

what do scientists do?



A COMIC BOOK
ABOUT MY
RESEARCH

SCIENCE IS WHAT HUMANS DO TO
BUILD AND ORGANISE KNOWLEDGE...

... FOR EXAMPLE THE KNOWLEDGE
THAT SERVES TO EXPLORE MARS

... BUT MY FRIENDS OFTEN HAVE NO
IDEA OF WHAT THE HELL I AM REALLY
DOING AS A SCIENTIST

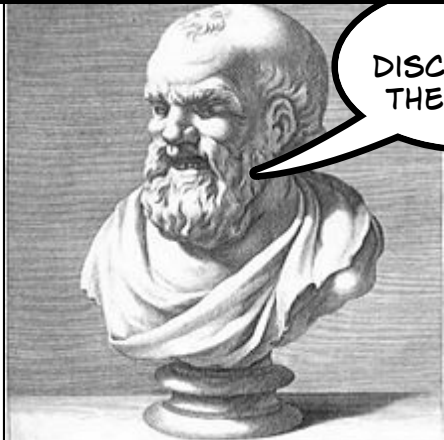


ARE
YOU STILL
DOING THAT
THING OF

I
SHOULD
EXPLAIN
MYSELF

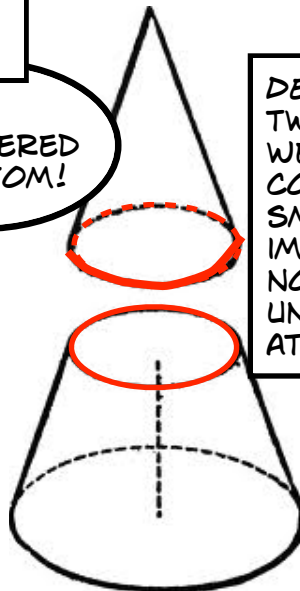
SO I DECIDED TO
WRITE A COMIC BOOK

CLASSIC SCIENTISTS DID SCIENCE
MAINLY THINKING ABOUT THINGS



DEMOCRITUS, 400 BC

I
DISCOVERED
THE ATOM!



DEMOCRITUS THOUGHT THAT IF THIS
TWO RED CIRCLES WERE IDENTICAL,
WE WOULD HAVE A CYLINDER, NOT A
CONE. HENCE ONE CIRCLE SHOULD BE
SMALLER THAN THE OTHER. THIS
IMPLIED FOR HIM THAT THERE WERE
NO CONTINUOUS, BUT ONLY DISCRETE
UNITS... HE CALLED THOSE UNITS
ATOMS.

WITH ONLY THINKING YOU
MAY REACH WRONG
CONCLUSIONS, BUT IN
THIS CASE HE GOT IT
QUITE RIGHT!



FRANCIS BACON, ~ 1600

KNOWLEDGE
IS POWER

MUCH LATER BACON
INTRODUCED THE
SCIENTIFIC METHOD

BASICALLY YOU HAVE AN IDEA,
THEN YOU HAVE TO TEST IT (MANY
TIMES) BEFORE ACCEPTING THAT
IDEA AS TRUE.

CURIOUSLY, BACON HIMSELF
NEVER USED IT. BUT ALL
SCIENTISTS DO IT NOW!

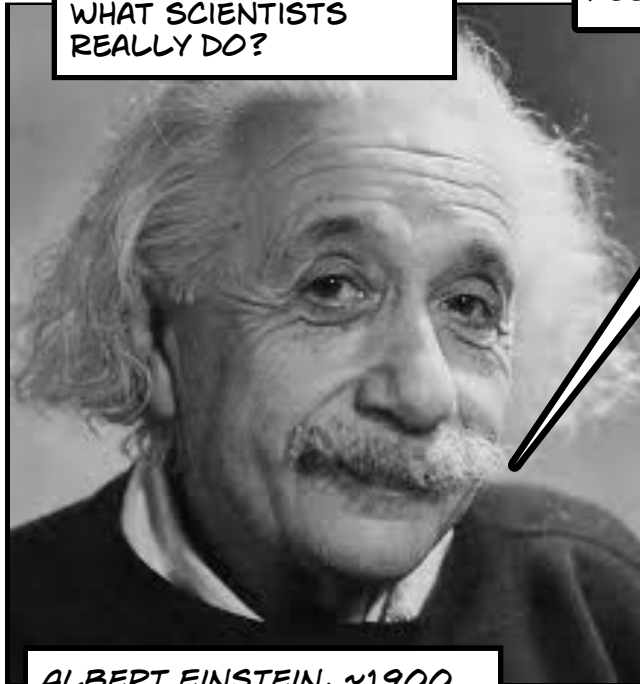
BUT HOW DO WE GENERATE AND TEST IDEAS?

