY, BUT IT WORKS - UNTIL WE FIND A BETTER EXPLANATION!



QUANTUM THEORY OVERTURNED A NUMBER OF FUNDAMENTAL ASSUMPTIONS ABOUT REALITY.

THE QUANTUM MODEL FITS A LOT MORE DATA WE COULD NOT EXPLAIN BEFORE!

BUT A QUANTUM BEHAVES LIKE A WAVE **AND** A PARTICLE! THAT'S NOT POSSIBLE!

IN THE QUANTUM MODEL, OUTCOMES ARE NEVER FIXED BUT DEPENDENT ON **PROBABILITY!**

BUT THAT CAN'T BE HOW REALITY WORKS, SURELY?

OH NO! DO YOU THINK IT COULD BE **REAL**?!

GOD DOES NOT PLAY DICE WITH THE UNIVERSE!

FAMOUS QUOTE BY EINSTEIN

LIGHT = PHOTON = **QUANTUM**



DURING THE PAST CENTURY, THERE HAS BEEN MORE RESEARCH IN PHYSICS THAN EVER BEFORE! SCIENTISTS INCREASINGLY WORK IN INTERNATIONAL TEAMS, EXCHANGING RESULTS.

THERE ARE MORE SUBAREAS THAN EVER BEFORE!

RESEARCH IS OFTEN BACKED BY GOVERNMENTS AND INDUSTRIES - NOT JUST UNIVERSITIES ANYMORE!

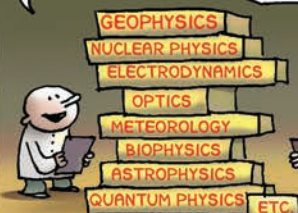
AT THE MOMENT WE HAVE TWO THEORIES TO EXPLAIN REALITY:

QUANTUM THEORY FOR THE VERY SMALL...

...AND **EINSTEIN'S THEORY OF RELATIVITY** FOR THE REST!

WILL WE EVER BE ABLE TO UNITE THESE TWO?

INTO ONE COMPREHENSIVE **THEORY OF EVERYTHING?**



THREE SUBAREAS OF PHYSICS





ELECTRICAL PHENOMENA HAVE BEEN KNOWN SINCE ANCIENT TIMES.

LIGHTNING
FOR INSTANCE

ELECTRIC EELS
ALSO CALLED
"THE THUNDER OF THE NILE"

AMBER
Look what happens
when I rub it vigorously!

Gross!



THERE ARE MANY MORE SYMBOLS
FOR ELECTRICAL APPLIANCES:



MOTOR



DIMMER



AMPLIFIER

ALTERNATING CURRENT
(OUTLET)

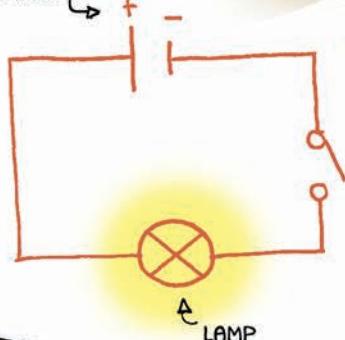


FUSE



PUSH BUTTON (a doorbell for instance)

BATTERY



THIS IS HOW YOU DRAW
AN **ELECTRICAL CIRCUIT** -
IN THIS CASE FOR A LAMP
WITH A BATTERY!

ON/OFF
SWITCH

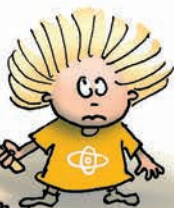


STATIC ELECTRICITY
IS A SHORTAGE OR SURPLUS OF ELECTRONS,
MAKING SOMETHING **ELECTRICALLY CHARGED**.

For instance HAIR

or a WOOLLEN SWEATER

WOOL, like HAIR,
is a material
that easily
loses its
electrons.



BRUSHING makes electrons jump away,
leaving the hair **POSITIVELY CHARGED**.

ME →
10 years old



LOOK!

I CAN DO **MAGIC**!

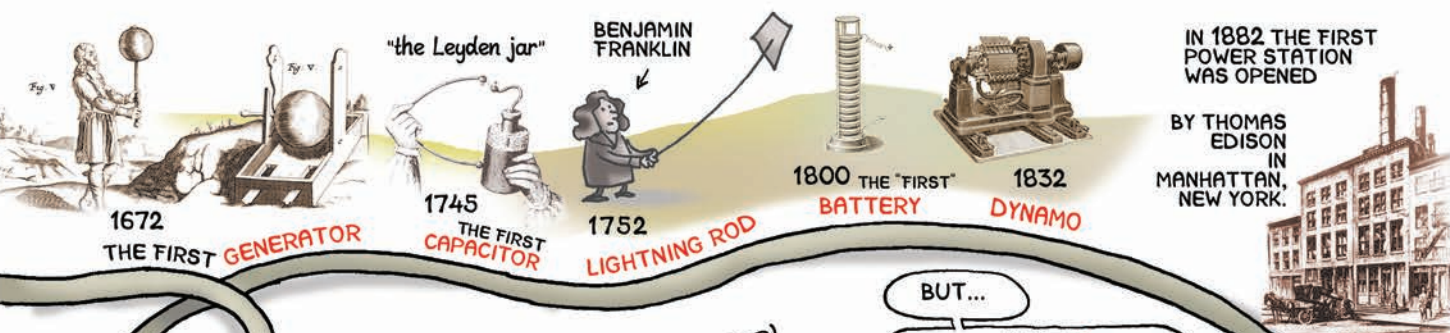
SPARK

CRACKLE



TURN OFF
THE LIGHTS!

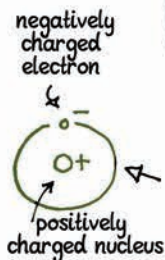
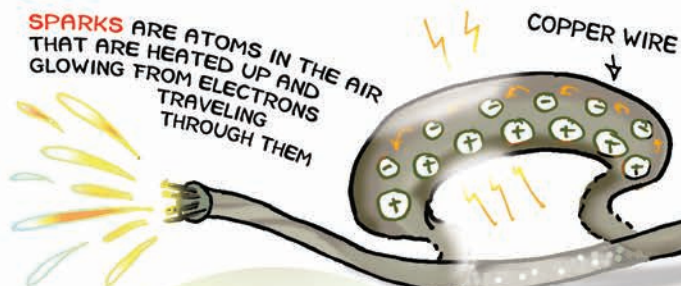
FROM THE 17TH CENTURY ON, THIS MYSTERIOUS POWER WAS HARNESSSED IN ALL KINDS OF **MACHINES**.



IN **CONDUCTIVE MATERIALS** (LIKE COPPER) **NEGATIVE ELECTRONS** MOVE FREELY BETWEEN **POSITIVE ATOMS**.

ELECTRICAL ENERGY CAN TRAVEL EASILY THROUGH THIS STREAM OF ELECTRONS.

SPARKS ARE ATOMS IN THE AIR THAT ARE HEATED UP AND GLOWING FROM ELECTRONS TRAVELING THROUGH THEM



BUT...

...WHAT IS **ELECTRICITY** EXACTLY?

WE FIGURED THAT OUT AS LATE AS THE TWENTIETH CENTURY!

How does it work?

When we discovered what atoms look like!



THE HUMAN BODY IS ALSO FULL OF ELECTRITY !

FOR INSTANCE IN **NERVE CELLS**

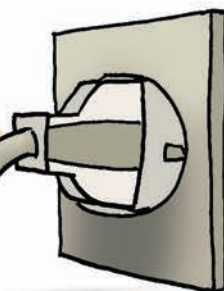


through **SODIUM IONS** instead of electrons

DO YOU EVER FEEL TIRED AND RUN DOWN? REMEMBER:

MY BODY IS **FULL OF ENERGY!**

That's a scientific fact!



THERMODYNAMICS

CAME UP IN THE 19TH CENTURY,
WITH THE SPECIFIC GOAL OF
ENHANCING STEAM ENGINES.

THERMODYNAMICS STUDIES THE
BEHAVIOR OF SYSTEMS
WITH REGARD TO HEAT, ENERGY,
PRESSURE AND THE EXCHANGE
OF HEAT WITH THE ENVIRONMENT.

SUCH A SYSTEM CAN
BE A MACHINE...

...OR EVEN AN ORGANISM!
THE HUMAN BODY IS ALSO A
THERMODYNAMIC SYSTEM!

OR AN EGG THAT'S
BEING BOILED,

OR
EARTH,

OR EVEN THE
UNIVERSE AS
A WHOLE!

THE **FIRST LAW** OF THERMODYNAMICS:
(ALSO CALLED **THE LAW OF CONSERVATION OF ENERGY**)

THE TOTAL AMOUNT OF ENERGY
IN A CLOSED SYSTEM REMAINS CONSTANT.

THE **SECOND LAW** OF
THERMODYNAMICS:

DIFFERENT PARTS IN A CLOSED
SYSTEM TEND TO SPREAD EVENLY
ACROSS THE SYSTEM UNTIL
EQUILIBRIUM IS ESTABLISHED.

THIS IS CALLED
ENTROPY.

SIR ISAAC'S
BUNGEE
EXPERIENCE



MOTION

NEWTON'S APPLE FELL DOWN IN A **STRAIGHT LINE**!
THERE ARE ALSO OTHER KINDS OF MOTION:

ROTATIONAL MOTION!

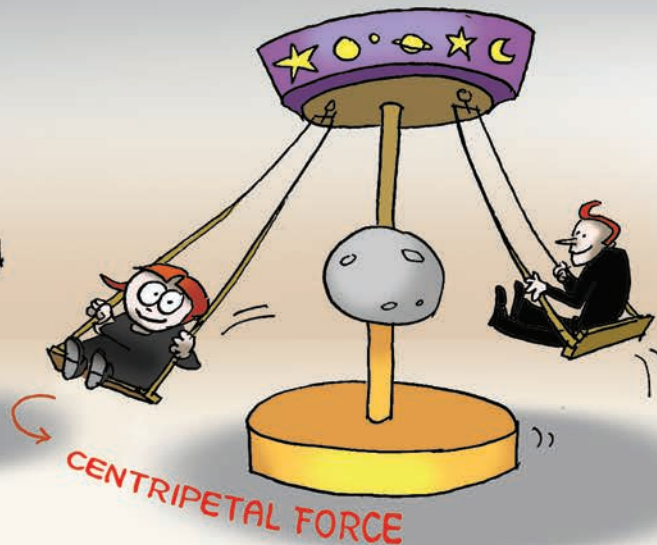
FOR INSTANCE
THE MOON AROUND
THE EARTH



BUT ALSO
EARTH AROUND ITS
OWN AXIS

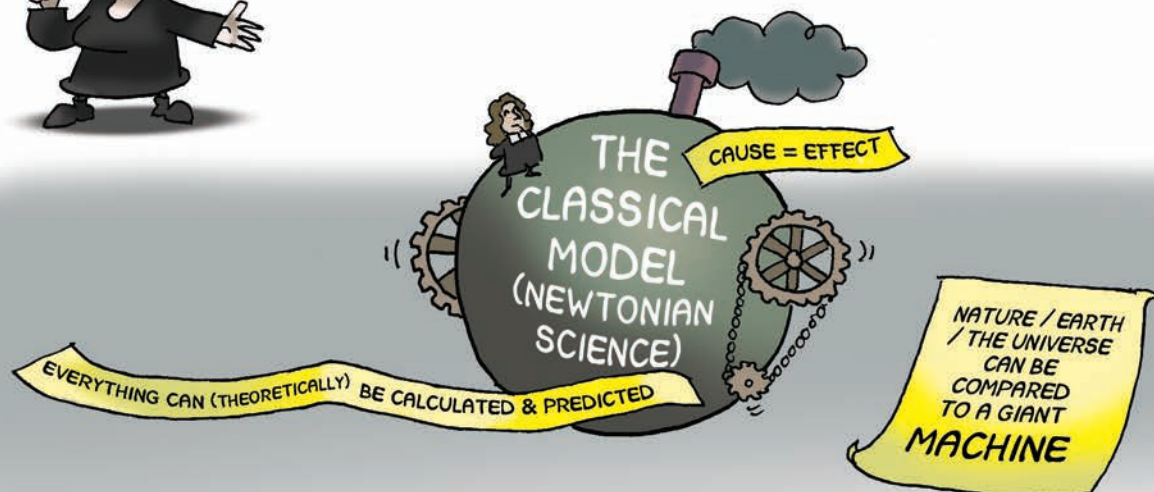


OSCILLATORY MOTION!





THESE THREE SUBAREAS AS DESCRIBED HERE,
ARE PART OF **CLASSICAL MECHANICS** !



UNTIL THE TWENTIETH CENTURY THIS WAS
THE MODEL SCIENTISTS WORKED WITH!

LOOK OUT!

AND THEN...

17TH → 19TH CENTURY



CLASSICAL



THEORY OF
RELATIVITY

QUANTUM
THEORY

EARLY 20TH CENTURY



BUT THAT'S FOR LATER!
WE NOW FOLLOW OUR
THREAD, PICKING IT UP
AT THE
NINETEENTH CENTURY!



THE NINETEENTH CENTURY



AGE
OF
DISCOVERIES

THE NINETEENTH CENTURY

WAS A TIME OF RAPID DEVELOPMENTS IN MANY AREAS:

IN INDUSTRY:

MACHINES
DO THE WORK BETTER, FASTER
AND CHEAPER THAN PEOPLE!

SOCIALLY:

WORKERS MOVED FROM THE
COUNTRY TO THE CITIES
TO WORK IN FACTORIES.



THE INDUSTRIAL REVOLUTION

IN THE MEDIA:

WE ARE
PRINTING MORE THAN EVER!

ASTRONOMY!

BOTANY!

GEOLOGY!

INTERESTING!

LET'S SET UP
SPECIAL CLUBS!



IN SCIENCE:

BETTER INSTRUMENTS!

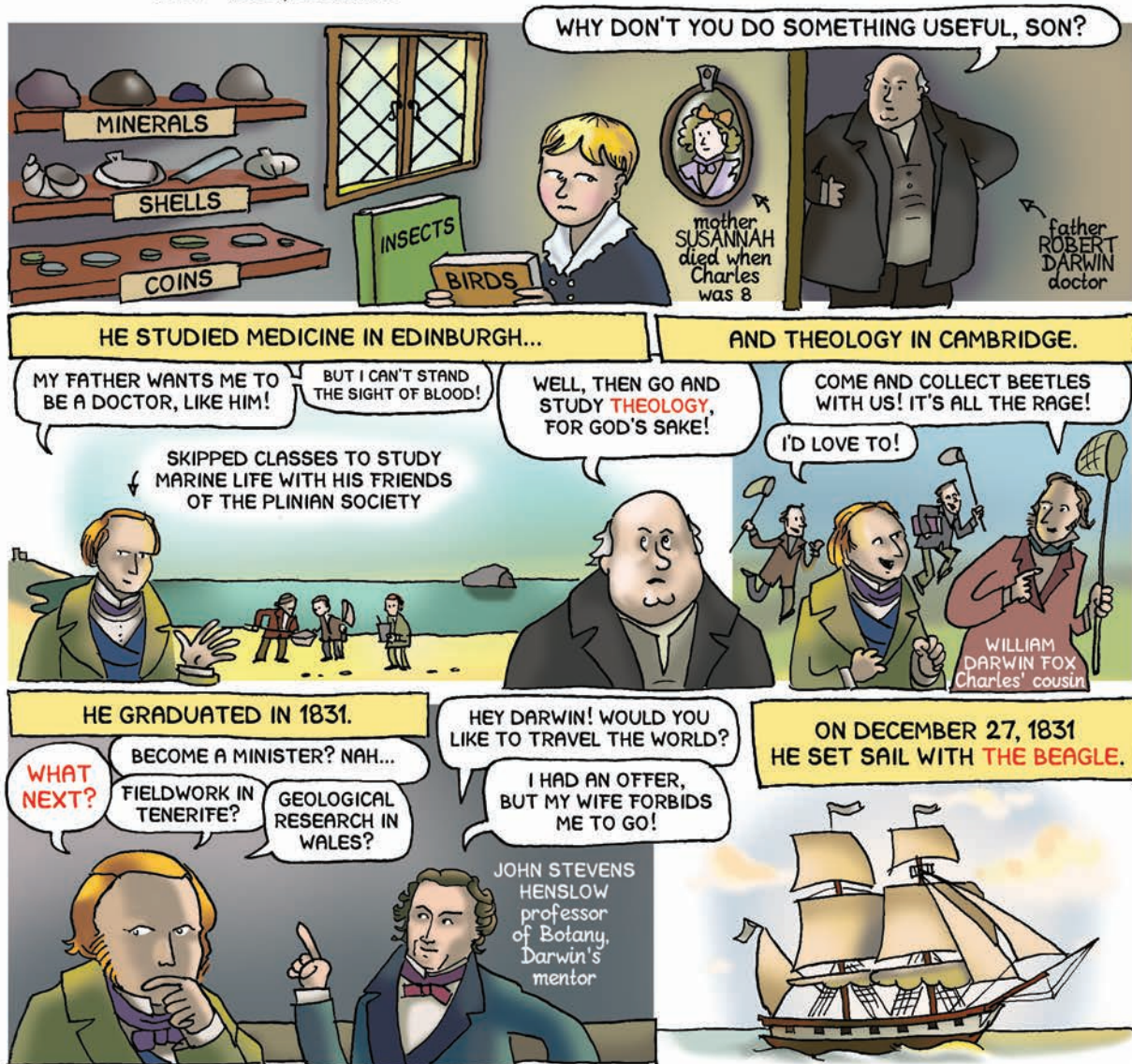
BETTER
TRANSPORT!

