

THE **CARTOON**
INTRODUCTION TO
CLIMATE
CHANGE

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THE WORLD'S FIRST AND ONLY **STAND-UP ECONOMIST**

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**PART
ONE**
OBSERVATIONS

CHAPTER 1

INTRODUCTION

**TWO STORIES ARE
GOING TO DOMINATE
THE 21ST CENTURY.**



STORY #1 IS ABOUT ECONOMIC GROWTH, ESPECIALLY IN POOR COUNTRIES IN ASIA AND AFRICA.



CAPITALISM AND FREE-MARKET ECONOMICS ARE GOING TO CREATE A LOT OF NEW WEALTH...



YOU'RE FEELING THE BENEFITS OF WHAT ADAM SMITH CALLED THE **INVISIBLE HAND**.

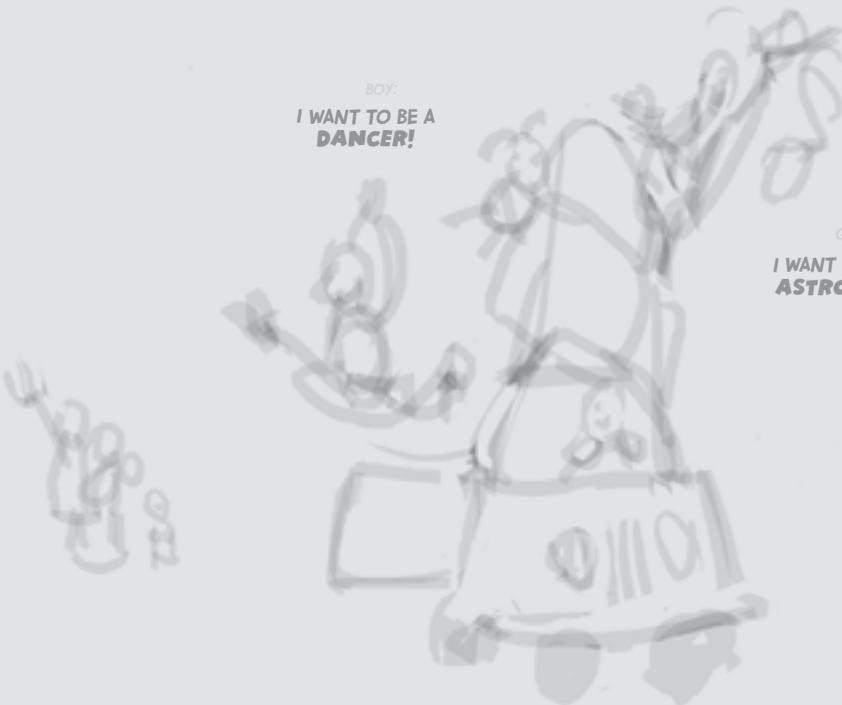
YOU CAN LEARN MORE ABOUT THAT IN THE **CARTOON INTRODUCTION TO ECONOMICS**.



... AND GIVE MANY MORE PEOPLE THE OPPORTUNITY TO PURSUE THEIR DREAMS.

BOY:
I WANT TO BE A DANCER!

GIRL:
I WANT TO BE AN ASTRONAUT!



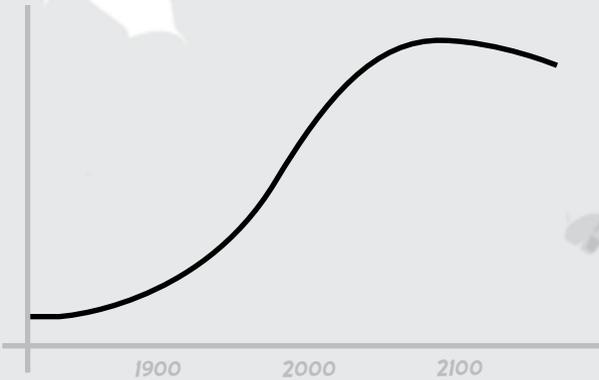
**WEALTHIER FAMILIES
TEND TO HAVE FEWER CHILDREN...**

KID FIGHT:

JUST AN IDEA, BUT
MAYBE SHE'S HITTING
HIM WITH HER
ASTRONAUT HELMET
AND HE'S CHOKING
HER WITH HIS TUTU

HAVING MORE KIDS
IS **NOT** ONE OF MY
DREAMS!

**... SO THE WORLD POPULATION IS LIKELY TO ~~PEAK~~ AT ABOUT
10 BILLION PEOPLE AND THEN SLOWLY DECLINE.**



SOON YOU'LL
GET THE
BREAK YOU
DESERVE.