OR IN OTHER WORDS,
WHAT SCIENTISTS
REALLY DO?

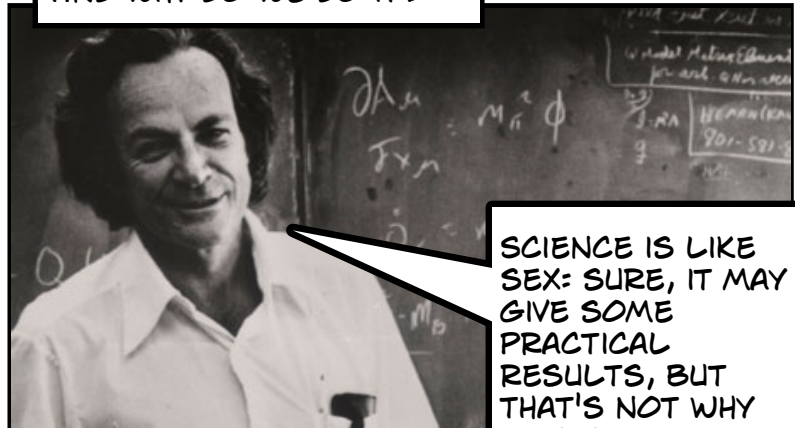
IF WE KNEW WHAT IT WAS WE WERE
DOING, IT WOULD NOT BE CALLED
RESEARCH, WOULD IT?

THERE ARE AS MANY WAYS OF
DOING SCIENCE (THAT IS, TESTING
IDEAS) AS THERE ARE SCIENTISTS.

AND WHY DO WE DO IT?



ALBERT EINSTEIN, ~1900



RICHARD FEYNMAN, ~1950

SCIENCE IS LIKE
SEX: SURE, IT MAY
GIVE SOME
PRACTICAL
RESULTS, BUT
THAT'S NOT WHY
WE DO IT.



**YES
IS MORE**

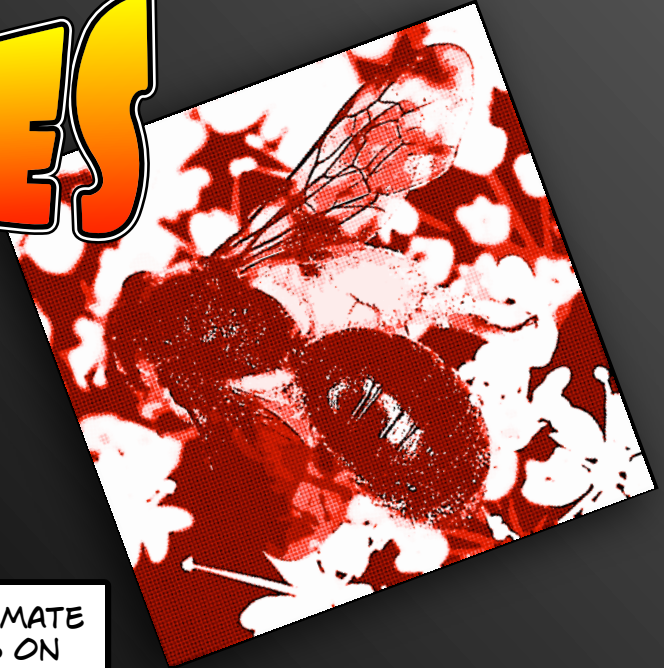
**SCIENCE IS ABOUT
FACTS, BUT
COMMUNICATION
IS ABOUT STORIES**

**THIS IS THE
STORY OF MY
RESEARCH**

**THIS
ARCHITECT,
BJARKNE
INGELS,
EXPLAINED ME
HIS BUILDINGS
IN A COMIC,
AND I LOVED
HIS STORY,
DESPITE I AM
NOT
PARTICULARLY
INTERESTED IN
BUILDINGS**