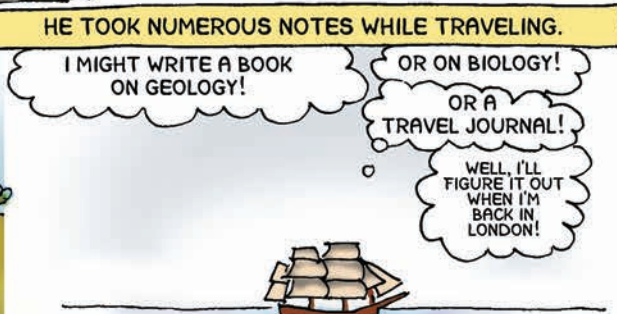
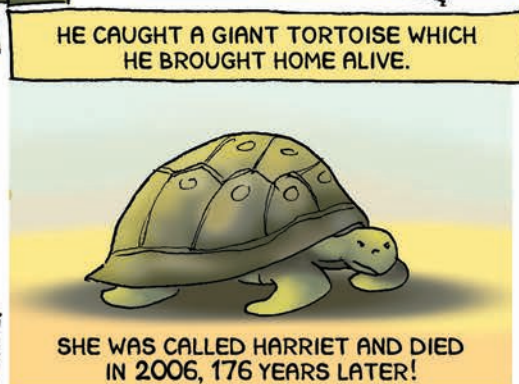
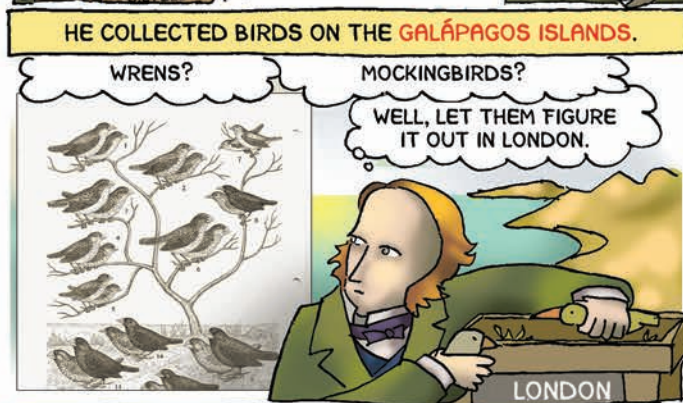
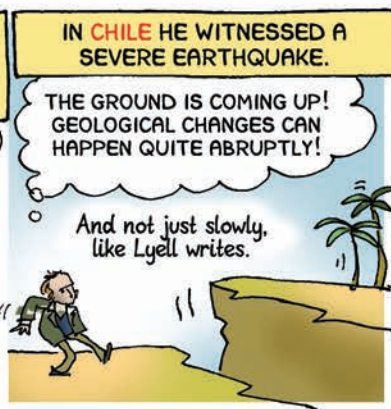
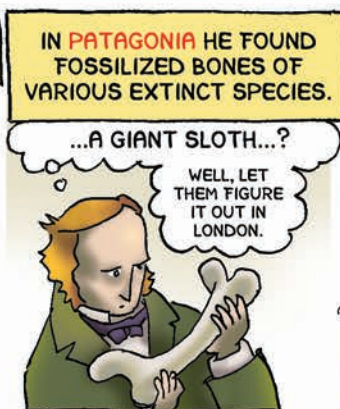
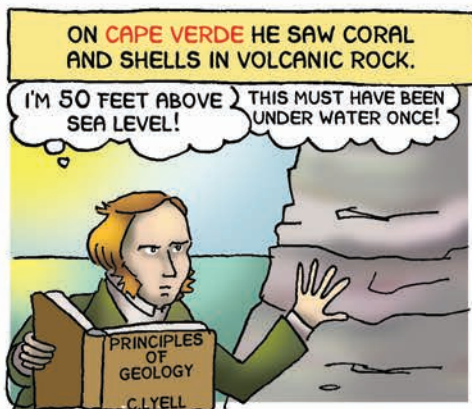
LET'S GO EXPLORING, SO WE CAN MAKE
MAPS OF THE WHOLE WORLD!



CHARLES DARWIN

1809 - 1882, ENGLAND





THE BEAGLE RETURNED TO ENGLAND ON OCTOBER 2, 1836 - AFTER ALMOST FIVE YEARS.



FROM 1837 ON, DARWIN PRIVATELY DEVELOPED HIS THEORY ON HOW NEW SUBSPECIES COULD EVOLVE FROM ONE DISTINCT ANIMAL SPECIES.

HMM... COULD IT BE THEIR BEAKS ADAPTED TO THE KINDS OF FOOD THAT WAS FOUND ON EACH ISLAND?

CAN SPECIES SLOWLY EVOLVE, INFLUENCED BY THEIR ENVIRONMENT?

for holes and crevices

for hard nuts

IF SO, THERE ARE A LOT OF IMPLICATIONS!

I'D BETTER THINK CAREFULLY ABOUT THIS.

IN 1839, HE MARRIED HIS COUSIN EMMA.

Should I marry or not? *

MARRY:

- constant companion
- friend in old age
- better than a dog anyhow

NOT MARRY:

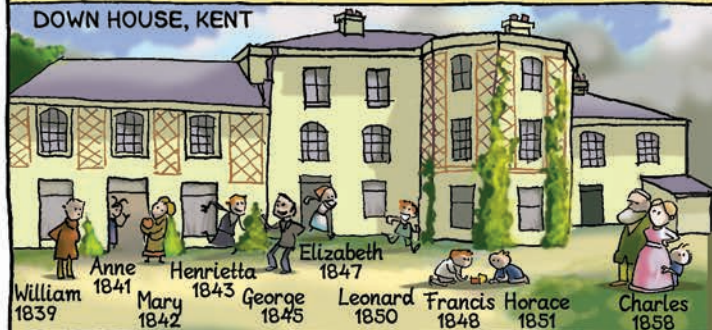
- less money for books
- terrible loss of time



* from Darwin's notebook 1838

OVER THE NEXT TWENTY YEARS, HE HAD TEN CHILDREN AND WORKED STEADILY ON HIS THEORY.

DOWN HOUSE, KENT



IN 1859 HE WAS READY: THE ORIGIN OF SPECIES WAS PUBLISHED AND WAS AN IMMEDIATE BESTSELLER!

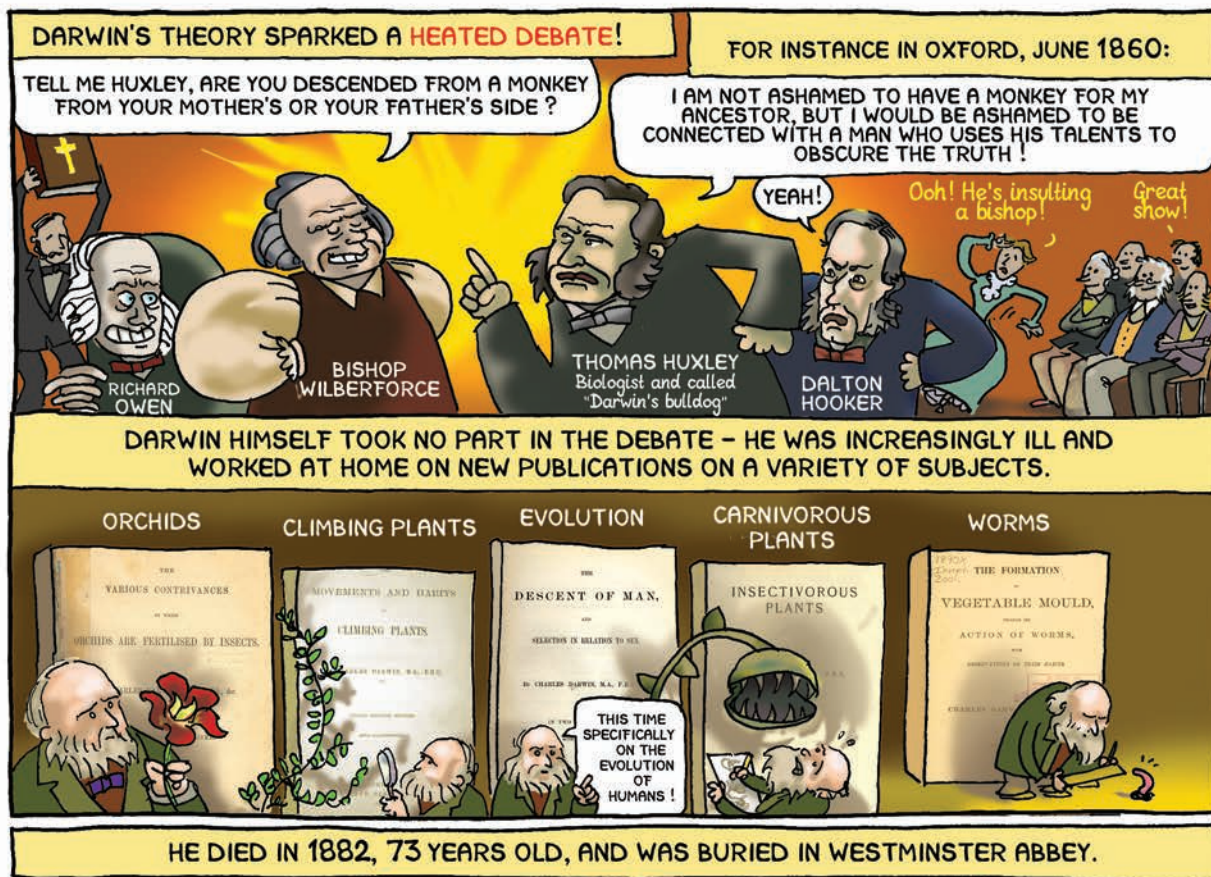
IN THE MEANTIME, ALFRED RUSSEL WALLACE HAD THOUGHT OF THE SAME THEORY, INDEPENDENTLY.

If I didn't publish now, he would get all the credit!

I GUESS THE TIME WAS RIPE FOR EVOLUTION!



WALLACE



HEY, SHOULDN'T YOU, AS A **THEOLOGIST**, COMMENT A BIT MORE ON DARWIN?

YOU MEAN ABOUT THE WHOLE **EVOLUTION VERSUS CREATION** DEBATE?

I THINK IT'S SUCH A NON-ISSUE! NO RELIGIOUS PERSON I KNOW LOSES ANY SLEEP OVER IT!

BESIDES, ORIGINALLY, THE ISSUES WITH DARWIN'S THEORY WERE NOT ABOUT CREATION, BUT ABOUT **NATURAL THEOLOGY**!

NATURAL THEOLOGY

DURING MY AGE AND STUDIES, **NATURAL THEOLOGY** PLAYED AN IMPORTANT ROLE!

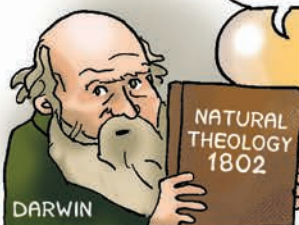
ESPECIALLY THIS BOOK BY THEOLOGIST **WILLIAM PALEY**!

WE CAN GET TO **KNOW GOD** BY **STUDYING NATURE**!

IMAGINE: YOU'RE WALKING ON A DESERTED BEACH AND FIND A **WATCH**...

...ISN'T IT OBVIOUS IT MUST HAVE BEEN MADE BY AN **INTELLIGENT CREATOR**?

The same goes for Nature!



NATURE IS SO INGENUOUS AND ELEGANT - IT MUST BEAR WITNESS OF AN **INTELLIGENT DESIGN**!

BUT MY THEORY SUGGESTED THAT ALL THAT COMPLEX BEAUTY IS THE RESULT OF A **NATURAL PROCESS**!



OLD DARWIN



AND WHAT
A PROCESS!

A **COLD, CRUEL** AND **ARBITRARY** PROCESS IN WHICH
COUNTLESS SPECIES ARE DOOMED TO EXTINCTION
IN FAVOR OF OTHERS THAT ARE BETTER ADAPTED!

WHAT KIND OF
INTELLIGENT DESIGN
IS THAT ?!

SO...

WE CAN **NOT** GET
TO KNOW GOD
THROUGH NATURE!

ONLY THROUGH THE
REVELATION OF SCRIPTURE
- THE BIBLE!

THEOLOGAINS

WITH MY THEORY,
I INVALIDATED
NATURAL
THEOLOGY...

...AND BANNED GOD
FROM NATURE!

SORRY! IT SEEMS THAT YOU
ARE **OUTSIDE** CREATION!

DID GOD DELIBERATELY
CREATE THE
PARASITIC WASP ?



DID GOD DELIBERATELY
LET MY TEN-YEAR-OLD
DAUGHTER DIE?

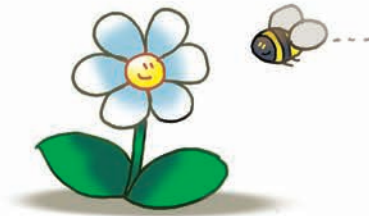
A GOD WHO COULD COME UP WITH THE
MECHANISM OF EVOLUTION - DOES HE
KNOW **MERCY** AND **PITY** AT ALL...?



ANNE D. 1861

I DON'T
KNOW...

BIOLOGY



HISTORY OF BIOLOGY



WHEN DID BIOLOGY START?

WHEN WE STARTED NAMING PLANTS?

WHEN WE STARTED FARMING?

WHEN WE STUDIED A SKELETON FOR THE FIRST TIME?

WHEN WE STARTED USING PLANTS AS MEDICINE?



SINCE ANCIENT TIMES, PEOPLE HAVE ACCUMULATED KNOWLEDGE OF PLANTS AND ANIMALS.

AYURVEDA ORIGINATED 3500 YEARS AGO IN INDIA AND IS STILL PRACTICED TODAY.

AROUND THE SAME TIME, THE EGYPTIANS STARTED DESCRIBING ILLNESSES AND THEIR CURES.

GREEK PHYSICIAN HIPPOCRATES (5TH CENTURY B.C.) IS CALLED 'FATHER OF WESTERN MEDICINE'.

IT'S ALL ABOUT BALANCE!

MEDICAL HEALTH AND SPIRITUAL HEALTH ARE INTERTWINED!



PAPYRUS
1600 B.C.

I MADE MY PUPILS SWEAR AN OATH TO KEEP TO CERTAIN PROFESSIONAL RULES!

MODERN DOCTORS STILL SWEAR A SIMILAR OATH!



IN THE MIDDLE AGES, THIS KNOWLEDGE WAS FURTHER ELABORATED.

IN THESE AGES, MY WORK WAS AUTHORITATIVE!

I INTRODUCED THE IDEA OF THE FOOD CHAIN!

MY BOOK WAS A STANDARD FOR CENTURIES!

I WROTE THIS PHARMACEUTICAL ENCYCLOPEDIA!

I KNEW A LOT ABOUT MEDICINAL PLANTS AND MINERALS!



4 FLUIDS
IN THE HUMAN BODY
• BLOOD
• YELLOW BILE
• BLACK BILE
• SLIME

4 TYPES OF PEOPLE:
• PASSIONATE
• CHARISMATIC
• MELANCHOLIC
• PHLEGMATIC

GALEN
129 - 200
TURKEY



AL-JAHIZ
781 - 869
IRAQ



AVICENNA
±980 - 1037
IRAN



IBN AL-BAITAR
1197 - 1248
ANDALUSIA



HILDEGARD OF BINGEN
1098 - 1179
GERMANY

IN THE RENAISSANCE, OLD BUT INCORRECT IDEAS WERE DISCARDED.

EVERYONE SEEMS TO BLINDLY ASSUME THAT GALEN WAS ALWAYS CORRECT - BUT DOES ANYONE EVER CHECK THIS?



ANDREAS VESALIUS
1514 - 1564
BELGIUM

HIS IDEAS ABOUT ANATOMY FOR INSTANCE?

NOOOO! GALEN CAN'T BE WRONG!

CAN HE?

THE PHYSICAL SCIENCES RELY TOO MUCH ON REASONING AND TOO LITTLE ON GOOD **OBSERVATIONS!** LET'S REMEDY THIS!



HE'S AN ARROGANT ASS - BRILLIANT, BUT AN ASS!

THE DR. HOUSE OF THE RENAISSANCE!

PARACELSUS
1493 - 1541
SWITZERLAND

IN THE 17TH AND 18TH CENTURY, MANY NEW SPECIES OF PLANTS AND ANIMALS WERE DISCOVERED.

LOOK AT ALL THIS STUFF WE FOUND IN THE NEW WORLD!



CARL LINNAEUS
1707 - 1778
SWEDEN

LET'S CAREFULLY **SYSTEMIZE** ALL OF THIS INFORMATION!

I BUILT ONE OF THE FIRST DECENT MICROSCOPES AND INTRODUCED THE CONCEPT OF THE **CELL!**

ROBERT HOOKE
1635 - 1703
ENGLAND

I AM CALLED THE **FATHER OF MICROBIOLOGY!**

DISCOVERIES:
- PROTOZOA
- RED BLOOD CELLS

ANTONIE VAN LEEUWENHOEK
1632 - 1723
THE NETHERLANDS

I STATED THAT **FOSSILS** ARE REMNANTS OF LIVING ORGANISMS!

NONSENSE! FOSSILS GROW LIKE THAT IN THE GROUND!

NICOLAS STENO
1638 - 1686
DENMARK

THE NINETEENTH CENTURY WAS A TIME OF RADICAL NEW THEORIES.

WE FORMULATED THE **CELL THEORY**:
- THE **CELL** IS THE BASIC UNIT OF STRUCTURE IN EVERY LIVING THING.
- CELLS MULTIPLY BY **DIVISION**.



SCHWANN
1810 - 1862
GERMANY

SCHLEIDEN
1804 - 1881
GERMANY

REMAK
1815 - 1865
POLAND/GERMANY

EARTH MUST BE MUCH **OLDER** THAN WE THOUGHT!

MAYBE EVEN 40 MILLION YEARS!

MORE!

LESS!

ALL THOSE GEOLOGICAL AND EVOLUTIONARY PROCESSES TAKE A LOT OF TIME!