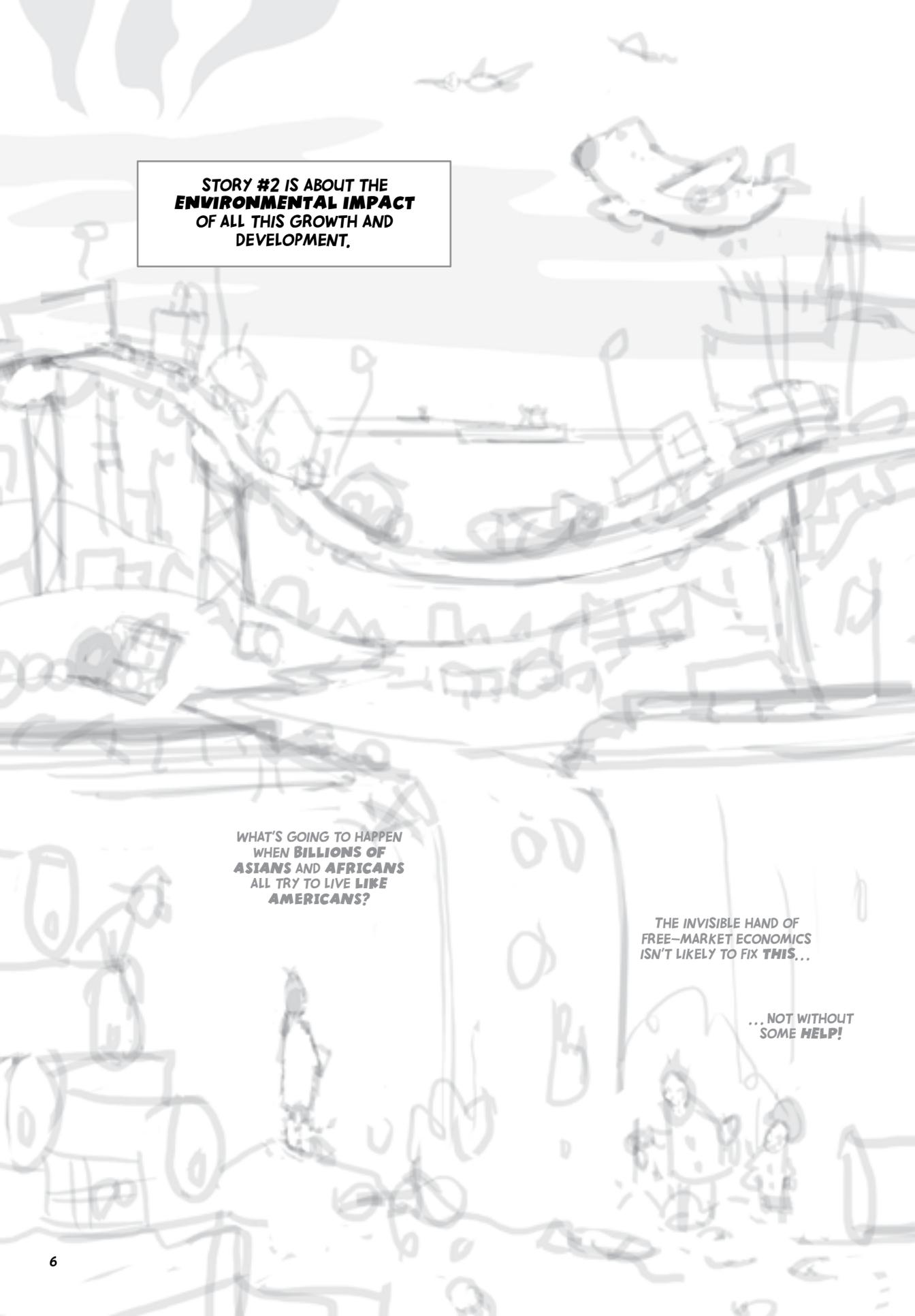
**AS A RESULT, STORY #1 POINTS IN A DIRECTION
THAT'S NOTHING SHORT OF **MIRACULOUS**.**

**LOOK, UP
AHEAD!**

A WORLD OF 2-6 BILLION
WELL-EDUCATED AND
THEREFORE **HEALTHY** AND
WEALTHY PEOPLE.

BUT IS THIS STORY **TOO
GOOD TO BE TRUE?**

WHAT ABOUT
STORY #2?

A hand-drawn illustration in a sketchy, sketchy style. It depicts a city scene with a winding road or river in the center. On the left, there are buildings and a car. On the right, there's another car and a person walking. In the foreground, there are more buildings and a person. The background shows a sky with a bird and a fish-like shape. The overall tone is one of environmental concern.

STORY #2 IS ABOUT THE ENVIRONMENTAL IMPACT OF ALL THIS GROWTH AND DEVELOPMENT.

WHAT'S GOING TO HAPPEN WHEN BILLIONS OF ASIANS AND AFRICANS ALL TRY TO LIVE LIKE AMERICANS?

THE INVISIBLE HAND OF FREE-MARKET ECONOMICS ISN'T LIKELY TO FIX THIS...

... NOT WITHOUT SOME HELP!

ENVIRONMENTAL CONCERNS COVER ALL SORTS OF TOPICS.

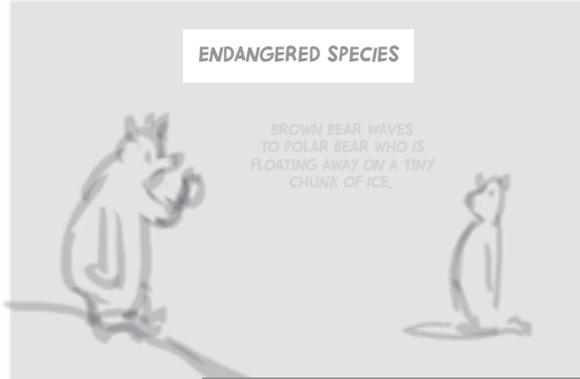
OVERFISHING



POLLUTION

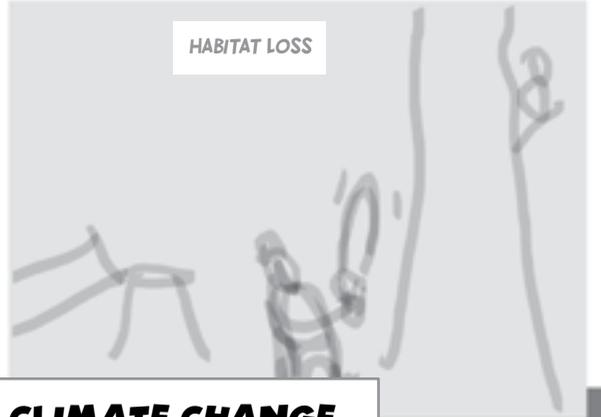


ENDANGERED SPECIES



BROWN BEAR WAVES
TO POLAR BEAR WHO IS
FLOATING AWAY ON A TINY
CHUNK OF ICE.

HABITAT LOSS



THIS BOOK FOCUSES ON CLIMATE CHANGE.

ALSO KNOWN
AS **GLOBAL
WARMING.**



CLIMATE CHANGE IS A **POLITICALLY CHARGED ISSUE.**

YOU'RE A
DENIER!

YOU'RE AN
ALARMIST!