HOT BEES



INVESTIGATING CLIMATE
CHANGE IMPACTS ON
BEES AND PLANTS
PHENOLOGY

BARTOMEUS ET AL. 2011 PNAS 108:20645-49

IN THE LAST 100 YEARS LOTS OF THINGS HAVE CHANGED VERY RAPIDLY IN THE WORLD, AND WE, HUMANS, ARE RESPONSIBLE FOR THIS ACCELERATED CHANGE



HUMAN POPULATION HIT 7 BILLION IN 2012



CO-2 EMISSIONS HAVE RAISED MEAN TEMPERATURES $\sim 1^{\circ}\text{C}$ SINCE 1900'S

WE ARE $+0.6^{\circ}\text{C}$ ABOVE THE 1950-1980 MEAN TEMPERATURE LEVELS

2010

7 BILLION PEOPLE

1980

1950

1880

4% OF LAND WAS AGRICULTURE IN ~ 1800

>20% OF LAND IS AGRICULTURE, NOW

1 BILLION PEOPLE

1820



...WE ALSO ARE WELL KNOWN FOR TRANSFORMING WILD AREAS INTO HUMAN DOMINATED LANDSCAPES

BUT... HOW ARE ALL THESE CHANGES
AFFECTING PLANTS AND ANIMALS?



THAT WAS OUR QUESTION WHEN I MOVED TO THE U.S. TO START MY POSTDOC AT RACHAEL WINFREE LAB. SPECIFICALLY WE WERE INTERESTED ON BEE RESPONSES TO GLOBAL CHANGE.




THIS IS RACHAEL

AND THIS IS A VERY CUTE WILD BEE



(YES, THERE ARE MANY MORE SPECIES THAN HONEYBEES, IN FACT THERE ARE TWICE AS MANY BEE SPECIES THAN BIRDS! AND MOST BEES LIVE SOLITARY, NOT IN BIG HIVES)




SO WE WANTED TO
COMPARE WHAT BEES
WERE DOING IN 1900
AND WHAT THEY ARE
DOING NOW

BUT... HOW DO YOU
INVESTIGATE THINGS
THAT HAPPENED IN
THE PAST?



YOU CAN
BUY A
DELOREAN

**BACK
TO
THE FUTURE**



OR YOU CAN
GO TO A
MUSEUM

UNFORTUNATELY, WE
DID THE LATER

THE AMNH IS FAMOUS
FOR ITS DINOSAURS...



BUT IT ALSO HAS
THE LARGEST BEE
COLLECTION IN THE
U.S., COMPRISING
>500.000
SPECIMENS



BEES
COLLECTED BY
AMATEUR
NATURALISTS AND
RESEARCHERS
SINCE 1880 TO
2011 CAN
EXPLAIN US THEIR
HISTORY



EACH SPECIMEN
HAS THIS LITTLE
LABELS WITH ITS
LATIN NAME,
COLLECTOR NAME,
DATE OF
COLLECTION AND
LOCALITY



JOHN ASCHER, THE
CURATOR OF THE BEE
SECTION, HAS A
PROJECT TO DATABASE
ALL THESE SPECIMENS,
AND THESE DATA WERE
WHAT WE NEEDED!

WHAT DO WE KNOW ABOUT BEES?