LORD KELVIN
1824 - 1907
SCOTLAND

GEOLOGISTS,
PALEONTOLOGISTS,
BIOLOGISTS

I CAME UP WITH THE **THEORY OF EVOLUTION!**



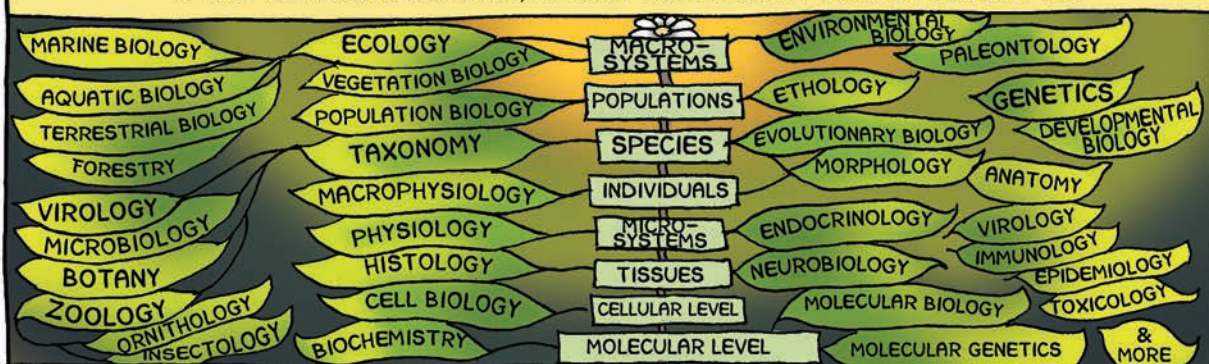
DARWIN
1809 - 1882
ENGLAND

AND I DISCOVERED THE LAWS OF **HEREDITY!**



MENDEL
1822 - 1884
AUSTRIA

IN THE TWENTIETH CENTURY, LOTS OF BRANCHES OF BIOLOGY DEVELOPED.



LATELY, DEVELOPMENTS IN SOME OF THESE BRANCHES MOVE AT INCREDIBLE SPEED.

BIOLOGY USED TO BE **DESCRIPTIVE** FOR CENTURIES, BUT NOW BIOLOGISTS ARE **EXPERIMENTING** MORE & MORE!

IN AGRICULTURE:

MORE!

ESPECIALLY MORE OF THE SAME!

IN THE PHARMACEUTICAL INDUSTRY:

WE'RE PRODUCING MEDICINE TO MAKE PEOPLE BETTER...

...BUT NOT SO MUCH BETTER THAT THEY DON'T NEED MEDICINE ANYMORE, OF COURSE!

MOST PROFITABLE MEDICINE:

* CHOLESTEROL REDUCERS
* ANTACIDS
* ANTI-DEPRESSANTS

AND THE FUTURE WILL BRING EVEN MORE POSSIBILITIES!

GENETIC MANIPULATION:

GROW YOUR OWN ORGANS!

SAFE!

FROM YOUR OWN DNA!

NO MORE WAITING LISTS FOR DONOR ORGANS!

WAIT!

CAN WE REALLY DO THIS? CAN WE PLAY GOD?

WE ALREADY ARE!

WE ARE CLONING ENDANGERED SPECIES!

MOUFFLON

NANOBOT

BIOTECHNOLOGY

WE SHOULD PAY MORE ATTENTION TO ECOLOGICAL SYSTEMS!

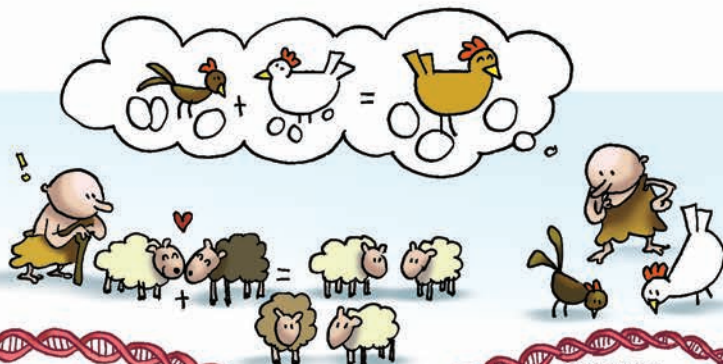
ORGANISMS DON'T EXIST IN ISOLATION - THEY ARE CONNECTED TO EACH OTHER AND THEIR ENVIRONMENT!

ECOLOGY

GENETICS



A LONG TIME AGO, PEOPLE DISCOVERED THAT CERTAIN TRAITS ARE PASSED ON FROM GENERATION TO GENERATION.



DNA LOOKS A BIT LIKE THIS IN CLOSE-UP!

IT CONSISTS OF TWO "SPINES" OF SUGAR AND PHOSPHATE MOLECULES, JOINED BY FOUR DIFFERENT BASES: GUANINE, CYTOSINE, ADENINE AND THYMINE!

DISCOVERED BY ME IN 1869!

FRIEDRICH MIESCHER

YES, BUT I WAS THE ONE WHO DISCOVERED THAT DNA CONTAINS GENETIC INFORMATION! IN 1944!

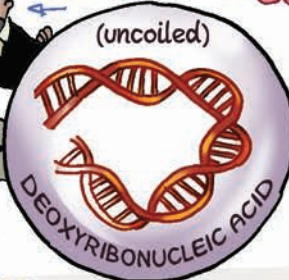
OSWALD AVERY

WE DISCOVERED THE SPECIAL HELIX STRUCTURE OF DNA IN 1953!

WATSON

FRANKLIN

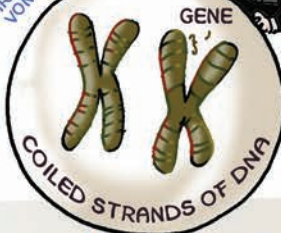
CRICK



IN THE DNA!

DISCOVERED BY ME AROUND 1850!

GENE



IN THE CHROMOSOMES...

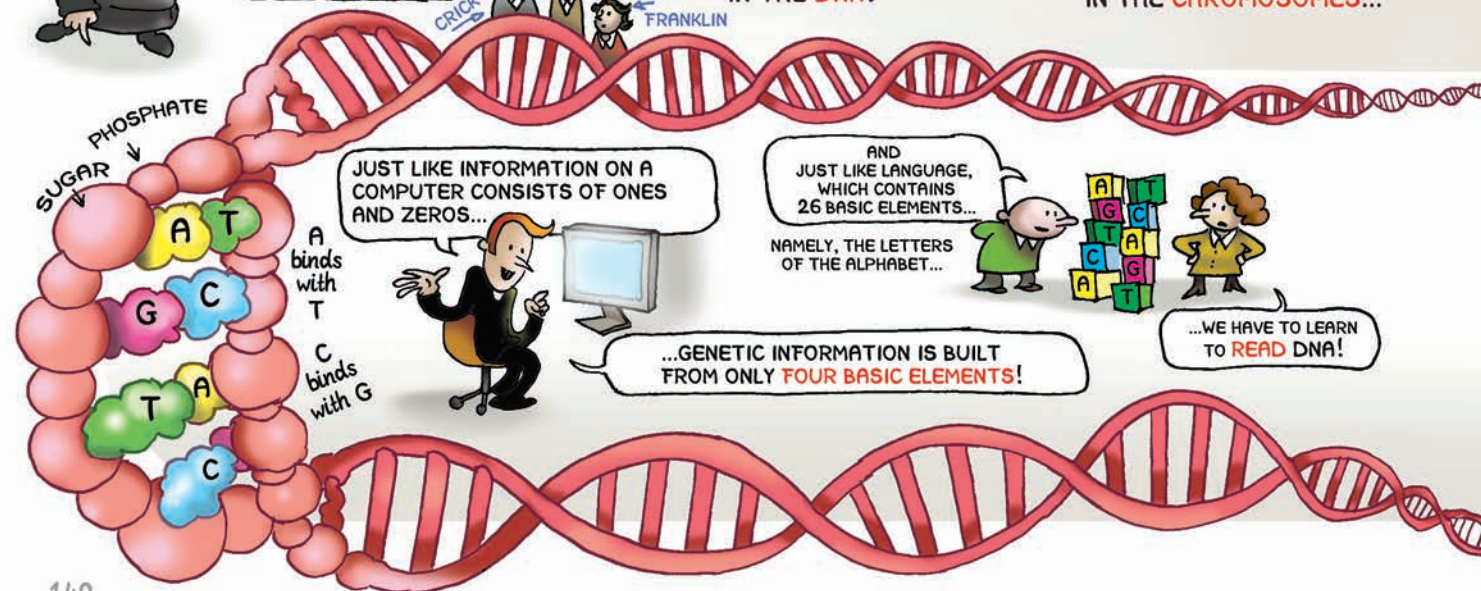
JUST LIKE INFORMATION ON A COMPUTER CONSISTS OF ONES AND ZEROS...

AND JUST LIKE LANGUAGE, WHICH CONTAINS 26 BASIC ELEMENTS...

NAMELY, THE LETTERS OF THE ALPHABET...

...GENETIC INFORMATION IS BUILT FROM ONLY **FOUR BASIC ELEMENTS!**

...WE HAVE TO LEARN TO **READ DNA!**



GREGOR MENDEL
(1822-1889) WAS
AN AUSTRIAN MONK
WHO WAS THE FIRST
TO DESCRIBE THE
**LAWS OF
HEREDITY.**

WITH PEA PLANTS!

I RESEARCHED
SEVERAL
TRAITS LIKE
HEIGHT, KIND
OF FLOWERS
AND COLOR
& SHAPE OF
THE PEAS!

THIS WAY, I FIGURED OUT THAT THERE ARE
DOMINANT AND RECESSIVE TRAITS, AND
THAT THEY ARE PASSED ON IN A VERY
PREDICTABLE WAY!

FOR EXAMPLE:
COLOR

Y YELLOW (dominant)
g GREEN (recessive)

SHAPE

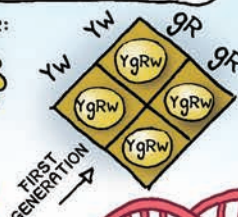
R ROUND (dominant)
w WRINKLY (recessive)

MOTHER:

YYww

FATHER:

ggRR



Mmm!
Pea soup!

DISCOVERED
BY ME IN
1665!

ROBERT
HOOKE

IN THE
CELL NUCLEUS...

IN (ALMOST)
EVERY LIVING CELL...

IN THE TWENTIETH CENTURY
WE DISCOVERED JUST
WHERE THIS BLUEPRINT
FOR ALL THESE TRAITS
RESIDES!

DISCOVERED
BY ME IN
1719!

ANTONIE VAN LEEUWENHOEK

THE DEVELOPMENTS
IN GENETICS ARE
MAKING HUGE LEAPS
IN THE PAST DECADES.

NOT ONLY ARE WE ABLE TO **CLONE**,
WE CAN ALSO REPLACE AND
IMPROVE (PARTS OF) DNA!

GENETICALLY MODIFIED
MAIZE AND TOMATOES

PLAY A ROLE IN
DEVELOPING
ANTI-HIV
MEDICINE

WITH THIS KNOWLEDGE, WE COULD
IN THEORY CREATE LIFE OURSELVES!

HELLO
DOLLY!

DOLLY, the first
cloned
mammal

in 1996

THANKS TO THIS PROJECT
WE KNOW HOW HUMAN DNA
IS STRUCTURED!

HUMAN GENOME
PROJECT 1990-2003

BLUE eyes?
That's so 2012!

DESIGNER
BABIES INC.

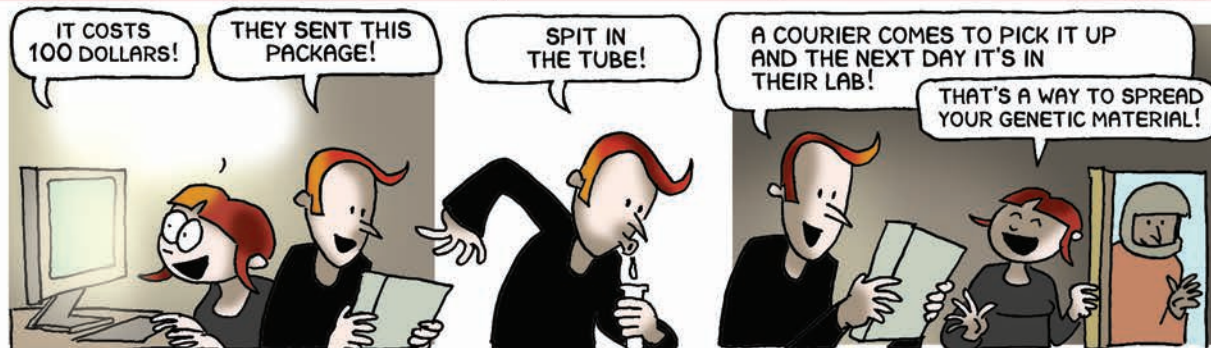
NEW!

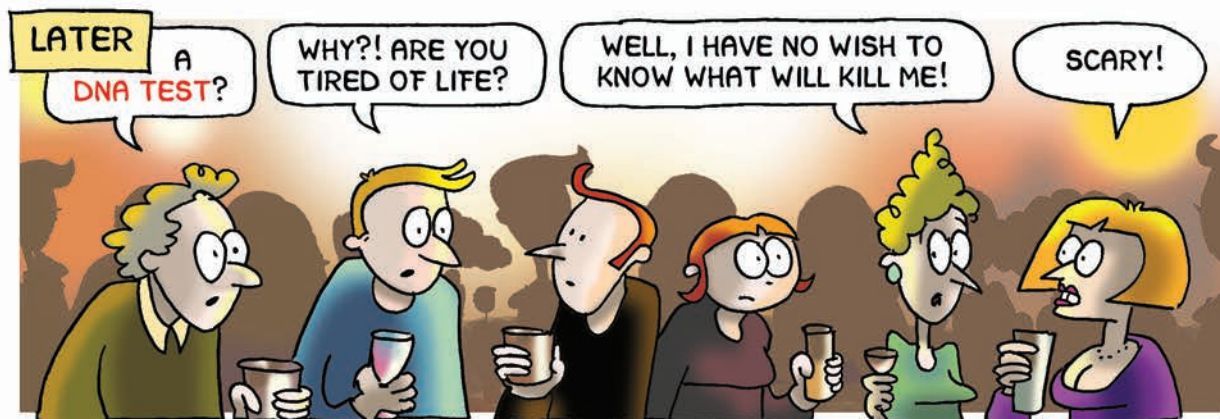
WHERE WILL
THIS LEAD US?

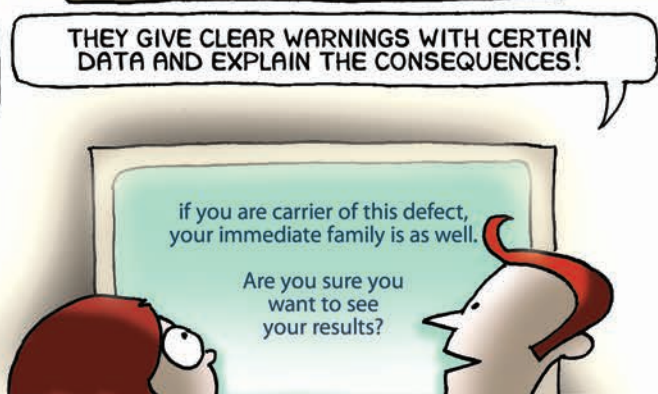
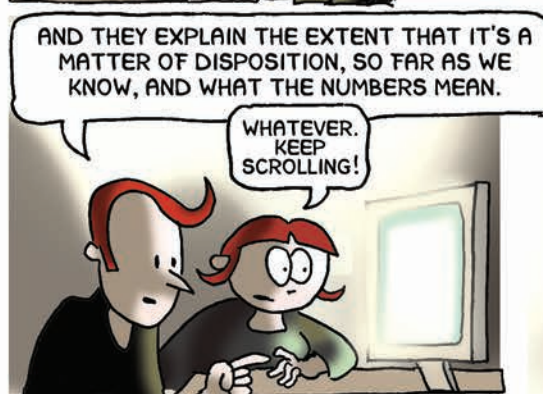
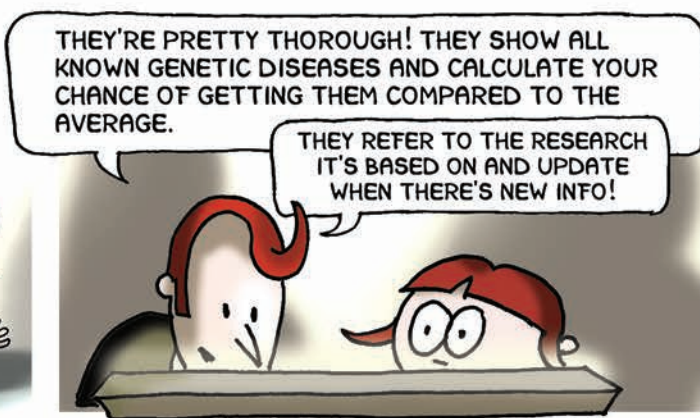


THE CHROMOSOME CHRONICLES

LET'S SCREEN THAT GENE!







DNA SEQUENCING IS NOT SCARY OR DIFFICULT AT ALL! I'LL SEND MY DNA TOO!

WITH OUR DATA, WE CONTRIBUTE TO BETTER KNOWLEDGE AND RESEARCH!

AND I JUST LIKE THE IDEA THAT MY DNA IS RECORDED SOMEWHERE.

WHO KNOWS, MAYBE I'LL GET CLONED IN 100 YEARS!

YEAH! OR THEY COULD COMBINE BOTH OUR DNA! WE MIGHT HAVE KIDS IN THE FAR FUTURE!

HAHA!

AND ONE DAY, THEY'LL READ THIS BOOK TO FIND OUT ABOUT THEIR PARENTS!