BROTHER

SISTER

DAD BETWEEN THEM

BUT IT MIGHT BE POSSIBLE TO FIND SOME **COMMON GROUND...**

THAT COMMON
GROUND IS GOING
TO BE 6 FEET UNDER
BECAUSE **WE'RE ALL
GOING TO DIE!**

NONSENSE,
**WE'RE ALL
GOING TO
LIVE!**

...BY THINKING OF CLIMATE
CHANGE AS A **THREAT.**

THESE ARE ON THE FRIDGE, LIKE
MAGNETIC POETRY, BUT MAGNETIC
THREATS.

FATHER SAYS THIS... HE'S TRYING TO
PROMOTE COMMUNICATION, THE KIDS
ARE ON THE COUCH SEETHING.

WHERE SHOULD WE PUT
CLIMATE CHANGE ON THIS
LIST OF THREATS?

VIOLENT VIDEO GAMES

NATIONAL DEBT

HOMELAND SECURITY

TERRORISM

ASTEROIDS

BIRD FLU

FAILING SCHOOLS

JUNK FOOD

POLLUTED DRINKING WATER.

BAD SPEELING

POVERTY

CLIMATE CHANGE

MAYBE IT'S AN **EXISTENTIAL THREAT**...

...AND MAYBE IT'S ONLY A **MINOR THREAT**...

CLIMATE CHANGE MIGHT
**DESTROY HUMAN
CIVILIZATION!**

WE SHOULD FOCUS ON
**POVERTY AND JOBS
AND CLEAN DRINKING
WATER!**



BROTHER



SISTER

...AND MAYBE IT'LL BE **DECADES** BEFORE WE KNOW FOR SURE,

AND BY THEN IT MIGHT
BE **TOO LATE TO
DO MORE!**

OR TO DO
LESS!

NO WONDER
CLIMATE CHANGE IS
SUCH A **WICKED
PROBLEM.**



THIS BOOK WILL HELP YOU **MAKE UP YOUR OWN MIND.**

AND LEARN **WHAT YOU
CAN DO ABOUT IT...**

...AND WHAT WE CAN
ALL DO TOGETHER!



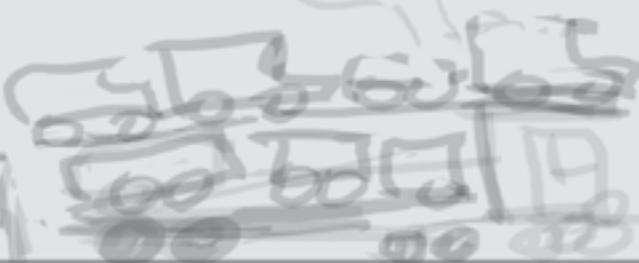
YOU MIGHT FIND IT HARD TO BELIEVE THAT HUMANS CAN
INFLUENCE THE ENTIRE PLANET...



... BUT THERE'S LOTS OF SCIENTIFIC EVIDENCE THAT
HUMAN ACTIVITY IS CHANGING THE CLIMATE.

MOST OF THE OBSERVED
WARMING SINCE THE MID-20TH
CENTURY IS **VERY LIKELY DUE**
TO HUMAN ACTIVITY.

1950s



2000s

**THIS BOOK IS ABOUT THE
SCIENTIFIC THEORY OF CLIMATE
CHANGE...**

**PART ONE:
OBSERVATIONS**

[AKA GLOBAL WARMING ("WANTED" POSTER?)
OR MAYBE SCIENTISTS SAY "WE SAID THERE'S A
LOT OF EVIDENCE, AND HERE IT IS!"]

**... AND ABOUT WHAT MIGHT HAPPEN
TO LIFE ON EARTH IF THAT SCIENTIFIC
THEORY IS **CORRECT**...**

**PART TWO:
PREDICTIONS**

**... AND ABOUT **WHAT WE CAN DO
ABOUT IT.****

**PART THREE:
ACTIONS**

[SO THE THREE PARTS ARE: WHAT'S
HAPPENING, HOW BAD WILL IT BE, WHAT CAN
WE DO ABOUT IT?]

A GOOD PLACE TO START IS WITH A FEW DEFINITIONS...

CLIMATE REFERS TO WHAT THE WEATHER IN A CERTAIN PLACE IS **USUALLY** LIKE,

SEATTLE IN JULY HAS
**SUNNY SKIES 90%
OF THE TIME.**

AFTERNOON HIGHS
ARE USUALLY 69–82F
(21–28C)...

... AND IT
**ALMOST NEVER
RAINS!**

SOUNDS
**PERFECT FOR
A WEDDING!**

USUALLY DOESN'T MEAN **ALWAYS**...

... SO YOU SHOULD THINK OF CLIMATE AS
AVERAGE WEATHER...

SORRY!
THIS IS VERY
UNUSUAL.

CLIMATE
IS WHAT YOU
EXPECT.

WEATHER
IS WHAT YOU
GET.

... AND **CLIMATE CHANGE** AS A **CHANGE IN AVERAGE WEATHER.**

ON AVERAGE,
THESE FLOWERS NOW
BLOOM **ONE WEEK
EARLIER THAN THEY
DID 50 YEARS AGO.**

...AND WITH AN *OBSERVATION.*

**EARTH'S CLIMATE
HAS *ALWAYS*
BEEN IN FLUX.**

**HERE ON PLANET EARTH,
CLIMATE CHANGE HAS
ALWAYS BEEN A
FACT OF LIFE...**

**...AND IT *ALWAYS*
WILL BE.**



LITTLE GIRL:

**BUT IF THE CLIMATE IS
ALWAYS CHANGING THEN
WHAT'S DIFFERENT
THIS TIME?**

LITTLE BOY:

**WHAT DO
PEOPLE HAVE
TO DO WITH IT?**

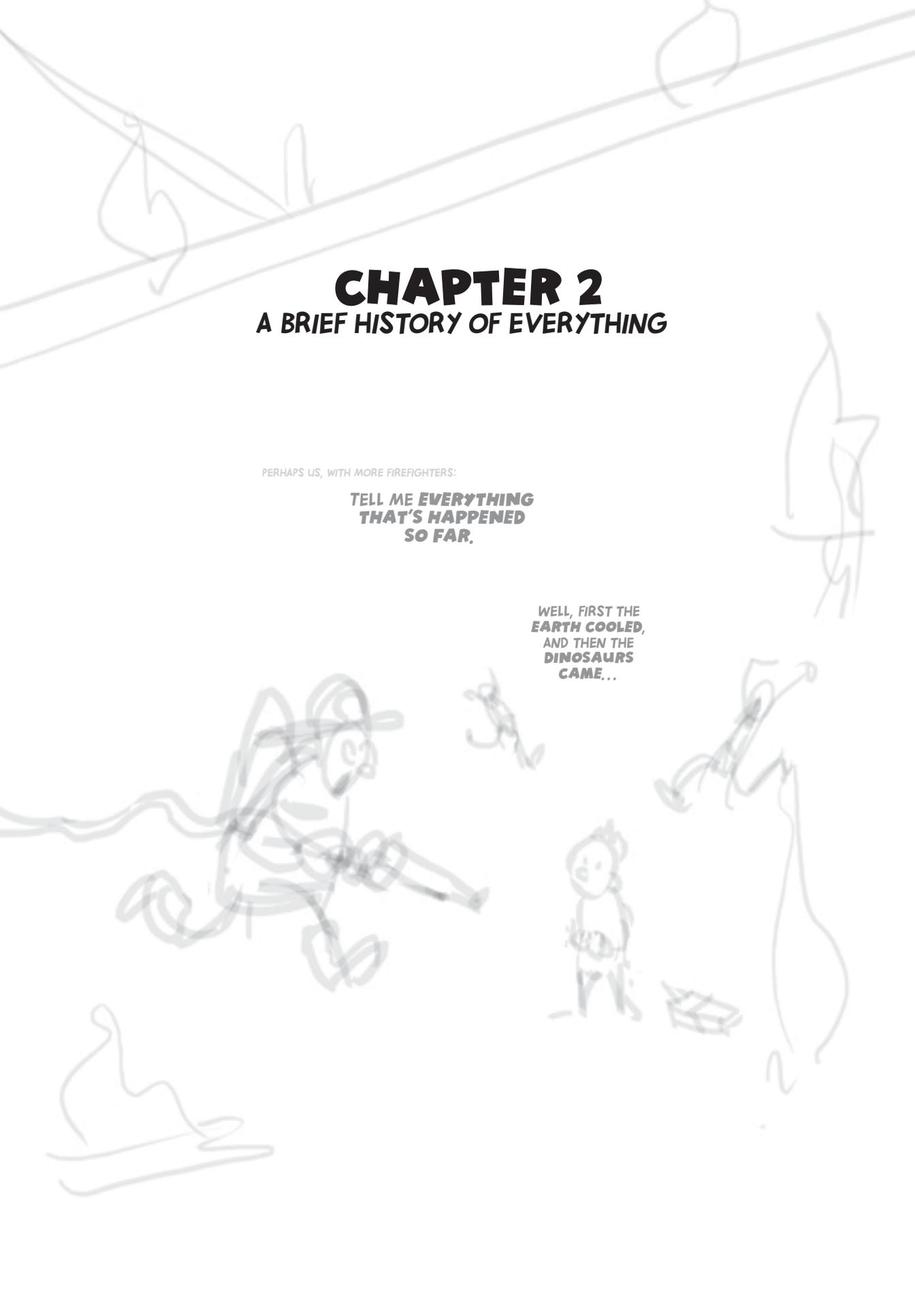
**THAT'S A GOOD
QUESTION!**

**LET'S START TO ANSWER
IT BY TAKING A BRIEF LOOK
AT THE HISTORY OF
PLANET EARTH.**



*I THOUGHT IT'D BE FUN TO HAVE
WARM CLOTHES AND WINTRY
CONDITIONS IN THIS PANEL...
NOT SURE IT WORKS YET, BUT
PERHAPS THERE'S SOMETHING
TO THE BRAINSTORM.*

*ONE SCIENTIST HOLDS A GLOBE,
THE OTHER A FLASHLIGHT...
NOT SURE IT MAKES SENSE, BUT
I THOUGHT THERE WAS SOME
CHANCE IT COULD FORSHADOW
THE ENERGY IN AND OUT EARTH
SUN RELATIONSHIP.*



CHAPTER 2

A BRIEF HISTORY OF EVERYTHING

PERHAPS US, WITH MORE FIREFIGHTERS:

**TELL ME EVERYTHING
THAT'S HAPPENED
SO FAR.**

**WELL, FIRST THE
EARTH COOLED,
AND THEN THE
DINOSAURS
CAME...**

THE EARTH FORMED ABOUT
4.6 BILLION YEARS AGO.

THAT'S A
LONG TIME!

SCIENTIST STANDING ON PRIMORDIAL ROCK LOOKING AT
THE TIMELINE, PERHAPS WITH BINOCULARS.

THIS SAME CHARACTER WOULD DO THE EXPLANATION AT
THE END OF THE CHAPTER COMPARING GEOLOGIC AND
HUMAN TIME SCALES.

4.6 bya 4 bya 3 bya 2 bya 1 bya Now

IN THE EARLY DAYS IT WAS A GREAT
MOLTEN BALL OF LIQUID ROCK...

... WHICH BELCHED OUT **HOT GASES** AND **WATER VAPOR**
TO FORM THE EARLY **ATMOSPHERE** AND **OCEANS.**



PERHAPS EARTH BURPS, MOON SAYS
"EXCUSE ME," OR PERHAPS NOT.



THE **FIRST LIFE FORMS** APPEARED IN THE OCEANS
ABOUT A BILLION YEARS LATER.

4.6 bya | | | | Now

WHAT DO YOU
CALL A SINGLE-CELLED
ORGANISM **FLOATING IN**
A PRIMORDIAL SEA?

BOB.

WHAT DO YOU
CALL A SINGLE-CELLED
ORGANISM **SHAPED**
LIKE A TUBE?

ROD.