SOLITARY BEES LAY EGGS IN LITTLE DARK HOLES, AND PROVISION THE EGGS WITH POLLEN. THE EGGS HATCH AND DEVELOP INTO LARVAS THAT EAT ALL THE POLLEN AND OVERWINTER (KIND OF HIBERNATION) IN A COCOON LIKE THIS ONE.

THIS IS A BEE COCOON



HOW DO THEY KNOW WHEN TO WAKE UP FROM HIBERNATION? HOW ARE THEY SYNCHRONISED WITH THE FLOWERS THAT ARE WAITING FOR THEM TO BE POLLINATED?



WHEN TEMPERATURES ARE HIGH ENOUGH IN SPRING, THEY SERVE AS A NATURAL ALARM CLOCK.



HELLO
WORLD

IN OUR FIRST PROJECT, WE WANTED TO KNOW IF THEIR ACTIVITY PERIOD IS SHIFTING EARLIER DUE TO THE RECENT INCREASE ON TEMPERATURES.

SO WE HYPOTHESED THAT CLIMATE WARMING WOULD ADVANCE THEIR EMERGENCE.

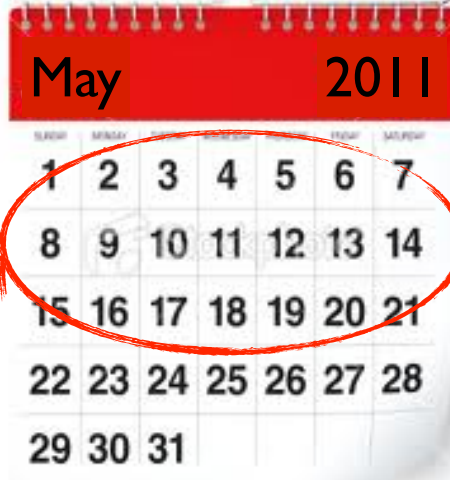
SOME RESEARCHERS POINT OUT THAT **PLANTS ARE FLOWERING EARLIER** THAN THEY USED TO FLOWER, HENCE, IF BEES DO NOT EMERGE EARLIER TOO, IT WOULD IMPLY THAT THESE FLOWERS WOULD NOT BE POLLINATED. SIMILARLY, IF BEES ARE MORE SENSITIVE TO CLIMATE CHANGE AND EMERGE BEFORE FLOWERS ARE READY, THESE BEES WOULD STARVE... A COMPLEX EQUILIBRIUM.

AFTER SOME MONTHS OF ANALYSING DATA, OUR PRELIMINAR RESULTS WERE PROMISING, BUT WE NEEDED MORE DATA... SO I CONVINCED MY WIFE TO VISIT CORNELL UNIVERSITY AND GET SOME REALLY OLD BEES DATA.

THE OLDEST RECORD IS FROM 1872.



AND WE COMPARED THE OLD BEES ACTIVITY PERIOD WITH THE CURRENT ONE. WE HAD OUR FIRST RESULT! **BEES ARE EMERGING 10 DAYS EARLIER DUE TO CLIMATE CHANGE**



AND THAT'S QUITE A LOT FOR A BEE THAT LIVES ONLY ABOUT 3 WEEKS!

BUT WE WERE NOT COMPLETELY HAPPY...

WAS 10 DAYS SIMILAR ENOUGH TO THE ADVANCE THAT FLOWERS WERE EXPERIENCING?

THAT WAS THE KEY QUESTION

WE NEED MORE DATA!



AND I SEARCHED THE LITERATURE TO FIND PLANT DATA!

YOU CAN SKIP THIS PAGE IF YOU DON'T CARE ABOUT STATISTICS (OR BEER)

AFTER 3 MORE MONTHS GATHERING THE PLANT DATA, WE COULD FINALLY COMPARE OUR BEE ADVANCING RATE WITH THE ADVANCE REPORTED FOR FLOWERING TIME... AND WE DID IT THANKS TO A COLD GLASS OF DARK BEER.

IN 1908 THE GUYS AT GUINNESS HAD THE SAME PROBLEM. HOW DO WE TEST IF TWO GUINNESS BOTTLES TASTE EQUALLY GOOD? BOTH QUESTIONS ARE ABOUT COMPARING TWO SAMPLES.