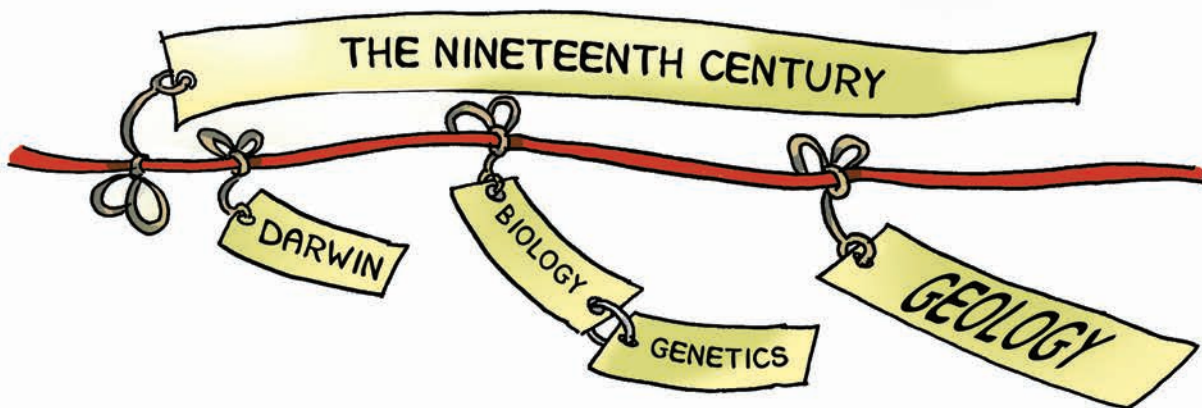
THEY MIGHT EVEN BE READING THIS RIGHT NOW!

HELLO! CHILDREN! MOMMY AND DADDY LOVE YOU!!!
EVEN THOUGH WE DON'T KNOW YOU!

BE GOOD
OVER THERE
IN THE FUTURE!

AND BEHAVE, WON'T YOU?
THE FUTURE IS NOT A TOY!

BE RESPONSIBLE
WITH OUR GENES!



ANOTHER SCIENCE THAT GREATLY
DEVELOPED IN THE NINETEENTH CENTURY,
IS **GEOLOGY** !



WE'RE GOING TO
MAP THE NEW
COASTLINES!

WE'RE
GOING TO
MEASURE
MOUNTAINS!

COLLECT
ROCKS!

FIND
GOLD!



STUDY OTHER
CULTURES!

RESEARCH
VOLCANOES!

DIG UP
FOSSILS!

GEOLOGY



HISTORY OF GEOLOGY



WHEN DID GEOLOGY START?

WHEN WE STARTED
GIVING DIRECTIONS?



WHEN WE STARTED
STUDYING ROCKS?

That's the
fourth spear
this week!



Try this rock!
It's harder
than the
rest!



WHEN WE BEGAN
MINING MINERALS?

Hematite! For its
beautiful
red color!



SWAZILAND
43,000 YEARS AGO

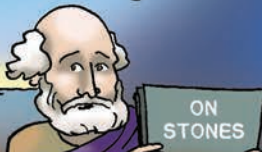
THE ANCIENT GREEKS STARTED TO STUDY ROCKS SYSTEMATICALLY.

I THINK THE EARTH CHANGES IN
SLOW PROCESSES WE CANNOT
PERCEIVE IN OUR SHORT LIVES.



ARISTOTLE
384 - 322 B.C.
GREECE

I DESCRIBED **VARIOUS TYPES**
OF ROCK, FROM COAL TO
MARBLE TO GEMSTONES!



THEOPHRASTUS
371 - 287 B.C.
GREECE

I WROTE ABOUT ALL KINDS OF NATURAL
STUFF, INCLUDING STONES! I ALREADY
RECOGNIZED THAT AMBER IS FOSSILIZED
TREE SAP!

Amber with
fossilized
insect



PLINIUS THE ELDER
23 - 79
ITALY

DURING THE MIDDLE AGES, SCHOLARS BUILT UPON THIS KNOWLEDGE.

THE INDIAN SUB-
CONTINENT WAS
SEA ONCE!



AL-BIRUNI
973 - 1048
AFGHANISTAN

I WROTE ABOUT
THE **ORIGIN** OF
MOUNTAINS AND
EARTHQUAKES!



AVICENNA
980 - 1037
PERSIA

I HAD THEORIES
ABOUT **CLIMATE**
CHANGES THAT TOOK
PLACE IN THE PAST!



SHEN KUO
1031 - 1095
CHINA

NICE, THESE THEORIES - BUT THEY NEED
TO BE IN ACCORDANCE WITH THE **BIBLE**!

THE BIBLE SAYS
EARTH IS ABOUT
5000 YEARS OLD!

AND THERE
ONCE WAS A
GREAT FLOOD!



CHRISTIAN SCHOLARS

That explains those
fossils we find on
mountain tops!

AFTER THE MIDDLE AGES GEOLOGICAL RESEARCH INCREASED, AND SO DID THE **CONTROVERSY**.

WHAT ABOUT ALL THESE **FOSSILS**?

MAYBE THE DEVIL PUT THEM THERE TO CONFUSE US!

HMPF! EASY! THOSE ARE REMNANTS OF PAST LIFE!

THE ANCIENT GREEKS SAW THAT ALREADY!

THEY CALL ME THE **FATHER OF MINERALOGY!** I WAS INTO MINING AND WROTE THIS BOOK!

AND THEY CALL ME THE **FATHER OF STRATIGRAPHY!** I STUDIED LAYERS OF ROCK!



MEDIEVAL CHRISTIAN SCHOLARS



LEONARDO DA VINCI
1452 - 1519
ITALY



GEORG AGRICOLA
1494 - 1555
GERMANY

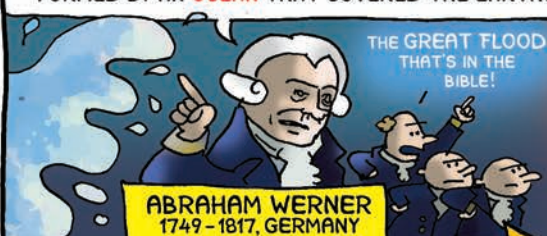


NICOLAS STENO
1638 - 1686
DENMARK

IN THE 18TH CENTURY, THE CONFLICT BETWEEN **NEPTUNISTS** AND **PLUTONISTS** EMERGED.

ALL THESE DIFFERENT LAYERS OF ROCK HAVE BEEN FORMED BY AN **OCEAN** THAT COVERED THE EARTH!

THE GREAT FLOOD THAT'S IN THE BIBLE!



ABRAHAM WERNER
1749 - 1817, GERMANY

NO, EARTH WAS FORMED THROUGH **VOLCANIC PROCESSES!**

HE'S RIGHT! THAT'S WHY HE'S CALLED THE FATHER OF GEOLOGY!



JAMES HUTTON
1726 - 1797
SCOTLAND

NEPTUNISTS

PLUTONISTS ALSO CALLED VOLCANISTS

IN THE 19TH CENTURY, IT WAS **CATASTROPHISM** VERSUS **UNIFORMITARIANISM**.

EARTH IS STATIC IN ITSELF, BUT IT CHANGES THROUGH **PERIODIC CATASTROPHES!**

YEAH! LIKE THE GREAT FLOOD!

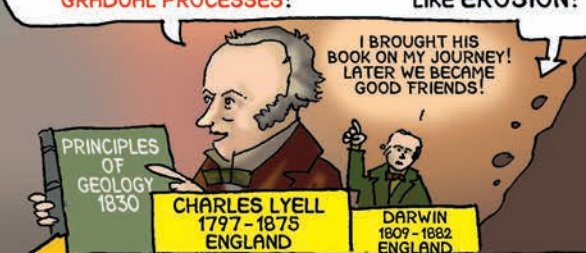


REV. BUCKLAND
1784 - 1850
ENGLAND

GEORGES CUVIER
1769 - 1832, FRANCE

NO, EARTH IS CONSTANTLY CHANGING, IN **GRADUAL PROCESSES!** LIKE **EROSION!**

I BROUGHT HIS BOOK ON MY JOURNEY! LATER WE BECAME GOOD FRIENDS!



CHARLES LYELL
1797 - 1875
ENGLAND

DARWIN
1809 - 1882
ENGLAND

CATASTROPHISM

UNIFORMITARIANISM ALSO CALLED GRADUALISM

IN THE TWENTIETH CENTURY, NEW **TECHNOLOGY** BROUGHT NEW INSIGHTS.

EARTH IS A LOT OLDER THAN WE THOUGHT!
PROBABLY A FEW **BILLION** YEARS!



ARTHUR HOLMES
1890-1965
ENGLAND

THIS AUSTRALIAN ZIRCON
IS THE OLDEST ROCK
ON EARTH



DATED 4.4 BILLION YEARS!
(USING RADIOMETRY)

I THINK THE CONTINENTS ARE MOVING!
I CALL IT **CONTINENTAL DRIFT**!



ALFRED WEGENER
1880-1930
GERMANY



FROM THE 1960S ON,
WE CALLED THIS
PLATE TECTONICS!



IT ALSO BECAME POSSIBLE TO MAP THE **BOTTOM OF THE SEAS**.



THIS STARTED A WHOLE NEW SCIENCE:
OCEANOGRAPHY!



THERE ARE MANY THINGS UNDER
WATER WE DO NOT UNDERSTAND!



THE BOTTOM OF THE OCEAN MOVES WITH A SPEED OF 1-10 CM A YEAR

FOR INSTANCE DEEP SEA VENTS

MODERN GEOLOGY DOESN'T JUST STUDY EARTH, IT STUDIES **SPACE**!

CRATERS!
MOUNTAINS!



ON THE **MOON** WE
FOUND ROCKS 4.5
BILLION YEARS OLD.

THE **MARS ROVER**
COLLECTS ROCKS
AND STUDIES THE
COMPOSITION OF
THE GROUND ON
MARS - 60 MILLION
MILES AWAY!



THE AGE OF THE EARTH

I CALCULATED IT
FROM THE BIBLE!



ARCHBISHOP
JAMES USSHER
± 1650

EARTH WAS
CREATED ON
OCTOBER 23,
4004 B.C.!

NONSENSE!



REVEREND
WILLIAM BUCKLAND
± 1820

THE BIBLE SAYS: "IN THE BEGINNING GOD
CREATED THE HEAVENS AND THE EARTH"!

BUT IT DOESN'T SAY HOW LONG
"IN THE BEGINNING" LASTED!

— MAYBE IT TOOK
MILLIONS OF YEARS!

I ESTIMATE EARTH'S AGE
TO BE BETWEEN 75,000 AND
168,000 YEARS!



GEORGES-LOUIS LECLERC
COUNT DE BUFFON
± 1770

98 MILLION YEARS! *



WILLIAM THOMSON
LORD KELVIN
*1862 AND *1869

24 MILLION
YEARS! *

I THINK: AT LEAST
306,622,400 YEARS!

APPROXIMATELY.



CHARLES DARWIN
1859

BASED ON
EXPERIMENTS
WITH COOLING!

1.6 BILLION YEARS !

4.54 BILLION
YEARS !

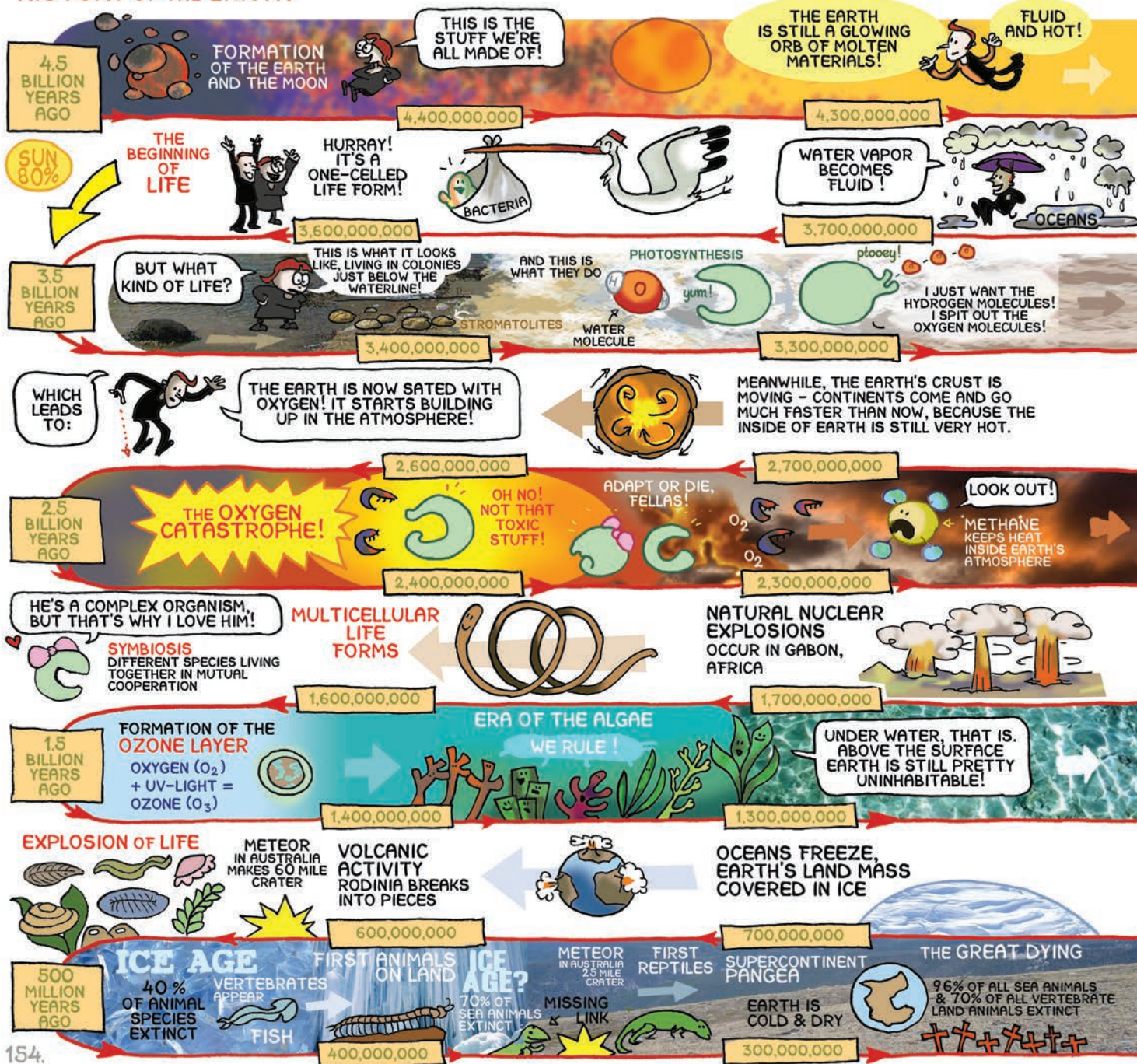
THAT'S THE
HIGHEST
WE'LL GO!

EARLY
RADIOMETRY
± 1910



MODERN
RADIOMETRY

HISTORY OF THE EARTH





HISTORY OF MAN

1.8
MILLION
YEARS
AGO



WE ACTUALLY KNOW VERY LITTLE ABOUT THE DEVELOPMENT OF MAN!



WE KNOW THAT LESS THAN 2 MILLION YEARS AGO, A SPECIES EMERGED IN AFRICA THAT WALKED UPRIGHT AND HAD A MUCH LARGER CRANIAL CAPACITY THAN ITS PREDECESSORS.

HOMO ERECTUS

WE CAME IN MANY SPECIES, WALKED UPRIGHT AND EVEN USED TOOLS SOMETIMES!

WE HAD TO!

THOSE PREDECESSORS HAD LEFT THE TREES MILLIONS OF YEARS BEFORE THAT, AND LIVED ON THE GRASSY PLAINS OF AFRICA.

1.6
MILLION
YEARS
AGO



HOMO ERECTUS WAS WAY SUPERIOR!

THE TREES LEFT US!

HOMO ERECTUS WAS A HUNTER. HE MADE FIRE AND COMPLEX TOOLS. AND TOOK CARE OF THE SICK!

HOW DO WE KNOW THAT?

WE'VE FOUND BONES WITH CERTAIN DEFORMITIES!

THESE ONLY OCCUR AFTER MONTHS OF ILLNESS!

THIS PERSON MUST HAVE RECEIVED CARE! IF NOT, HE WOULD HAVE DIED SOONER!

1.7 MILLION YEARS OLD

1.4
MILLION
YEARS
AGO

HOMO ERECTUS SPREAD ACROSS THE EARTH AT AN AMAZING SPEED!

BUT HOW?!

DID THEY HAVE BOATS ALREADY?

WHEEE!

AUSTRALIA

ASIA

EUROPE

AFRICA

1.2
MILLION
YEARS
AGO

1
MILLION
YEARS
AGO

DID THEY HAVE LANGUAGE?!

NO.

WELL, MAYBE SOUNDS!

Like monkeys, communicating by grunts & yells!

LOOK AT THEIR BRAINS, THEY MIGHT HAVE HAD!

They did have a Broca's area!

NO! THEIR LARYNX WAS IN THE WRONG PLACE!

IF THEY DID, WHAT WOULD THEY HAVE TALKED ABOUT?

Would they have used it only for orders and warnings? Or would they tell stories? Or sing?

THE ASHES IN THE ATMOSPHERE BLOCKED OUT THE SUN. THIS CREATED MORE SNOW AND ICE, WHICH REFLECTED SUNLIGHT, COOLING EARTH EVEN MORE. IT WAS VERY COLD FOR A LONG TIME.

640,000 YEARS AGO THE SUPERVOLCANO IN YELLOWSTONE ERUPTED. NO HUMANS WERE LIVING IN AMERICA (WE THINK), BUT THE EFFECTS WERE FELT WORLDWIDE.

800
THOUSAND
YEARS
AGO

600
THOUSAND
YEARS
AGO

THE PROBLEM WITH PALEONTOLOGY IS THAT OUR THEORIES ARE BASED ON VERY LITTLE EVIDENCE!

Just a few pieces of skull and bone.

HARDLY EVER A WHOLE SKELETON!

EVERY NEW FIND IS A BREAKTHROUGH!