YOU AND YOUR
JOKES ARE SO
PRIMITIVE!

HAROLD

THEN, AFTER **HUNDREDS OF MILLIONS OF YEARS OF EVOLUTION...**

4.6 bya

Now

WHAT DO YOU CALL A SINGLE-CELLED ORGANISM THAT **LIVES IN YOUR MAILBOX?**

BILL.

WILL YOU TWO **SHUT UP!**

I'M TRYING TO CONCENTRATE!

HAROLD

... SOME OF THESE ORGANISMS FIGURED OUT **PHOTOSYNTHESIS...**

EUREKA!

AMOEBAS LEAP OUT OF A BATHTUB AND RUNS AROUND OUTSIDE,

HUSBAND SAYS:

EK! HARRIET, COME BACK HERE!

... WHICH IS THE **CHEMICAL REACTION** THAT ALLOWS **GREEN THINGS LIKE PLANTS AND ALGAE TO GROW.**

PHOTOSYNTHESIS TURNS **SUNLIGHT, WATER AND CARBON DIOXIDE...**

... INTO THINGS LIKE **BROCCOLI AND BEAN SPROUTS.**

OH GREAT,

GREEN THINGS ARE THE **BASE** OF THE **FOOD CHAIN.**

WITHOUT **THEM** THERE COULD BE **NO US.**

HOW ABOUT WE ADD THIS IN GLOSSARY ENTRY TOO, IT HELPS MAKE PHOTOSYNTHESIS FEEL IMPORTANT.

BUT IT'S ALSO HOW SUGAR IS FORMED!

I VOTE TO PUT THIS IN THE GLOSSARY UNDER PHOTOSYNTHESIS:

I'M IMAGINING THIS IN THE GLOSSARY, I'M RECOMMENDING IT BECAUSE IT MAKES THE MATERIAL FEEL REAL. SUGAR IS ENERGY, IT COMES FROM THE SUN DIRECTLY THROUGH PHOTOSYNTHESIS.



NOWADAYS, GREEN THINGS PLAY A KEY ROLE IN THE CARBON CYCLE...

EVERY YEAR ABOUT 120 BILLION TONS OF CARBON GETS SUCKED IN BY PLANTS THROUGH **PHOTOSYNTHESIS...**

EVERY YEAR ABOUT 90 BILLION TONS OF CARBON **DISSOLVES IN SEAWATER...**

...AND ABOUT THAT MUCH RETURNS TO THE ATMOSPHERE.

... AND ABOUT THAT MUCH RETURNS TO THE ATMOSPHERE THROUGH **FIRE, DECOMPOSITION,** AND **RESPIRATION** BY PLANTS AND ANIMALS.

SEE THE GLOSSARY FOR MORE DETAILS, LIKE **OCEANIC PHOTOSYNTHESIS.**

ALSO BY NICE TO HAVE A DYNAMIC FEEL HERE IN THE DRAWINGS, SO IT FEELS EXCITING.

FISH AND PLANTS AND FIRE AND BIRDS AND ETC.

LATER ON WE'LL SEE THE INFLUENCE OF **HUMAN ACTIVITY.**

SCIENTIST IN CAR OR ON BIKE

... WHICH IS CRUCIAL TO ALL LIFE ON EARTH.

LEFT-TO-RIGHT LINE-UP OF A PLANT A COW A PERSON
THE COW EATS THE PLANT, THE PERSON LOOKS AT THE COW HUNGRILY, WITH FORK AND KNIFE...
THE FINAL LINE CAN BE SAID BY A SCIENTIST.

ABOUT 60% WATER AND 20% CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER, MOST OF THE REST IS CARBON,

ABOUT 60% WATER AND 20% CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER, MOST OF THE REST IS CARBON,

ABOUT 60% WATER AND 20% CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER, MOST OF THE REST IS CARBON,

YOU ARE WHAT YOU EAT!

BETWEEN ABOUT 2.5 AND 1.5 BILLION YEARS AGO, HOWEVER, GREEN THINGS DID SOMETHING PERHAPS EVEN MORE IMPORTANT.

4.6 bya

Now

THEY PUMPED LOTS AND LOTS OF **OXYGEN** INTO THE ATMOSPHERE,

ALL OF THE OXYGEN IN THE AIR GOT THERE THROUGH PHOTOSYNTHESIS!

SCIENTIST HOLDING PLANT.

GETTING OXYGEN (O₂) INTO THE ATMOSPHERE WAS REALLY IMPORTANT BECAUSE...

KID

DUH! BECAUSE **ANIMALS** NEED OXYGEN TO BREATHE.

SCIENTIST #2

WELL, YES...

... BUT THIS WAS A BILLION YEARS BEFORE **ANIMALS.**

... BECAUSE IT LED TO THE CREATION OF A LAYER OF OZONE (O₃) IN THE UPPER ATMOSPHERE.

KID

WHAT'S SO IMPORTANT ABOUT **THAT?**

PERHAPS IN ASTRONAUT SUITS.

SCIENTIST #2

WELL, **DUH.**

SCIENTIST #3

LET ME TELL YOU...

THE OZONE LAYER SHOULD BE AT THE BOTTOM OF THE STRATOSPHERE, NOT AT THE TOP OF THE TROPOSPHERE.

OZONE LAYER

WHEN I DO THE DRAWING I'LL MAKE THE LAYERS LOOK LIKE THIS:

[HTTP://WWW.NC-CLIMATE.NCSU.EDU/EDU/K12/OZONELAYER/BODY](http://www.nc-climate.ncsu.edu/edu/k12/ozonelayer/body)

AND UNIFY IT WITH THE PANEL ON PAGE 9

BEFORE THE OZONE LAYER, THE ONLY PLACE LIFE COULD SURVIVE WAS IN THE OCEAN.

4.6 bya

now

THE SUN GENERATES
VISIBLE LIGHT...