LUCKILY, CLAUDE GUINNESS KNEW OF THE IMPORTANCE OF THE SCIENTIFIC METHOD AND HIRED GOOD STATISTICIANS TO WORK FOR HIM.

AND WILLIAM SEALY GOSSET CAME WITH A BRILLIANT IDEA FOR COMPARING TWO MEANS WHEN SAMPLES ARE SMALL. THE T-TEST.



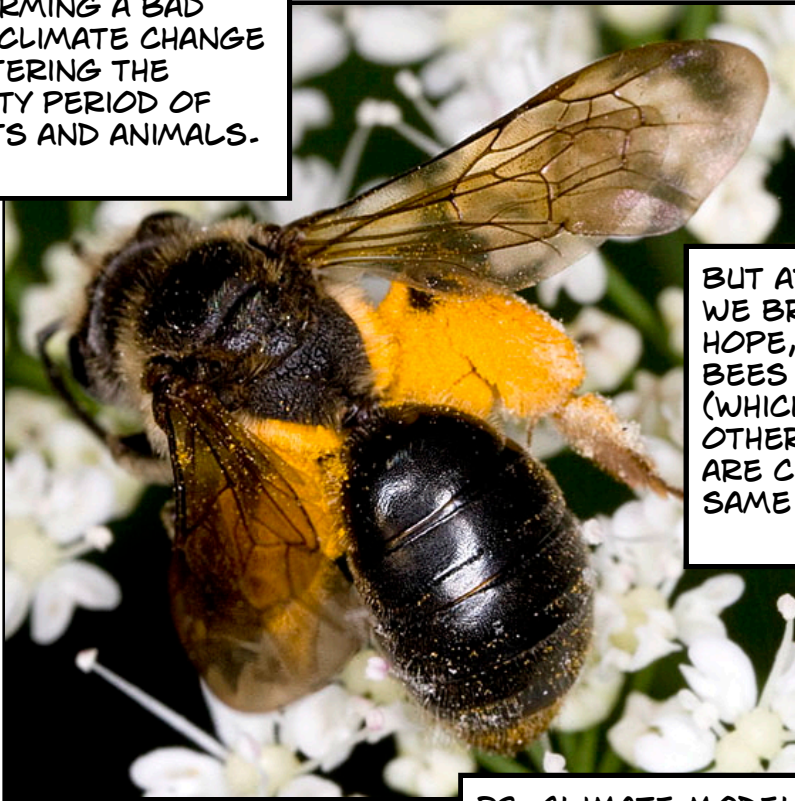
UNFORTUNATELY, SCIENCE IS NOT ALWAYS AS OPEN AS IT SHOULD BE, AND GOSSET HAD TO SIGN THE PAPER WITH A PSEUDONYM, STUDENT, WHICH GIVES NAME TO THE STUDENT'S T-TEST.

GUINNESS BEER TASTES ALWAYS THAT GOOD THANKS TO STATISTICS, AND WE STILL KEEP USING THE T-TEST

IN A NUTSHELL: AFTER TESTING OUR DATA, WE FOUND OUT THAT BEES AND FLOWERS ARE ADVANCING AT THE SAME PACE!



SO WE ENDED UP
CONFIRMING A BAD
NEW: CLIMATE CHANGE
IS ALTERING THE
ACTIVITY PERIOD OF
PLANTS AND ANIMALS.



BUT AT THE SAME TIME
WE BROUGHT SOME
HOPE, BECAUSE BOTH
BEES AND PLANTS
(WHICH RELY IN EACH
OTHER FOR SURVIVAL)
ARE CHANGING AT THE
SAME PACE...

...SO FAR.

PS: CLIMATE MODELS INDICATE TEMPERATURE WILL
KEEP INCREASING... WOULD PLANTS AND BEES BE
ABLE TO KEEP PACE WITH THIS CHANGES? WE
DON'T KNOW.

To be continued...