HOMO SAPIENS IS THE NAME OF OUR OWN SPECIES. WE EMERGED IN AFRICA, ABOUT 200,000 YEARS AGO.

CHARACTERISTICS:

- NO HEAVY BROW IN THE SKULL
- LARGE BRAIN VOLUME
- CAPACITY TO PASS ON NON-HEREDITARY BEHAVIOR (CULTURE)
- LANGUAGE

400
THOUSAND
YEARS
AGO



200
THOUSAND
YEARS
AGO

GENETIC RESEARCH REVEALED THAT WE ARE ALL DESCENDANTS OF ONE WOMAN WHO LIVED ABOUT 160,000 YEARS AGO.

YOU ALL HAVE MY MITOCHONDRIAL DNA!

70,000 YEARS AGO, HOMO SAPIENS LEFT AFRICA.

ACHIEVEMENTS:

WORKING METAL

NUCLEAR ENERGY

SEWING CLOTHES

AGRICULTURE

PLASTIC

100 YEARS AGO

60,000 YRS AGO

10,000 YRS AGO

5,000 YRS AGO

100 YEARS AGO

NOW

AT LEAST **WE, HOMO SAPIENS**,
WON'T HAVE TO WORRY
THAT OUR PRESENCE ON
EARTH WILL GO UNNOTICED!

WE'RE ALREADY LEAVING A
TRAIL OF **PLASTIC AND NUCLEAR**
WASTE THAT WILL BE THERE
FOR MILLIONS OF YEARS TO COME!

OOH! CLASSIC HOMO SAPIENS!

FASCINATING!

SCIENTISTS
OF THE
FUTURE



BY THE **END** OF THE NINETEENTH CENTURY
PEOPLE THOUGHT SCIENTIFIC DISCOVERIES WERE ALMOST AT AN END!

MOM, DAD - I WANT
TO BECOME A
SCIENTIST!

OH NO!

DON'T YOU HAVE ANY
AMBITIONS AT ALL, SON?!



I INTRODUCED THE
PERIODIC TABLE FOR
CHEMICAL ELEMENTS!



MENDELEEV
1834 - 1907
RUSSIA

I UNITED OPTICS,
ELECTRICITY AND
MAGNETISM!



JAMES CLERK MAXWELL
1831 - 1879
SCOTLAND

THOSE ALL
OBEY THE
SAME LAWS,
I FOUND OUT!

THEY ARE ALL
ELECTROMAGNETIC
WAVES!

I DISCOVERED THE ELECTROMAGNETIC
RADIATION WE NOW CALL X-RAYS!

SOME CALL THEM
ROENTGEN RAYS, BUT
I PREFER X-RAYS!



WILHELM ROENTGEN
1845 - 1923
GERMANY

SCIENCE IS NOW ONLY A MATTER OF
FILLING IN THE BLANKS!

THE TWENTIETH CENTURY WILL
BRING US NO SURPRISES!

OR WILL IT?



EINSTEIN



ALBERT EINSTEIN

WHAT DOES IT TAKE TO BE A BRILLIANT SCIENTIST?

A BIT OF MATH...

BIT OF PHYSICS...

BUT MOST OF ALL: **A CREATIVE MIND !**

THIS WAS NOT ENCOURAGED AT MY HIGH SCHOOL.

LEARN BY HEART AND DON'T ASK QUESTIONS!

EINSTEIN, YOU WON'T GO FAR!

16 YEARS OLD

BORN: 1879, GERMANY.
GREW UP IN SWITZERLAND.
HE LIVED IN AUSTRIA,
GERMANY, BELGIUM AND
EMIGRATED TO THE
UNITED STATES
IN 1933.
DIED: 1955, USA.

ALSO PRACTICAL:

INTELLIGENT FRIENDS TO SHARE YOUR IDEAS WITH !

I HELPED HIM WITH GEOMETRY!

WE FORMED A CLUB WITH HIM: THE OLYMPIA ACADEMY! WE ATE TOGETHER, READ BOOKS, TALKED ABOUT ANYTHING AND EVERYTHING!

I MET HIM AT THE POLYTECHNIC INSTITUTE WHERE WE STUDIED TOGETHER! WE MARRIED IN 1903!

I WAS HIS BEST FRIEND AND COLLEAGUE AT THE PATENT OFFICE! HE CALLED ME 'THE BEST SOUNDING BOARD IN EUROPE'!

WITH FRIENDS LIKE THAT, WHO NEEDS A UNIVERSITY EDUCATION?



MARCEL GROSSMANN
1878 - 1936



KONRAD HABICHT
1876 - 1958



MAURICE SOLOVINE
1875 - 1958



MILEVA MARIĆ
1875 - 1948



MICHELE BESSO
1873 - 1955



AND!

THE TIME MUST BE RIPE !

FOR ME, THAT WAS THE YEAR 1905!

MY 'WONDER YEAR'!

26 YEARS OLD

SON HANS ALBERT

THERE WERE SOME UNSOLVED PROBLEMS IN PHYSICS!

WORKING AT A PATENT OFFICE, EVALUATING PATENT APPLICATIONS FOR ELECTROMAGNETIC DEVICES.

I GOT TO PUBLISH MY ARTICLES ABOUT THESE PROBLEMS IN THE PROMINENT SCIENTIFIC MAGAZINE 'ANNALEN DER PHYSIK'!

IN 1905 I PUBLISHED FOUR ARTICLES THAT CHANGED SCIENCE FUNDAMENTALLY!

EVERYONE KNOWS MY FAMOUS EQUATION:

E IS FOR ENERGY!



$$E = mc^2$$

M IS FOR MASS!

BUT WHAT DOES IT MEAN EXACTLY?

C IS THE SPEED OF LIGHT!



MASS AND ENERGY ARE THE SAME!
ENERGY IS FREED MATTER, AND
MATTER IS FIXED ENERGY!



THIS EXPLAINED HOW RADIATION WORKS.



c^2 IS A HUGE NUMBER!
(186,000 MILES PER HOUR TIMES ITSELF!)

THIS MEANS THAT IN EVERY PIECE OF MATTER, A HUGE AMOUNT OF POTENTIAL ENERGY IS STORED
- EVEN IN YOU !

AND ALSO HOW STARS CAN BURN FOR BILLIONS OF YEARS WITHOUT BEING DEPLETED!



NOW WE UNDERSTAND HOW IT IS POSSIBLE THAT THE UNIVERSE IS SO OLD!

THE HUMAN BODY HARBORS 7 TIMES 10^{18} JOULES OF POTENTIAL ENERGY - THAT'S 30 HYDROGEN BOMBS!

I WILL EXPLODE!!!



YEAH, SURE.



FORTUNATELY IT'S DIFFICULT TO RELEASE THIS POTENTIAL ENERGY EFFICIENTLY!

NEWTON HAD **DESCRIBED**
GRAVITY, BUT HE HAD NOT
EXPLAINED IT!

SO IT STILL REMAINED
A RATHER MYSTERIOUS
POWER-AT-A-DISTANCE.
THIS BOTHERED ME.



I CAME UP WITH AN EXPLANATION:
THE THEORY OF RELATIVITY !

SO FAR, SCIENTISTS
ASSUMED THAT TIME AND
SPACE WERE **ABSOLUTE**
CONCEPTS!

SPACE WILL ALWAYS
BE THE SAME! IT
DOES NOT MOVE!

TIME AND SPACE
ARE THE BACKDROP
FOR EVENTS, BUT
ARE NOT
INFLUENCED
BY THEM!



NEWTON

BUT I FIGURED THEY ARE
RELATIVE - DEPENDANT ON
THE OBSERVER!

I WENT EVEN
FUTHER:
THEY ARE
INEXTRICABLY
LINKED IN THE
WHOLE OF
SPACE-TIME !



YOU CAN PICTURE IT LIKE A
RUBBER SHEET IN WHICH OBJECTS
CAUSE DENTS - THESE DISTORTIONS
IN SPACE-TIME MAKE OBJECTS
'ROLL' TOWARDS EACH OTHER.
THAT'S GRAVITY !

FUNNY FACTS

I TOLD YOU YOU NEEDED
A CREATIVE MIND!



IN MY THEORY, THESE CLOCKS
ALWAYS DISPLAY THE SAME TIME!

EVEN WHEN YOU SEND
ONE INTO SPACE!



NEWTON

IN MY THEORY, A CLOCK THAT IS IN
MOTION WILL RUN A LITTLE SLOWER!



EINSTEIN

WHEN YOU MOVE,
TIME GOES SLOWER.

BUT YOU DON'T
PERCEIVE THIS
YOURSELF!

A TRAIN THAT SPEEDS
BY 60% OF THE
SPEED OF LIGHT...

LOOKS COMPRESSED
WHEN WATCHED
FROM THE STATION!

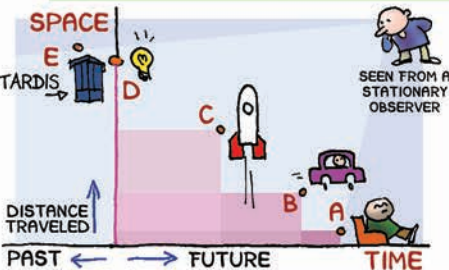
THE CLOCK ON THE TRAIN
RUNS SLOWER THAN THE
CLOCK IN THE STATION -
EVERYTHING ON THE TRAIN
MOVES SLOWER!

BUT TO THE PEOPLE
ON THE TRAIN, EVERYTHING
SEEMS NORMAL!



STATION

111,600 MILES PER SECOND



WHEN SOMETHING ACCELERATES, ITS MASS INCREASES.

THE CLOSER YOU GET
TO THE SPEED OF
LIGHT, THE HEAVIER
YOU GET!

THE ADDED ENERGY OF
THE ACCELERATION IS
CONVERTED TO MASS!

$E=MC^2$, REMEMBER?

EXERCISE TO LOSE WEIGHT?!
I DON'T THINK SO!

AS SOON AS I MOVE,
I GAIN WEIGHT!

- A. AT A STANDSTILL, TIME MOVES NORMALLY.
- B. IN MOTION, TIME SLOWS (NOT NOTICEABLY).
- C. IN RAPID MOTION OVER LONG DISTANCES, TIME SLOWS EVEN MORE (NOTICEABLY!).
- D. AT THE SPEED OF LIGHT, TIME STANDS STILL.
- E. CONCEIVABLY, AT A SPEED GREATER THAN THE SPEED OF LIGHT, TIME WOULD GO BACKWARDS!

IS THAT ALL REALLY
TRUE? OR JUST
THEORY?

IT'S REAL! ALL OF THESE
EFFECTS WERE MEASURED!

WE JUST DON'T
EXPERIENCE THEM
IN DAY-TO-DAY LIFE!

BUT NOTHING GOES
FASTER THAN
THE SPEED OF
LIGHT!

OR DOES
IT?!

OH NO, IT DOESN'T.

SEPTEMBER 2011,
CERN, SWITZERLAND:
- NEUTRINO GOES
FASTER THAN LIGHT?!

OOPS!
WRONG

THE THEORY OF RELATIVITY PREDICTS THAT HEAVY OBJECTS BEND LIGHT. THIS WAS CONFIRMED IN 1919 DURING AN ECLIPSE.

BY ME!

THE SUN BENDS THE LIGHT OF THE STARS BEHIND IT!



ARTHUR EDDINGTON
1882 - 1944
ASTRONOMER

From the island of Principe on the equator

THIS CONFIRMATION OF HIS THEORY MADE EINSTEIN INSTANTLY WORLD FAMOUS!

HEY, IS THAT -

HEY, PROFESSOR! EXPLAIN US YOUR THEORY, WILL YOU?

I'M AFRAID YOU ARE CONFUSING ME WITH SOMEONE ELSE!

I GET THAT ALL THE TIME!



HE WAS ONE OF THE LEADERS ON THE SUBJECT OF QUANTUM THEORY AND TOOK PART IN THE FAMOUS SOLVAY CONVENTION IN 1927.

IT IS AN IMPOSING THEORY BUT IT DOESN'T SIT WELL WITH ME.

GOD DOES NOT PLAY DICE WITH THE UNIVERSE!

STOP TELLING GOD WHAT TO DO WITH HIS DICE!

NIELS BOHR



IN 1933 THE NAZIS CAME TO POWER IN GERMANY.

THEORETICAL PHYSICS IS NOT REAL SCIENCE!

WE'RE EMIGRATING TO AMERICA!

SCIENCE SHOULD BE PRACTICAL!

GET HIM! WITH HIS USELESS THOUGHT EXPERIMENTS!

We want to build bombs!

Typically Jewish!



ELSA
HIS SECOND WIFE

IN 1939 HE ADVISED PRESIDENT ROOSEVELT TO CONDUCT NUCLEAR RESEARCH.

WE KNOW THAT HITLER WANTS TO MAKE AN ATOM BOMB!

HE WILL NOT HESITATE TO USE IT!

IN HINDSIGHT, I REGRET DOING THIS!

BUT AT THAT TIME, I FELT WE HAD TO!



SCIENTISTS FLED FROM NAZI GERMANY

EINSTEIN DIED IN AMERICA IN 1955. HIS BODY WAS CREMATED, BUT HIS BRAIN WAS PRESERVED.

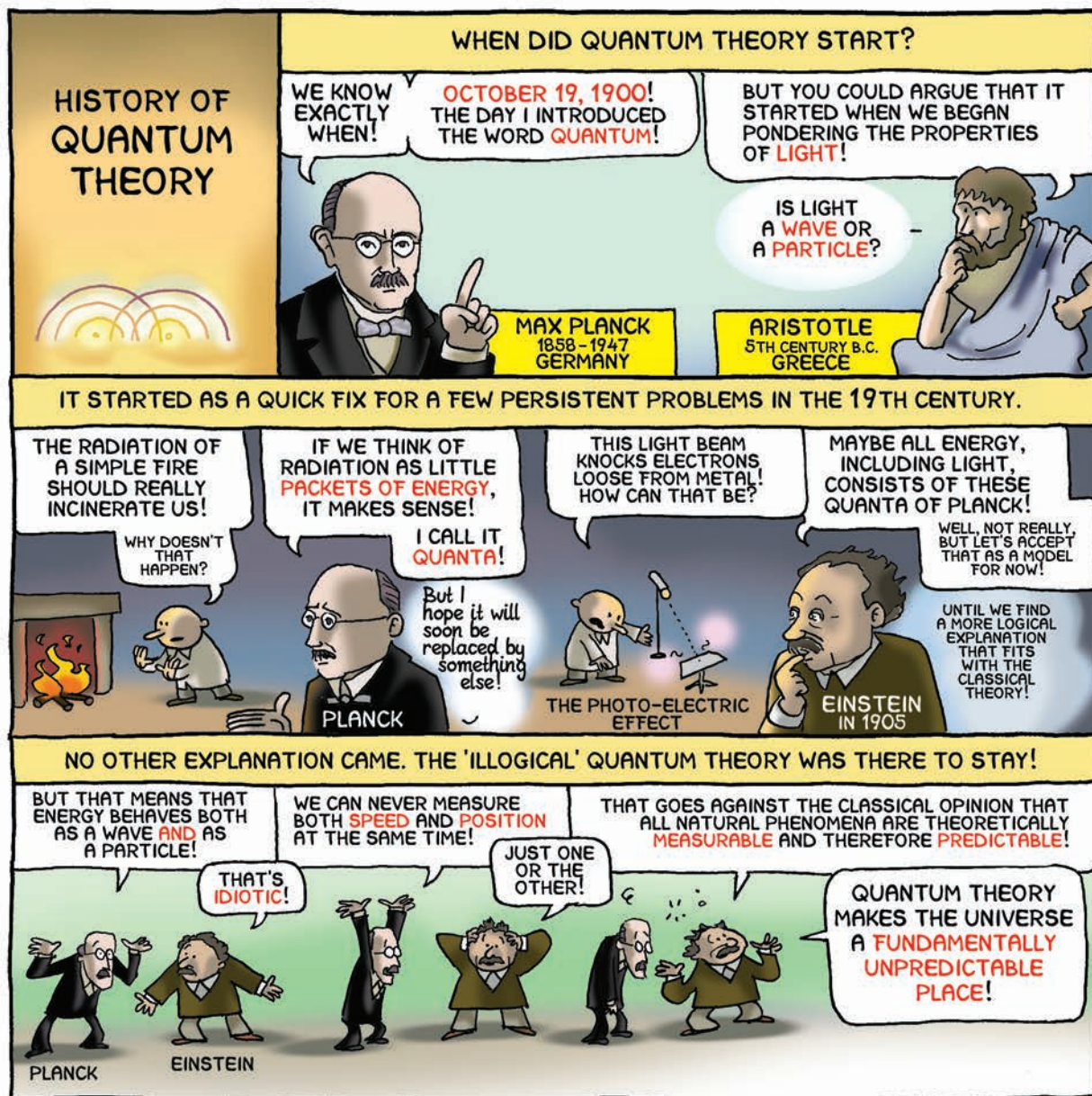
MAYBE WE'LL FIND OUT WHAT MADE HIS MIND SO EXCEPTIONAL!

THERE'S A WEIRD COIL HERE!



QUANTUM THEORY





VARIOUS SCIENTISTS THOUGHT ABOUT THE IMPLICATIONS OF QUANTUM THEORY.

I FOUND OUT THAT QUANTUM APPLIES TO **ALL MATTER**! NOT JUST RADIATION AND LIGHT!



LOUIS DE BROGLIE
1892 - 1987
FRANCE

I CAME UP WITH THE **UNCERTAINTY PRINCIPLE**!



WERNER HEISENBERG
1901 - 1976
GERMANY

APPARENTLY, THIS UNCERTAINTY IS REAL AND FUNDAMENTAL! A PARTICLE HAS NO SPECIFIC POSITION UNTIL WE MEASURE IT! BEFORE THE MEASUREMENT, IT EXISTS IN A KIND OF **PROBABILITY STATE**!