AMROBEAS IN SCHOOL,
UNDERWATER:

SCARY TEACHER
SCARING THEM

... BUT IT ALSO GENERATES
**DEADLY ULTRAVIOLET
RADIATION.**

**AFTER THE OZONE LAYER, THE SUN'S
DEADLIEST UV RAYS GOT BLOCKED...**

4.6 bya

now

**OZONE IS LIKE
SUNSCREEN
FOR THE ENTIRE
PLANET.**

A BOTTLE OF SUNSCREEN HERE
WITH A CLEVER NAME AND SOME
TEXT LIKE:

**PARTIAL PROTECTION
AGAINST UVA AND UVB,
COMPLETE PROTECTION
AGAINST DEADLY UVC.**

JUST PLAYING WITH IDEAS HERE, BUT MAYBE
TWO BOTTLES:

SUNSCREEN: PROTECTS AGAINST UVA AND UVB
FOR UP TO 2 HOURS.

OZONE: PROTECTS AGAINST DEADLY UVC FOR
BILLIONS OF YEARS AND COUNTING.

[MAYBE SOMETHING ABOUT

NOW WITH CATALYTIC ACTION!

TO ALLUDE TO THE NIFTY FACT THAT OZONE
BLOCKS UVC WITHOUT ITSELF GETTING USED
UP. INSTEAD WHAT HAPPENS (I THINK) IS THAT
UVC KNOCKS O₃ INTO O₂+O, AND THEN THEY
RECOMBINE AND CAN BLOCK MORE UVC.]

... AND, ABOUT ABOUT A **BILLION YEARS AGO,**
LIFE STARTED MOVING **ONTO THE LAND.**

4.6 bya

Now

CALL BACK TO THE "EUREKA" MOMENT FROM P3:

HAROLD STREAKS ONTO LAND, WIFE SAYS:

OH NO, HARRIET, NOT AGAIN!

**NO WONDER EVERYBODY GOT WORRIED WHEN SCIENTISTS DISCOVERED
A HOLE IN THE OZONE LAYER IN THE 1980S.**

DESPITE WHAT MANY PEOPLE THINK,
THE OZONE HOLE IS **NOT** CLOSELY
RELATED TO GLOBAL WARMING...

SCIENTIST TO GUYS DRINKING SODAS
AND CARRYING SIX PACKS OF SODAS,

ENVIRONMENTAL
PROBLEMS ARE **NOT**
ALL THE SAME...

... AND YOU CAN'T
SOLVE THEM ALL BY
RECYCLING.

... BUT IT IS VALUABLE TO **COMPARE** AND **CONTRAST** THE TWO ISSUES...

THE OZONE HOLE IS
RELATED TO HUMAN EMISSIONS OF
OZONE-DESTROYING GASES SUCH AS
CHLOROFLUOROCARBONS (CFCS).

I'LL STRIVE TO MAKE THIS GRAPHIC RESONATE
WITH THE OZONE LAYER ON THE PREVIOUS
SPREAD... TO INDICATE THAT THE GASES
ACCUMULATE IN DIFFERENT LAYERS,

PERHAPS ON THE PLANET, A TINY TINY FACTORY
EMITS THE CFCS AND A TINY TINY CAR EMITS THE
CO2

PERHAPS THE LINES ARE SAID BY SCIENTISTS IN
ASTRONAUT COSTUMES,

Y SAYS: SINCE WE HAVE AN IMAGE ON THE PREVIOUS
SPREAD IDENTIFYING WHERE THE OZONE LAYER IS,
MAYBE WE SHOULD REPLICATE THAT THERE AND THEN
INDICATE WHERE MOST OF THE GHGS ARE (NAMELY
IN THE TROPOSPHERE, THE LAYER CLOSEST TO THE
EARTH). NOTE THAT THERE ARE SOME GHGS ABOVE
THE TROPOSPHERE, BUT MOST RESIDE THERE,

G REPLIES: GOOD IDEA! I'LL PLAN TO UNIFY THIS WITH
THE GRAPHIC ON PAGE 7,

GLOBAL WARMING IS RELATED TO HUMAN
EMISSIONS OF **GREENHOUSE** GASES
SUCH AS **CARBON DIOXIDE (CO2).**

... AND WE CAN TAKE HEART FROM THE **HAPPY ENDING**
TO THE OZONE HOLE PROBLEM,

[SCIENTIST #1:

PRESIDENT REAGAN
HELPED PHASE OUT CFCS
AND THE OZONE LAYER IS
RECOVERING.

SCIENTIST #2:

IF ONLY GLOBAL
WARMING WAS SO
EASY!

BUT LET'S GET BACK TO THE **HISTORY**
OF **PLANET EARTH...**

**THE PAST BILLION YEARS HAVE SEEN
WILD CHANGES IN THE CLIMATE.**

4.6 bya

Now

I THINK THIS LINE WORKS GREAT
COMING OUT OF HARRIET'S
LONG SUFFERING HUSBAND

**THE ONLY THING
PERMANENT IS
CHANGE.**

**THERE WERE TIMES WHEN
ICE COVERED ALMOST EVERYTHING...**

4.6 bya

Now

**THIS SNOWBALL
EARTH IS FREEZING!**

**GOOD THING THERE
WEREN'T ACTUALLY
PEOPLE BACK THEN!**

**...AND AT LEAST ONE TIME WHEN
THE NORTH POLE WAS TROPICAL.**

4.6 bya

Now

MAN IN POOL, SWEATING:

WAITER, GET ME AN ICED
TEA!

WAITER:

SORRY, THERE'S **NO ICE**,

**GOOD THING THERE
WEREN'T ACTUALLY
PEOPLE BACK THEN!**

OF CENTRAL IMPORTANCE TO OUR STORY IS THE CARBONIFEROUS PERIOD, SOME 350–300 MILLION YEARS AGO...

4.6 bya

Now

**GIANT SCORPIONS!
GIANT COCKROACHES!
GIANT CROCODILES!**

THIS WASN'T JUST BEFORE PEOPLE, THIS WAS EVEN BEFORE DINOSAURS.