MAX BORN
1882 - 1970
GERMANY

NIELS BOHR
1885 - 1962
DENMARK

THE COPENHAGEN INTERPRETATION
BY HEISENBERG, BORN & BOHR, 1927

THERE WILL ALWAYS BE UNCERTAINTY EITHER ABOUT THE **PLACE** OR THE **SPEED** OF A PARTICLE!

We cannot measure both at the same time!

BUT THAT'S **CRAZY**!



ERWIN SCHRÖDINGER
1887 - 1961
AUSTRIA

I WILL DEMONSTRATE JUST **HOW CRAZY** BY THIS THOUGHT EXPERIMENT:

IMAGINE: YOU PUT A CAT IN A BOX WITH A RADIOACTIVE MECHANISM AND A BOTTLE OF POISON. THERE'S 50% CHANCE THE RADIOACTIVE MATERIAL WILL DECAY AND RELEASE THE POISON.



THIS GUY IS INSANE!

AND WHAT YOU ARE ACTUALLY SAYING IS THAT THE CAT IS 50% DEAD **AND** 50% ALIVE **UNTIL** THE MOMENT WE LOOK IN THE BOX!

YES, THAT'S WHAT IT BOILS DOWN TO.



IN OCTOBER 1927 ALL THE PROMINENT QUANTUM SCIENTISTS CAME TOGETHER IN BRUSSELS, AT THE FAMOUS SOLVAY CONVENTION, TO TALK ABOUT THEIR IDEAS.

QUANTUM THEORY INDICATES THERE'S A CLOSE RELATIONSHIP BETWEEN OBSERVER AND EXPERIMENT! REALITY IS ONE BIG SYSTEM IN WHICH EVERYTHING IS CONNECTED!



BUT I STILL DON'T LIKE IT!

Planck

Einstein

Schrödinger

Heisenberg

de Broglie

Born

Bohr

WAVE AND /OR PARTICLE

WHAT ARE THE BASIC PARTS THAT MAKE UP EVERYTHING?
WHAT DO THEY LOOK LIKE?
HOW DO THEY BEHAVE?

DEMOCRITUS
±460 - ±380 B.C.
GREECE

**SMALL, SOLID
INDIVISIBLE
PARTICLES
THAT MOVE IN
A STRAIGHT
LINE!**

I'M CALLING
THEM A-TOMS!
 α -TOMOS =
in-divisible!

WHAT ABOUT LIGHT?

I THINK LIGHT IS NOT PARTICLES, BUT A DISTURBANCE IN THE ELEMENT AIR!

LIGHT MOVES
THROUGH AIR
LIKE A **WAVE**!

ARISTOTLE
384-322 B.C.
GREECE

I THINK LIGHT MOVES
IN RAYS, CONSISTING
OF LIGHT PARTICLES!

ALHAZEN
965-±1040
PERSIA

THE DOUBLE-SLIT EXPERIMENT

WHEN YOU SHOOT **SOLID PARTICLES**,
LIKE MARBLES, THROUGH A SLIT,
YOU GET A PATTERN ON THE SCREEN
BEHIND OF **A STRAIGHT LINE!**

WHEN YOU USE TWO
SLITS, YOU GET THE
PATTERN OF TWO
STRAIGHT LINES!

NOW LET'S REPEAT THE EXPERIMENT, BUT THIS TIME WITH WAVES!

I FIGURED IN 1905 THAT LIGHT IS MADE OF PACKETS OF ENERGY - QUANTA - THAT BEHAVE SOMETIMES AS A WAVE, AND SOMETIMES AS A PARTICLE!

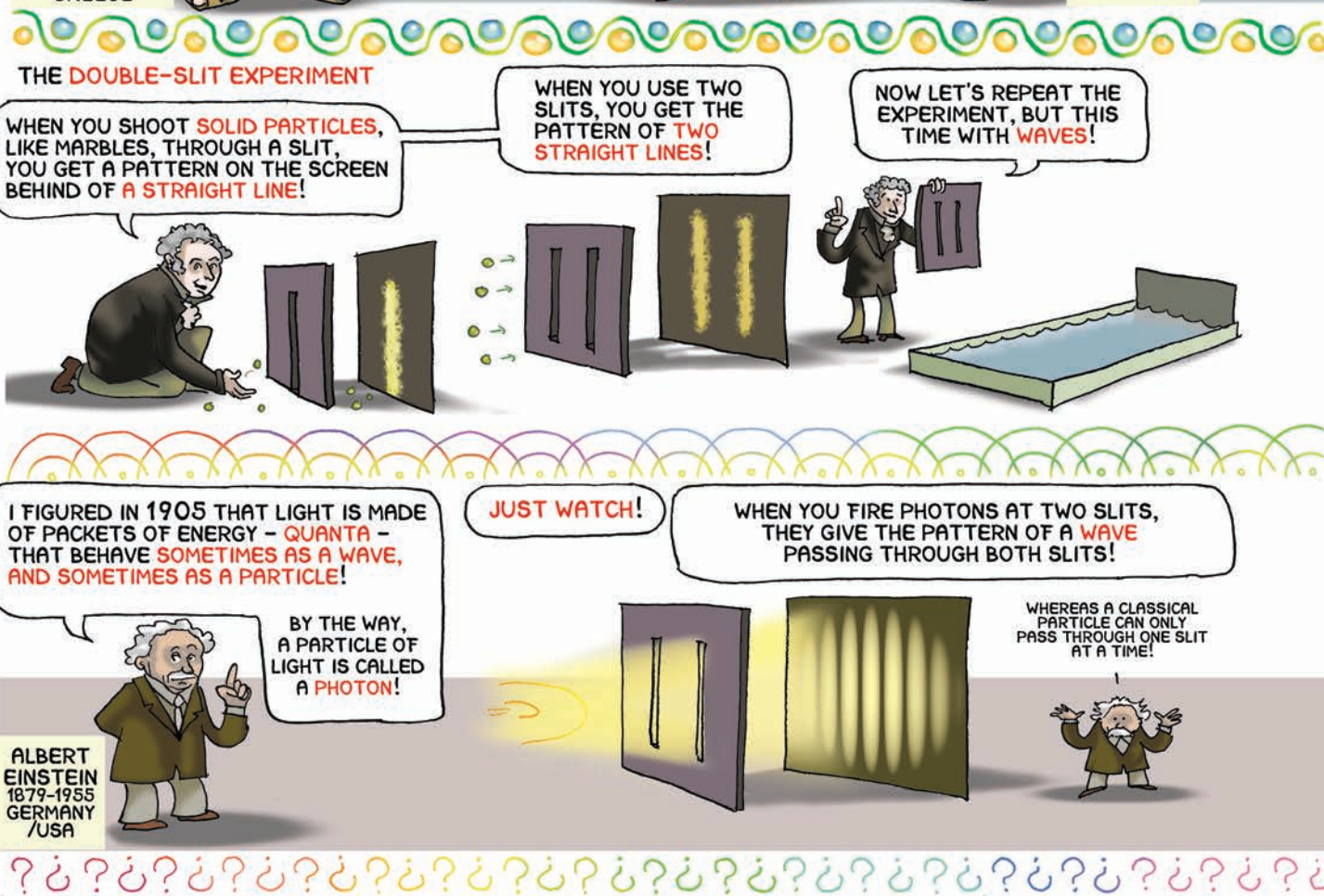
BY THE WAY,
A PARTICLE OF
LIGHT IS CALLED
A **PHOTON**!

ALBERT
EINSTEIN
1879-1955
GERMANY
/USA

JUST WATCH!

WHEN YOU FIRE PHOTONS AT TWO SLITS,
THEY GIVE THE PATTERN OF A **WAVE**
PASSING THROUGH BOTH SLITS!

WHEREAS A CLASSICAL
PARTICLE CAN ONLY
PASS THROUGH ONE SLIT
AT A TIME!



LIGHT IS A **WAVE**!
IT TRAVELS AS AN IMPULSE
THROUGH OTHER ATOMS!

NATURE
KNOWS NO
VACUUM!

RENÉ
DESCARTES
1596-1650
FRANCE



LIGHT IS **PARTICLES**!
ONLY PARTICLES CAN MOVE
IN SUCH STRAIGHT LINES!

ISAAC
NEWTON
1643-1727
ENGLAND



WAVE!

CHRISTIAAN
HUIJGENS
1629-1695
NETHERLANDS

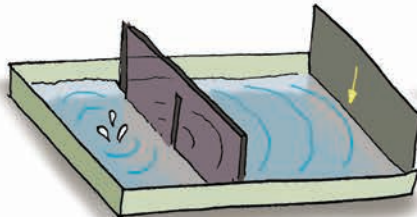


YOU CAN STOP FIGHTING, BOYS!
MY **DOUBLE-SLIT EXPERIMENT**
PROVED CONCLUSIVELY IN 1805 THAT
LIGHT IS A **WAVE**!

THOMAS
YOUNG
1773-1829
ENGLAND



A WAVE THAT GOES THROUGH
ONE SLIT GIVES THE PATTERN
OF **ONE STRAIGHT LINE**...



A WAVE THAT PASSES THROUGH
TWO SLITS GIVES THE PATTERN
OF **MULTIPLE LINES** !



I SHOWED THAT **LIGHT** MOVING THROUGH **TWO SLITS** GIVES THE SAME **MULTIPLE PATTERN**!



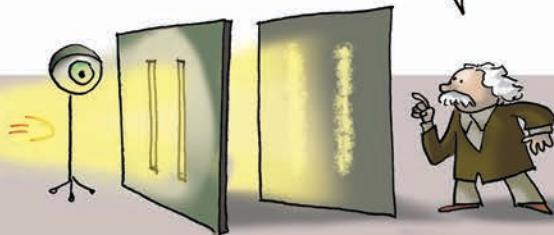
SO LIGHT IS
A **WAVE**!

NOW
HERE'S
SOMETHING
FUNNY:

WHEN WE PUT A DEVICE AT THE
TWO SLITS TO DETERMINE
THROUGH WHICH SLIT THE PHOTON
TRAVELS, WE GET THE PATTERN
A **PARTICLE** WOULD GIVE!

SO THE FACT THAT
WE ARE **OBSERVING**,
ALTERS THE
BEHAVIOR OF THE
QUANTUM PARTICLE?

BUT HOW CAN WE **VISUALIZE** SUCH A
PARTICLE? IT IS A PARTICLE AND A WAVE
AT THE SAME TIME! OUR BRAIN HAS NO
IMAGE FOR THIS!



Mysterious,
eh?



PLUS:
THE FORM IN
WHICH I MANIFEST
MYSELF IS
RELATED TO
WHETHER YOU WATCH ME OR NOT!



BUT WHAT DOES
QUANTUM **MEAN**?

WHAT DOES IT
TELL US ABOUT OUR
DAY-TO-DAY
REALITY?

IS IT SOMETHING **REAL**?

IT SOUNDS LIKE THAT AGE-OLD RIDDLE:

IF A TREE FALLS IN THE WOODS AND THERE IS
NO ONE AROUND TO HEAR, DOES IT MAKE A SOUND?

ACCORDING TO QUANTUM THEORY,
IT WOULD EVEN BE A QUESTION
IF THERE WERE A TREE AT ALL!

WELL...

MANY SCIENTISTS USE QUANTUM THEORY
AS SOMETHING PURELY **PRACTICAL**...

AND OTHERS SPECULATE ABOUT THE
ROLE **CONSCIOUSNESS** MIGHT HAVE.

YOU PUT IN
DATA ON
THIS SIDE...

AND YOU GET THE
EXPECTED OUTCOMES
ON THE OTHER SIDE!

IT WORKS!

Don't think about it
for too long!

QUANTUM
FORMULAS
 ψ

WE SEE
CONNECTIONS
WITH THE WAY THE
BRAIN WORKS!

COMPUTER
SCIENCE!

EVEN
RELIGION!

ARTIFICIAL
INTELLIGENCE!

HOWEVER IT MAY BE, QUANTUM THEORY
IS ONE OF THE FACTORS THAT HAS LED
TO A **SHIFT** IN THE WAY SCIENCE
VIEWS THE WORLD!

THE CLASSICAL WORLDVIEW

DETERMINISM
OUTCOMES OF PROCESSES
ARE THEORETICALLY FIXED

IF WE'D KNOW POSITION
AND SPEED OF EVERY
PARTICLE IN THE
UNIVERSE...

...WE WOULD
BE ABLE TO PREDICT
EVERYTHING!



THE UNIVERSE LOOKS LIKE A
MACHINE



EMPHASIS ON
STUDYING
SEPARATE
PARTS

OPPOSITES ARE
INCOMPATIBLE

THINGS
BEHAVE EITHER
AS A WAVE...

OR AS A
PARTICLE!

NOT
BOTH!



OBJECTIVE OBSERVATION

THE THINGS I OBSERVE
ARE THE SAME TO
ANY OTHER
OBSERVER!

IT HAS NOTHING TO
DO WITH ME AS AN
INDIVIDUAL!



REDUCTIONISM

COMPLEX THINGS CAN BE STUDIED
BY REDUCING THEM TO
SMALL FUNDAMENTAL
PARTS



THE QUANTUM WORLDVIEW

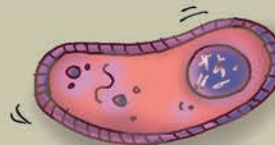
NON-DETERMINISM
OUTCOMES AREN'T FIXED

WE CAN'T KNOW BOTH
POSITION AND SPEED
OF A PARTICLE
AT THE
SAME TIME!

HARD PREDICTIONS DON'T EXIST,
ONLY STATISTICAL
PROBABILITIES!



THE UNIVERSE LOOKS LIKE AN
ORGANIC SYSTEM



EMPHASIS ON
STUDYING THE
INTERDEPENDENCE
OF PARTS

OPPOSITES
COMPLEMENT EACH OTHER

QUANTUM PARTICLES
BEHAVE AS WAVES
AND PARTICLES!

IT'S LIKE
YIN AND YANG!



I even adopted this
sign into my family's
coat of arms!

NIELS BOHR →



SUBJECTIVE PARTICIPATION

THE THINGS I OBSERVE
ARE AFFECTED BY MY
OBSERVATION!

I'M NOT SEPARATE FROM
MY OWN EXPERIMENT...

...I'M PART
OF IT!



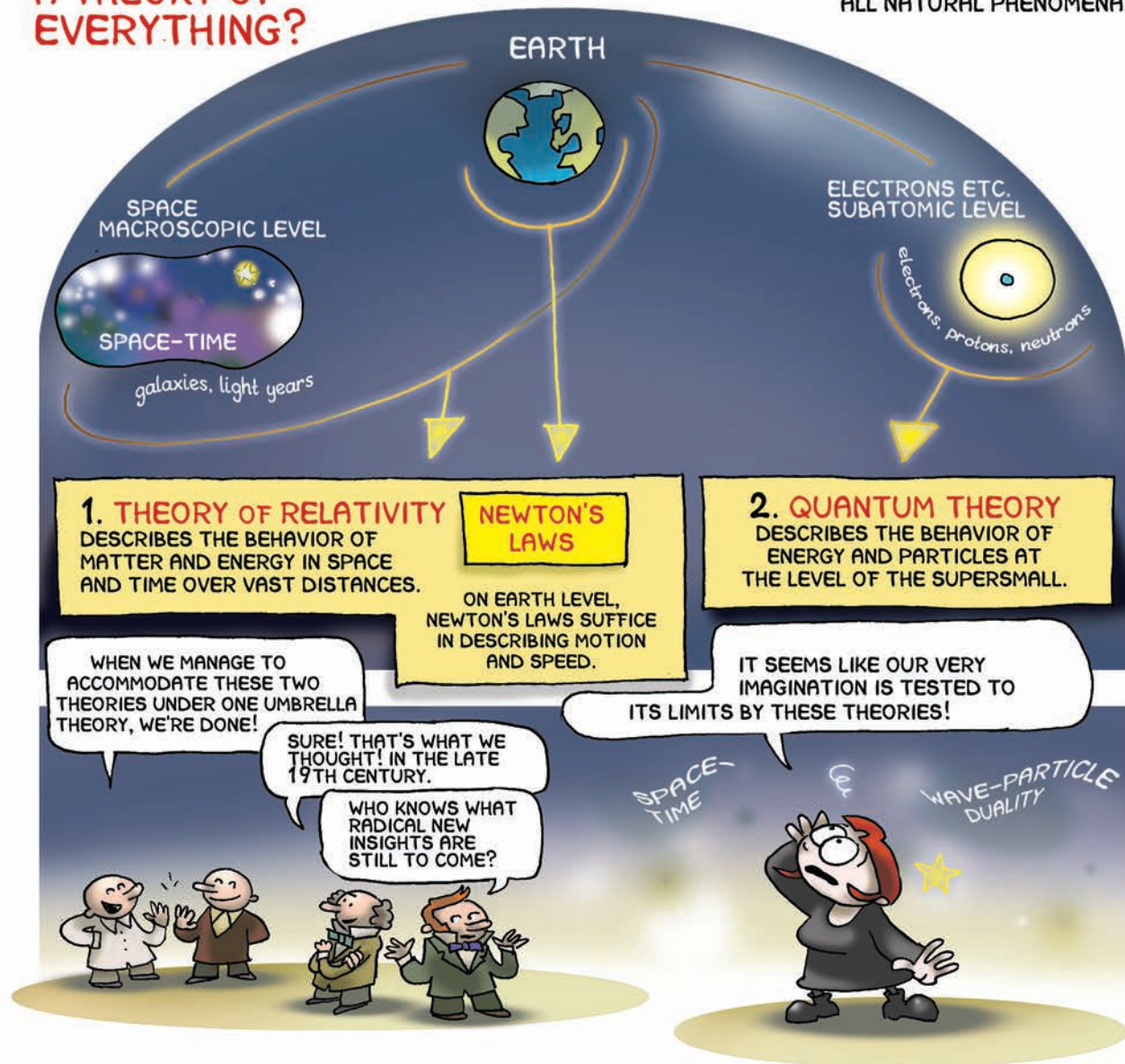
HOLISM

COMPLEX THINGS CAN ONLY BE STUDIED
AS THE INTERRELATIONSHIP
OF THEIR PARTS



**NEXT STOP:
A THEORY OF
EVERYTHING?**

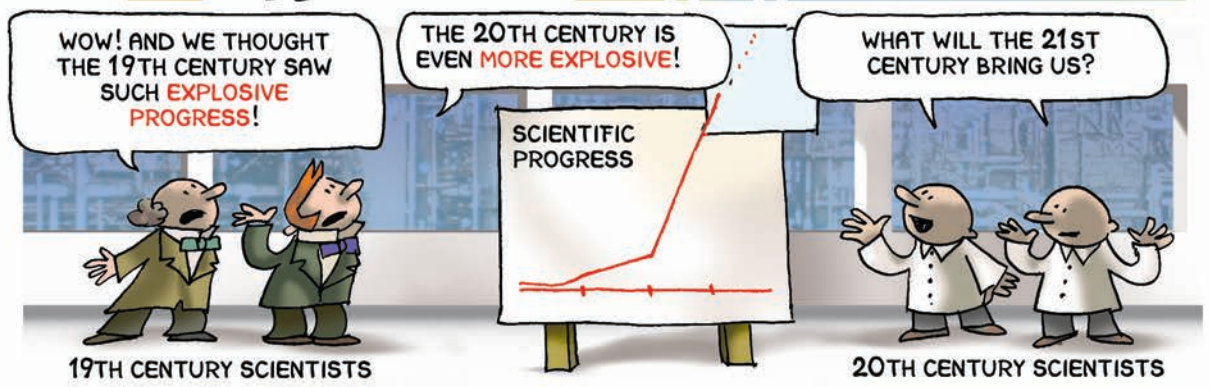
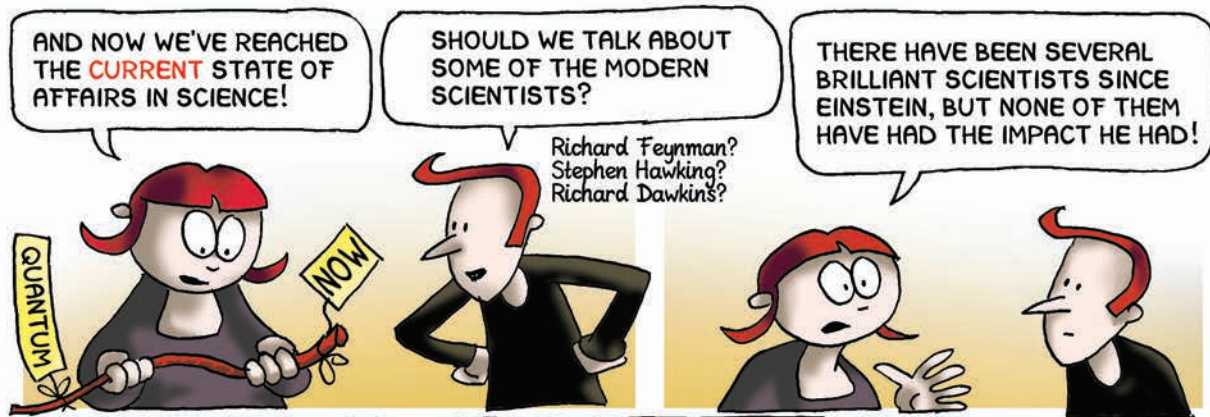
AT THIS MOMENT WE HAVE **TWO THEORIES**
THAT TOGETHER EXPLAIN
ALL NATURAL PHENOMENA.



WHERE ARE WE
HEADING?



SCIENCE
OF THE
FUTURE



WHERE DOES SCIENCE STAND AT THE BEGINNING OF THE 21ST CENTURY?

AMERICA USED TO BE THE LEADER IN SPACE TRAVEL, BUT NOW NO LONGER HAS THE FUNDS!

PRIVATE BUSINESSES ARE ORGANIZING SPACE JOURNEYS FOR THE GENERAL PUBLIC!

WITH US, YOU PAY ONLY 95,000 DOLLARS!

NINE COUNTRIES IN THE WORLD HAVE **NUCLEAR WEAPONS** NOW!

UNMANNED SPACECRAFT TRAVEL TO PLANETS FAR AWAY!

MERCURY, HERE I COME!

THE **INTERNET** BRINGS ALL OF US CLOSER! IT MAKES IT POSSIBLE FOR SCIENTISTS ALL OVER THE WORLD TO SHARE AND COMPARE THEIR FINDINGS AND START INTERNATIONAL RESEARCH TEAMS!

THE FREEDOM OF THE INTERNET IS THREATENED, HOWEVER, BY A NUMBER OF ORGANISATIONS WHO WANT TO RESTRICT IT!

WHERE WILL THAT LEAD?

WE USE THIS **GIANT UNDERGROUND STRUCTURE** TO ACCELERATE SUBATOMIC PARTICLES TO ALMOST THE SPEED OF LIGHT!

AND THEN WE MAKE THEM COLLIDE!

LET'S SEE WHAT HAPPENS!

Until now they behave exactly as Einstein predicted!

IN 2003, WE MAPPED OUT THE ENTIRE **HUMAN GENOME**!

NOW WE BUILD ON THAT KNOWLEDGE BY RESEARCHING THE **GENETIC DEVELOPMENT OF CANCER**!

Maybe it won't be long before we can cure cancer!

WE ARE LOOKING FOR **BLACK HOLES**!

THEY ARE CELESTIAL BODIES SO BIG AND HEAVY THAT THEIR GRAVITY RETAINS EVERYTHING - EVEN LIGHT!

We can't see them, but from the behavior of surrounding stars and planets we can deduce they're there!

WHEN WE FIND THESE, THAT'S ANOTHER PIECE OF EVIDENCE FOR EINSTEIN'S THEORY OF HOW THE UNIVERSE WORKS!

Russia is number one now!

Working on it!

Not too fast!

WE'RE MAKING **NANOBOTS** THAT CAN DO REPAIRS INSIDE THE BODY!

COOL!

WE WANT CLEAN ENERGY!

CERN SWITZERLAND

HUMAN GENOME PROJECT

CANCER GENOME PROJECT



HOW WILL SCIENCE
DEVELOP IN THE
FUTURE?

TO GET AN IDEA,
WE CAN TAKE A LOOK
AT THE PAST!

WHAT HAS MOTIVATED
SCIENTISTS THROUGH
THE CENTURIES?



OUR MOTIVATION?
LOVE OF KNOWLEDGE!

LITERALLY:
PHILO-SOPHIA!

WE WANT TO KNOW **FOR THE SAKE OF KNOWING!**

WHO ARE
WE?

HOW DOES IT
ALL WORK?

VERY EXALTED MOTIVES!

BUT THERE
ARE OTHER
MOTIVATIONS, TOO!



THIRST FOR KNOWLEDGE



THE PHILOSOPHER'S STONE!

WHEN WE HAVE THAT,
WE'LL MAKE **GOLD** !

THE ELIXIR OF LIFE!

FOREVER
YOUNG!

BIGGER!

FASTER!

BETTER!

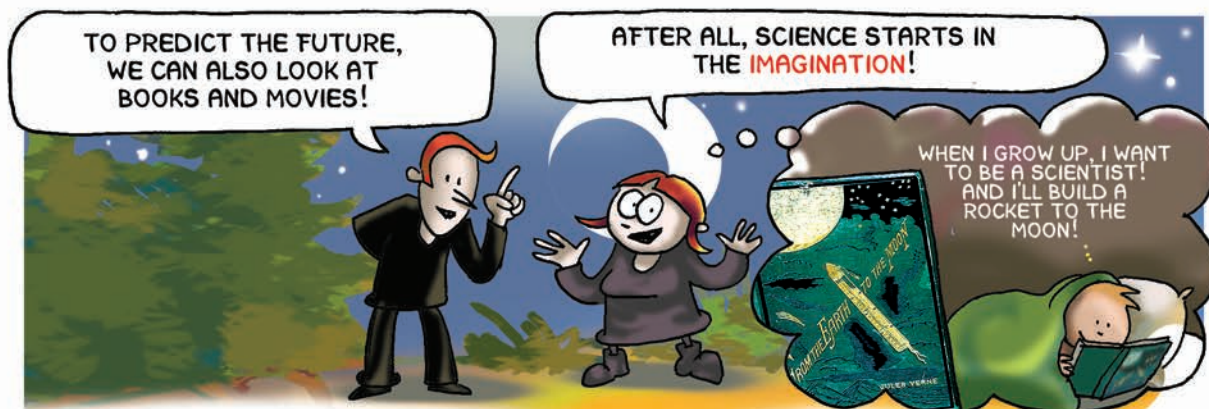


GREED

IMMORTALITY



COMPETITION

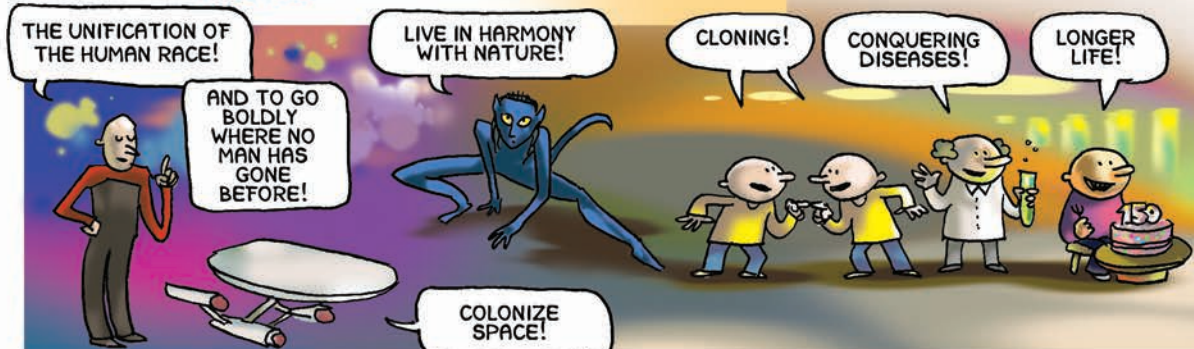


SCIENCE FICTION SHOWS WHAT WE HOPE AND EXPECT FROM SCIENCE...

... AND WHAT WE **FEAR!**



RECURRING **THEMES** OF OUR AGE ARE:



IF WE CAN BALANCE OUR INNATE **OPPORTUNISTIC MOTIVES** A BIT
WITH THE DEVELOPMENT OF **SUSTAINABLE RESOURCES**,
SCIENCE WILL HAVE A BRIGHT FUTURE AHEAD!



THERE! THE
PLANET IS CLEAN...

EQUAL DIVISION
OF MEANS...

WORLD PEACE...

NOW WE'RE READY TO GO
INTO SPACE! WHO KNOWS
WHAT WE'LL FIND THERE?!

MAYBE
GOLD!



LONGER AND
HEALTHIER
LIVING...



GOLD!!!



OR WILL IT?





INDEX

- Abelard of Bath, 39
Acceleration, 163
Agricola, Georg, 69, 151
Al-Biruni, 150
Al-Farghani, 106
Al-Haytham (Alhazen), 59, 106, 168
Al-Jahiz, 138
Al-Kashi, Jamshid, 46
Al-Khwarizmi, 39, 59, 106
Al-Razi, 59
Al-Tusi, 106
Alchemy, 68-69, 116
Alexander the Great, 51
Algebra, 39
Alhazen (Al-Haytham), 59, 106, 168
Alpher, Ralph, 108
Ampère, André-Marie, 121
Anaximander, 28, 36
Anning, Mary, 81, 84
Apeiron, 28
Archimedes, 32, 36, 46
Aristotle, 38, 50-54, 55, 61, 94, 95, 150, 166, 168
Aronofsky, Darren, 46
Astronomy, 105-112
Atoms, 28, 68, 69, 72, 74, 75, 95, 168
Atomism, 69, 94
Averroes, 58
Avery, Oswald, 142
Avicenna (Ibn-Sina), 59, 138, 150
Axiom, 34, 35
Ayurveda, 138

Babbage, Charles, 46
Babylonians, 21, 24, 30, 38
Baron-Cohen, Simon, 117
Barrow, Isaac, 114
Bartók, Béla, 48

Barton, Catherine, 117
Bassi, Laura, 81
Beagle, 130-132
Becquerel, Antoine Henri, 72
Beguín, Jean, 69
Béguyer de Chancourtois, Alexandre-Émile, 82
Bell, Alexander, 121
Berkeley, George, 49
Berzelius, Jöns Jacob, 69
Besso, Michele, 160
Bhaskara, 49
Big Bang, 108
Biology, 137-140
Biotechnology, 140
Black body, 122
Black holes, 175
Blackburn, Elizabeth, 81
Bohr, Niels, 72, 164, 167, 171
Born, Max, 167
Boyle, Robert, 69
Brahe, Tycho, 107
Brahmagupta, 49
de Broglie, Louis, 167
Buckland, William, Reverend, 83, 151, 153
Bush, Kate, 46

Cancer Genome Project, 175
Cantor, Georg, 47
Cavendish, Margaret, 80, 84
Catastrophism, 151
Chadwick, James, 72
Chaloner, William, 116
du Châtelet, Émilie, 81
Cell theory, 139
Celsius, Anders, 121
CERN, 163, 175
Charlemagne, 59

Chemistry, 63-76
 Classical Mechanics, 128
 Columbus, Christopher, 59
 Conservation of Mass, the Law of, 69
 Copenhagen Interpretation, 167
 Copernicus, Nicolaus, 95, 96, 107, 120
 Cori, Gerty, 81
 de Coulomb, Charles-Augustin, 121
 Crick, Francis, 82, 142
 Curie, Marie, 72, 81
 Curie, Pierre, 72
 Cuvier, Georges, 83, 151

 Dalí, Salvador, 48
 Dalton, John, 69, 95, 121
 Darwin, Charles, 130-136, 139, 151, 153
 Darwin, Robert, 131, 133
 de Medici, 89
 Deduction, 53
 Democritus, 68, 95, 168
 Descartes, René, 169
 Determinism, 171
 DNA, 72, 142-147
 Dolly, sheep, 143
 Dominicans, 58
 Double-slit experiment, 168-169

 Ecology, 140
 Eddington, Arthur, 164
 Edison, Thomas, 82, 125
 Einstein, Albert, 108, 122, 159-164, 166-169, 174
 Electricity, 124-125
 Electrons, 72, 75
 Electron microscope, 76
 Elements (book), 34, 38, 39
 Elements (chemical), 69-71
 Elements (five), 61, 68, 74, 95, 120

 Elixir of Life, 68, 176
 Entropy, 126
 Euclid, 34, 36, 38
 Euler, Leonhard, 40
 Ether, 61, 68, 74
 Eureka, 23, 32

 Fahrenheit, Daniel Gabriel, 121
 Faraday, Michael, 121
 Feynman, Richard, 40, 174
 Fibonacci, Leonardo, 39
 First Principle, 26, 28
 Fox, William Darwin, 131
 Franklin, Benjamin, 125
 Franklin, Rosalind, 82, 142

 Galapagos Islands, 132
 Gamow, George, 108
 Galen, Claudius, 95, 138
 Galilei, Galileo, 39, 40, 95-96, 107, 120
 Geber (Ibn Hayyan, Jabir), 59, 69
 Genetics, 141-147
 Genetic Manipulation, 140, 143
 Geometry, 34
 Geology, 149-152
 Golden Ratio, 48
 Gould, John, 133
 Gravity, 94, 107, 118, 162
 Greider, Carol, 81
 Grossmann, Marcel, 160

 Habicht, Konrad, 160
 Halley, Edmond, 115
 Hardy, Godfrey Harold, 40
 Harriet, giant tortoise, 132
 Hawking, Stephen, 43, 174
 Heisenberg, Werner, 167

Henslow, John Stevens, 131, 133
 Heredity, 142-143
 Herschel, Caroline, 81, 84
 Hildegard of Bingen, 80, 138
 Hippocrates, 138
 Holism, 171
 Holmes, Arthur, 152
 Homo Erectus, 156
 Homo Sapiens, 156
 Hooke, Robert, 139, 143
 Hooker, Dalton, 134
 Hubble, Edwin, 108
 Huijgens, Christiaan, 107, 169
 Human Genome Project, 143, 175
 Hutton, James, 151
 Huxley, Thomas, 134
 Hypatia of Alexandria, 80, 84

 Ibn Al-Baitar, 138
 Ibn Hayyan, Jabir (Geber), 59, 69
 Ibn Sina (Avicenna), 59, 138, 150
 Induction, 53
 Industrial Revolution, 121, 130
 Infinity, 47

 Jesuits, 96
 Joliot-Curie, Irène, 81
 Joule, James, 121

 Kanada, 68
 Kelvin, Lord (William Thompson), 139, 153
 Kepler, Johannes, 39, 95, 107, 120
 Keynes, John Maynard, 117
 Kirchoff, Gustav, 107

 Lavoisier, Antoine, 69, 74, 78
 Lavoisier, Marie, 77-79
 Leclerc, Georges-Louis (Conte of Buffon), 153
 van Leeuwenhoek, Antonie, 139, 143

 Linnaeus, Carl, 139
 Logic, 35, 38, 40, 50, 53, 58-59, 76
 Lovelace, Ada, 81, 84
 Lyell, Charles, 132, 133, 151