(HERE'S LINKS TO COOL CARBONIFEROUS [HYPERLINK "HTTP://WWW.BBC.CO.UK/NATURE/HISTORY OF THE EARTH/CARBONIFEROUS"](http://www.bbc.co.uk/nature/history_of_the_earth/carboniferous) TREES AND [HYPERLINK "HTTP://WWW.BBC.CO.UK/NATURE/ANCIENT EARTH/COAL FOREST"](http://www.bbc.co.uk/nature/ancient_earth/coal_forest) SWAMPS AND [HYPERLINK "HTTP://SCIENCE.NATIONALGEOGRAPHIC.COM/SCIENCE/PREHISTORIC-WORLD/CARBONIFEROUS/"](http://science.nationalgeographic.com/science/prehistoric-world/carboniferous/))

(ANIMALS LIKE 6-FOOT CENTIPEDES, MAMMOTH COCKROACHES, 3-FOOT SCORPIONS, DRAGONFLIES THE SIZE OF SEAGULLS, AND 20-FOOT CROCODILES.)

[ALTERNATIVELY, THE SCIENTISTS COULD BE PADDLING RIGHT-TO-LEFT ACROSS THE GRAPHIC, SAYING "ABOUT 300 MILLION YEARS AGO..." "SHORTLY BEFORE THE DINOSAURS!" AND THEN THERE'S THE JAWS OF A T-REX OR SOMETHING EMERGING FROM THE RHS OF THE PAGE (MAYBE RISING OUT OF THE SWAMP?). BUT... I'M A BIT WORRIED ABOUT HAVING HUMANS AND DINOSAURS IN THE SAME GRAPHIC, IT MIGHT BE OKAY AS LONG AS WE'RE CLEARLY BEING JOKEY ABOUT IT, BUT IT MIGHT BE A POINT OF CONTENTION WITH REVIEWERS, ALSO TECHNICALLY OUR DINOSAURS DIDN'T APPEAR UNTIL ABOUT 230M YEARS AGO... BU; IT'S "SHORTLY" CARBONIFEROUS MEANS "COAL BEARING" ON GEOLOGIC TIME SCALES!]]

[HERE'S SOME [HYPERLINK "HTTP://EN.WIKIPEDIA.ORG/WIKI/CARBONIFEROUS"](http://en.wikipedia.org/wiki/carboniferous) "LIFE" COOL IMAGES OF THE PERIOD.]

... BECAUSE SOME OF THE ORGANISMS THAT DIED THEN...

WHAT DO YOU CALL A SINGLE-CELLED ORGANISM LYING IN A HOLE?

AMOEBAS HAVING A FUNERAL

DOUG.

... GOT BURIED AND COOKED UNDERGROUND FOR HUNDREDS OF MILLIONS OF YEARS...

KNOCK KNOCK

WHO'S THERE?

OIL,

OIL WHO?

OIL BE BACK.

... AND EVENTUALLY TURNED INTO CARBON-BASED FOSSIL FUELS.

JUST AN IDEA, BUT MAYBE A GAS STATION SIGN THAT HAS A GIANT COCKROACH OR SCORPION OR FERN OR SOMETHING, AND INSTEAD OF MOBIL IT'S CALLED CARBONIFEROUS?

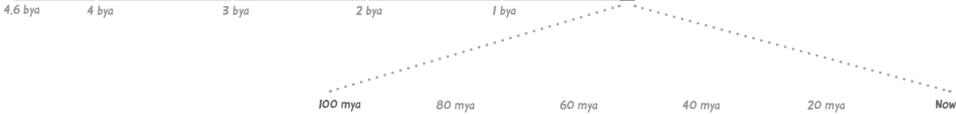
(GOOGLE "SINCLAIR GAS" AND YOU'LL SEE THE DINO IMAGE, THAT'S KIND OF WHAT I'M THINKING...)

THAT'S WHERE A LOT OF OUR COAL COMES FROM...

... AND PLENTY OF OIL AND NATURAL GAS TOO.

FILLING UP CAR,

DURING THE LAST 100 MILLION YEARS...



IS IT WORTH MENTIONING HERE HOW IMPORTANT CONTINENTAL POSITIONING IS... ANTARCTICA IS SORT OF AN AIR CONDITIONING UNIT... JUST SOMETHING TO FLAG THIS PART OF THE EQUATION?
 I'M THINKING NO, BUT LEAVING THIS NOTE, SINCE IT SEEMS IMPORTANT TO INCLUDE SOME MORE SPECIFICS ABOUT THIS SOMEWHERE.

... THE CONTINENTS SLOWLY DRIFTED INTO THE POSITIONS THEY HAVE TODAY...

CONTINENTS MOVE AT ABOUT THE SPEED THAT YOUR FINGERNAILS GROW...

... ABOUT 100 MILES EVERY MILLION YEARS.

JUST AN IDEA, BUT MAYBE THERE'S A COFFIN HERE AND THESE WORDS ARE COMING FROM SOMEONE HIDDEN INSIDE THE COFFIN, EXCEPT FOR ONE OR TWO CREEPY HANDS WITH LONG FINGERNAILS!

CORPSE WITH LONG FINGERNAILS?

ONE CONTENENT HERE

ONE CONTENENT HERE

... AND SPECIES EITHER DIED OFF OR SLOWLY EVOLVED INTO THE FORMS THEY HAVE TODAY.

THANKS TO AN **ASTEROID 65 MILLION YEARS AGO...**

PERHAPS A LITTLE RODENT SAYS THIS LINE

... WE SAID GOODBYE TO THE **VELOCIRAPTOR...**

... AND HELLO TO THE **CHICKEN.**

PERHAPS A PERSON SAYS THIS, SOMEHOW POSITIONED SO IS IN THE SAME PLACE AS THE RODENT.

THE IDEA IS TO HIGHLIGHT THE EVOLUTION FROM DINOSAURS INTO BIRDS.

SO THE CHICKEN AND THE DINOSAUR HAVE THE SAME GESTURE.

EVEN MORE RECENTLY, THE EARTH'S CLIMATE HAS CALMED DOWN A BIT...



NO SNOWBALL EARTHS...

... AND NO TROPICAL NORTH POLES!