 Madhava, 46
 Mantell, Gideon, 83
 Maragheh observatory, 106
 Marconi, Guglielmo, 82
 Maric, Mileva, 160
 Mars, 107, 108, 152
 Mary the Prophetess, 80
 Mathematics, 37-49
 Matematikoi, 30
 Maxwell, James Clerk, 158
 Mayans, 21
 Mendel, Gregor, 139, 143
 Mendeleev, Dimitri, 69, 70, 82, 158
 Merian, Maria Sibylla, 80
 Merith Ptah, 80
 Mesopotamia, 21
 Miescher, Friedrich, 142
 Mitchell, Maria, 81, 84
 Moebius, August, 47
 Moebius strip, 47
 Moseley, Henry, 72
 Motion, 95, 118, 120, 127
 Muslim scholars, 39, 55, 59, 69

 von Nägeli, Karl-Wilhelm, 142
 Nanobots, 140, 175
 Natural Theology, 135-136
 Neptunists, 151
 Neptune, 107, 111, 112
 Neutrons, 72, 75
 Newton, Isaac 39, 40, 81, 95, 107, 113-118, 120, 127, 162, 163, 169, 172
 Nightingale, Florence, 81, 84
 Nitroglycerin, 64-65

Nobel, Alfred, 121
 Oceanography, 152
 Origin of Species (book), 133
 Owen, Richard, 83, 133, 134
 Oxygen, 66
 Oxygen catastrophe, 154

 Pacioli, Luca, 39, 48
 Paley, William, 135
 Paracelsus, 69, 139
 Particle physics, 75
 Pasteur, Louis, 121
 Penzias, Arno Allan, 108
 Periodic table, 69-72
 Pi, 46
 Pharmaceutical Industry, 140
 Phi, 48
 Philosopher's stone, 68
 Phlogiston, 69
 Photo-electric effect, 166
 Photons, 168-169
 Photosynthesis, 154
 Physics, 119-128
 Planck, Max, 166, 167
 Plato, 38, 51, 52
 Plinius the Elder, 150
 Plutonists, 151
 Polo, Marco, 58
 Principia Mathematica (book), 39, 115-116
 Protons, 72, 75
 Proxima Centauri, 111, 112
 Ptolemy, 60, 95, 106
 Pythagoras, 30, 36

 Quantum theory, 102, 122, 165-172

 Radioactivity, 71
 Reductionism, 171

 Religion and Science, 31, 98-104
 Remak, Robert, 139
 Relativity, Theory of, 122, 162, 164, 172
 Robert of Chester, 39
 Roentgen, Wilhelm, 158
 Roosevelt, Franklin D., 164
 Russell, Bertrand, 40
 Russell's Paradox, 40
 Rutherford, Ernest, 72, 75

 Schleiden, Matthias, 139
 Schrödinger, Erwin, 167
 Schrödingers cat, 102, 167
 Schwann, Theodor, 139
 Science fiction, 177
 Scientific method, 52-53
 Shen Kuo, 150
 Solovine, Maurice, 160
 Somerville, Mary, 81
 Space-time, 162, 163, 172
 Space travel, 175
 Steam engine, 126
 Steno, Nicolas, 139, 151
 Stevin, Simon, 39
 Stonehenge, 106

 Tesla, Nikola, 82
 Thales of Miletus, 26, 36
 Theano, 80
 Theophrastus, 150
 Theory of Everything, 122, 172
 Thermodynamics, 126
 Thomas Aquinas, 58
 Thompson, William (Lord Kelvin), 139, 153

 Uniformitarianism, 151
 Uranus, 107
 Urban VIII, Pope, 97
 Ussher, James, Archbishop, 153

Vesalius, Andreas, 95, 139
da Vinci, Leonardo, 59, 87-92, 151
Vitalism, 69
Volta, Alessandro, 121
Voltaire, 81

Wallace, Alfred Russel, 133
Water, 26, 74
Watson, James, 82, 142
Watt, James, 121
Wave Particle Duality, 122, 168-169, 172
Wegener, Alfred, 152
Werner, Abraham, 151

Wilberforce, Bishop, 134
Wilkins, Maurice, 82
Wilson, Robert Woodrow, 108
Winkelmann, Maria, 80
Wöhler, Friedrich, 69

X-rays, 158

Young, Thomas, 168-169

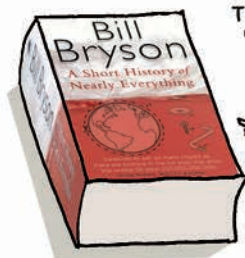
Zero, 49
Zu Chongzhi, 46



MORE TO WATCH & READ

BILL BRYSON A SHORT HISTORY OF NEARLY EVERYTHING

BOOK



THIS IS A
GREAT
BOOK!

A MUST-READ!
IT WAS A BIG
INSPIRATION FOR
OUR OWN BOOK!



THE FOR BEGINNERS SERIES



NUMEROUS
SUBJECTS
EXPLAINED
IN WORDS
AND PICTURES!



BOOK

COMIC

BEAGLE - ON THE FUTURE OF SPECIES

DVD



IN 2009, A DUTCH SAILBOAT FULL OF
INTERNATIONAL SCIENTISTS AND
ARTISTS REVISITED THE
SITES OF DARWIN'S JOURNEY!



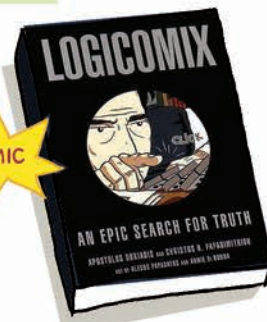
VERY
FASCINATING
& EDUCATIONAL!

A UNIQUE
GRAPHIC NOVEL
ABOUT
BERTRAND RUSSELL
AND LOGIC!



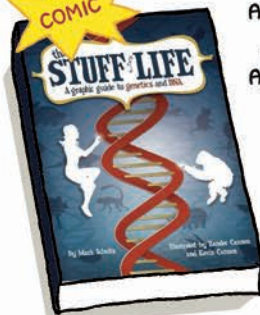
LOGICOMIX

COMIC



THE STUFF OF LIFE A GRAPHIC GUIDE TO GENETICS AND DNA

COMIC



A COMIC ABOUT GENETICS!

PRETTY
ADVANCED
STUFF!

FOR
DIE-HARDS!



EINSTEIN AND EDDINGTON

MOVIE

THIS MOVIE GIVES A GREAT
DEPICTION OF THE TIME
EINSTEIN LIVED!
WITH THE ACTORS WHO
PLAYED GOLLEM AND DR. WHO!



AND THIS IS ANOTHER
BOOK WE MADE!

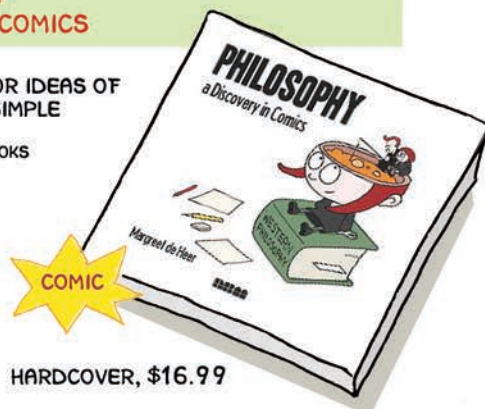


PHILOSOPHY: A DISCOVERY IN COMICS

"...ENCAPSULATES THE MAJOR IDEAS OF
WESTERN THOUGHT INTO A SIMPLE
AND HONEST NARRATIVE."
- THE NEW YORK JOURNAL OF BOOKS

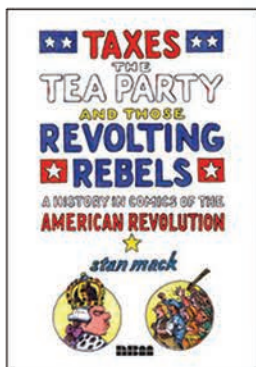
"...DRAWS PHILOSOPHY OUT OF THE
ABSTRACT, ACADEMIC ETHER AND
CONNECTS IT TO REAL PEOPLE AND
THEIR LIVES." - THE LIBRARY JOURNAL

"...A PERFECT INTRO TO THE COMPLEX
AND WEIGHTY TOPIC OF PHILOSOPHY."
- THE COMICS BULLETIN



HARDCOVER, \$16.99

OTHER EDUCATIONAL BOOKS BY NBM PUBLISHING:



TAXES, THE TEA PARTY AND THOSE REVOLTING REBELS - BY STAN MACK

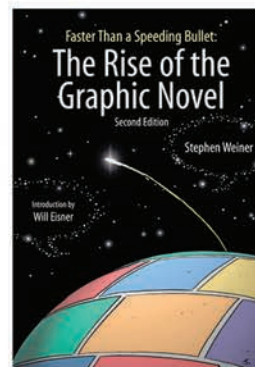
"ENDEARINGLY IRREVERENT AND WELL-RESEARCHED. WHILE EXCELLENT FOR CLASSROOM-
CENTERED TWEENS AND TEENS, THESE REVOLTING REBELS SHOULD STAR IN ALL ADULT
COLLECTIONS, TOO." - LIBRARY JOURNAL STARRED REVIEW

HARDCOVER, \$16.99

THE RISE OF THE GRAPHIC NOVEL - BY STEPHEN WEINER

"THIS IS A PERFECT BOOK FOR ANYONE TRYING TO WRAP
HIS OR HIS HEAD AROUND THE FIELD OF COMICS,
A QUICK AND SMART OVERVIEW OF THE FIELD
THAT SPANS BOTH DECADES AND GENRES."
- CORY DOCTOROW, BOINGBOING

HARDCOVER, \$14.99



ADD \$4 P&H.
SEE MORE WITH FEATURES AND REVIEWS AT OUR WEBSITE,
INCLUDING MARGREET POSTING ON OUR BLOG:
WWW.NBMPUB.COM

WE HAVE OVER 200 GRAPHIC NOVELS AVAILABLE, WRITE FOR A COMPLETE CATALOG:
NBM 160 BROADWAY, STE. 700, EAST WING
NEW YORK, NY 10038

A BIG THANKS TO OUR SCIENTIFIC THINKTANK:

RUTGER OCKHORST, DIRK-JAN SCHEFFERS, ZWAANTJE HARMELINK & ANGUS HOEFS

& OUR INCORRIGIBLE PROOFREADERS:

YOLANDA JESSE (DUTCH)
& DAN SCHIFF (ENGLISH)

WHO GUARDED THIS BOOK AGAINST MANY A BLUNDER.



This book takes you on a chronological journey from the Ancient Greeks to Quantum Theory, with comic artist Margreet de Heer and her husband Yiri as your guides.

In a playful and informative way, they explore various fields of science – from mathematics in the time of Pythagoras and the progress from mystic alchemy to experimental chemistry in the Middle Ages, through the rapid developments in physics and astronomy of the 17th century Scientific Revolution and the popularization of biology and geology in the 19th century, to the eventual controversial emergence of Quantum Theory, which still shapes the field of science today.

On the way they meet many famous scientists: Archimedes, who yelled “Eureka!”, Galileo, who got into a fight with the Church, Newton, who saw an apple falling and Darwin, who went on a journey to the other side of the world. But they also encounter lesser-known scientists, including Marie Lavoisier and Rosalind Franklin, whose important contributions to the field are spotlighted.

Science: a Discovery in Comics is a colorful and instructive book that mixes facts with questions, history with experiment and information with humor.

Comic artist Margreet de Heer is the author of *Philosophy: a Discovery in Comics*, which earned critical acclaim for the fun and original way in which it dealt with the topic of philosophy.

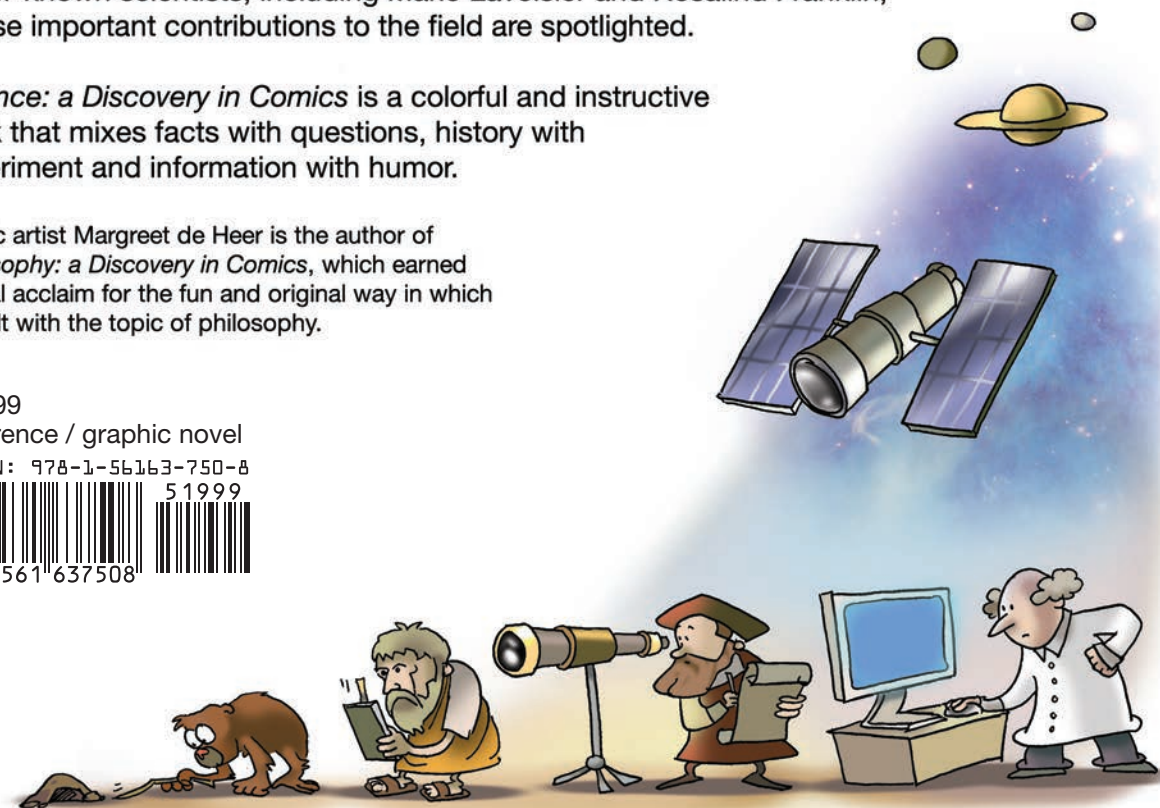
\$19.99

Reference / graphic novel

ISBN: 978-1-56163-750-8

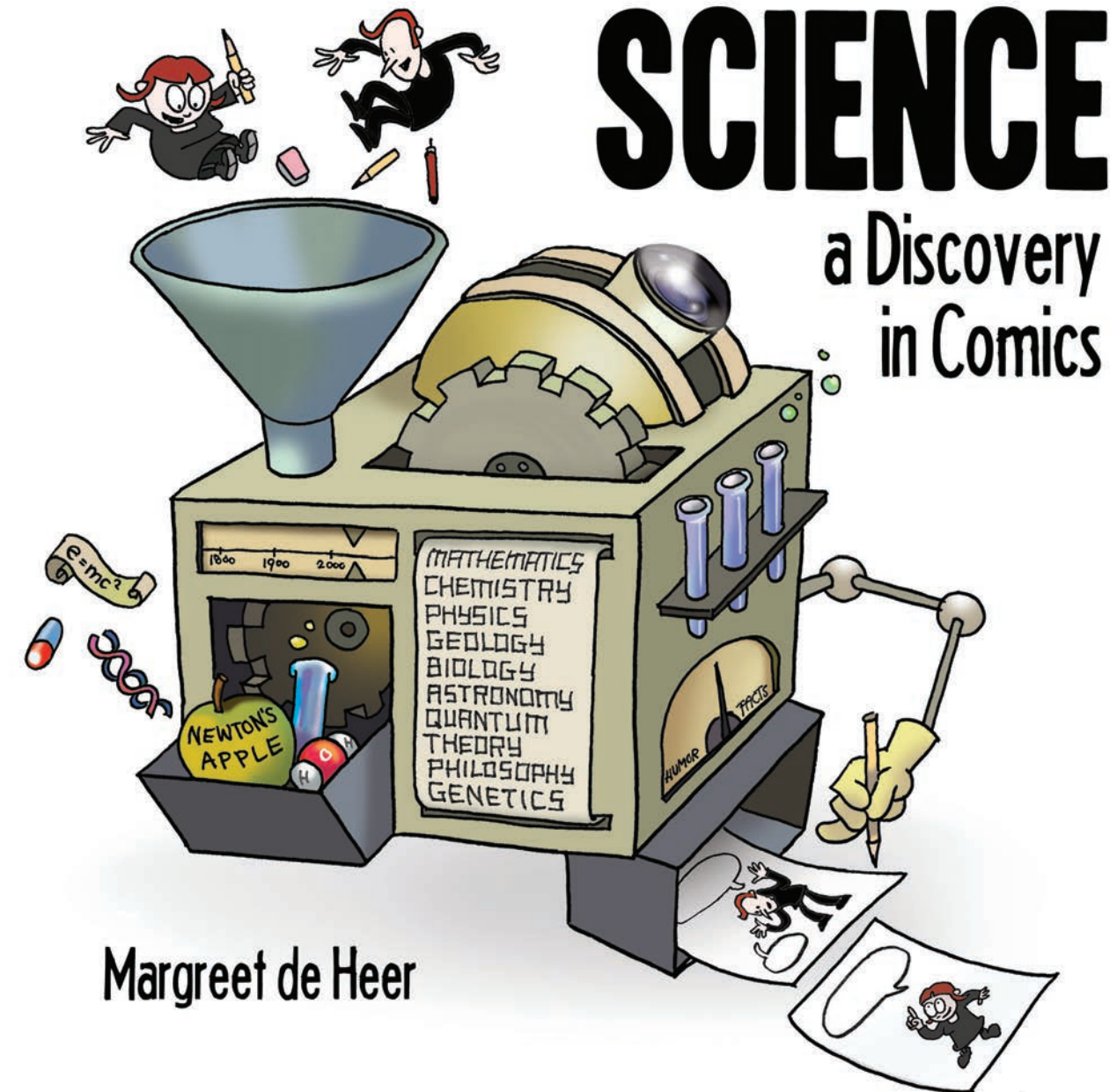


9 781561 637508



SCIENCE a discovery in comics

Margreet de Heer



Margreet de Heer