... BUT CALM IS A RELATIVE TERM.

LOOK, I'VE CALMED DOWN!

WOW, WHAT WERE YOU LIKE BEFORE?

SCIENTIST

KID GOING BONKERS

IN PARTICULAR, OVER THE PAST
2.5 MILLION YEARS THE PLANET HAS GONE
THROUGH **PERIODIC CYCLES...**

100 mya

Now

HOW ABOUT A ROLLER COASTER HERE? WE COULD HAVE IT ROUGHLY FOLLOW THE
TEMPERATURE PROFILE OVER THE LAST 2.5 MILLION YEARS, AND IN DOING SO IT
WOULD FORESHADOW THE STUFF IN THE NEXT CHAPTER.

... OF WARM PERIODS...

SAME LANDSCAPE HERE AND BELOW,
BUT THE ONE BELOW HAS HUGE
GLACIERS INVADING.

PERHAPS BOTH PICTURES ALSO FEATURE
AN ELEPHANT, HERE HE'S GOT NO HAIR,
BELOW HE'S GOT A WARM COAT OF HAIR.

OR MAYBE THE COOL PERIOD HAS A
MAMMOTH FROZEN INTO THE GLACIER?

... AND COOL PERIODS.

SCIENTISTS CALL THESE
COOL PARTS **GLACIAL
PERIODS.**

THIS PICTURE HAS A HUGE GLACIER AND
WOOLY MAMMOTHS.

EVERYONE
ELSE CALLS THEM
ICE AGES.

MODERN HUMAN BEINGS APPEARED IN AFRICA ONLY ABOUT 200,000 YEARS AGO...

100 mya

Now

BE NICE IF THE SCIENTIST WAS RIDING THE DINOSAUR AND THE DINOSAUR WAS LOOKING RIGHT HERE AT THE BLACK LINE, BUT I'M NOT SURE IT'LL BE POSSIBLE WITH THESE LINES,

TA DA!

DINOSAUR

MAMMOTH

THAT'S **NOTHING** COMPARED TO 100 MILLION YEARS...

...AND **EVEN LESS** COMPARED TO 4.6 BILLION YEARS,

HUMAN TIME SCALES ARE WAY DIFFERENT THAN **GEOLOGIC TIME SCALES**,

LADY GAGA OR SCIENTIST

... AND IT WASN'T LONG BEFORE THEY STARTED ASKING TOUGH QUESTIONS.

I WONDER WHERE I CAN **CATCH SOME FISH?**

I WONDER HOW I CAN **AVOID BEING EATEN BY A TIGER?**

I WONDER WHAT **CAUSED THE ICE AGES?**

IF WE DO ENERGY IN AND OUT FIRST, THEN THIS COULD BE:

I WONDER WHAT CAUSES CLIMATE CHANGE?

[MAYBE THE PERSON IS NEAR A BOULDER FIELD OR SOMETHING? IT WAS THE PRESENCE OF WEIRD BOULDERS FROM FAR AWAY THAT LED SCIENTISTS TO REALIZE THAT THERE WERE GIANT GLACIERS & ETC BACK IN THE DAY,

CHAPTER 3

THE ICE AGES

OLD, PERHAPS SWAP WITH BOSTON"

**GO BACK 15,000 YEARS
AND THIS WAS UNDER A
MILE OF ICE!**

IF WE USE MANHATTAN,
THAT TIMELINE/AMOUNT
ISN'T QUITE CORRECT...

[HTTP://WWW.
NYCGOVPARKS.ORG/
ABOUT/HISTORY/GEOLOGY](http://www.nycgovparks.org/about/history/geology)

I SUPPOSE IT DOESN'T NEED
TO BE IDENTIFIABLE AS
MANHATTAN, BUT MAYBE A
BEACH SCENE WOULD MAKE
JUST AS MUCH SENSE???

NICE IDEA THAT
SKYSCRAPERS ARE
COVERED, BUT BEACH SAYS
HOT.

I'M NOT SURE ABOUT THIS GAG... A BIT OBSCURE... I
THINK WE COULD USE THE OLD ONE THOUGH, IT'S FUN
AND STANDS ALONE.

PEOPLE SELLING STUFF AT A STREET FAIR:

YOUR NAME ON A GRAIN OF RICE,

YOUR LIFE HISTORY ON A MICROCHIP,

YOUR PLANET'S HISTORY IN A BUBBLE OF AIR,

WORRIED THIS GAG MAY BE DISTRACTING,

EARLY GEOLOGISTS HYPOTHESIZED THAT THERE **MUST** HAVE BEEN **ICE AGES**.

WHAT COULD HAVE CARRIED
THESE GIANT ROCKS HERE
FROM **THOSE DISTANT**
MOUNTAINS?

THERE MUST HAVE
BEEN **MASSIVE**
GLACIERS!

OR
PREHISTORIC
GIANTS!

I'LL DRAW HER
AS A CYCLOPS
:-)

20TH CENTURY SCIENTISTS CONFIRMED
THIS BY STUDYING EARTH'S TWO REMAINING
GIANT ICE SHEETS.



ONE'S OVER
GREENLAND...

2 SCIENTISTS, ONE STANDS ON
OTHERS SHOULDERS

... THE OTHER'S OVER
ANTARCTICA

THESE ICE SHEETS
WERE BUILT UP OVER
HUNDREDS OF
THOUSANDS OF
YEARS.

PENGUINS...

Things
Snow
Got

COMPRESSED,
TRAPPING ANCIENT AIR
IN ANCIENT ICE.

**BY DRILLING DOWN
THROUGH THAT ICE...**

I'VE GOT A
6-FOOT COD!

I'VE GOT A
MILE-LONG
ICE CORE!

... AND ANALYZING THE VARIOUS LAYERS...

IT'S A BIT LIKE
GUTTING FISH,
BUT NOT AS MESSY.

**... SCIENTISTS CAN MEASURE THE AVERAGE SURFACE TEMPERATURE
OF PLANET EARTH FAR INTO THE DISTANT PAST.**

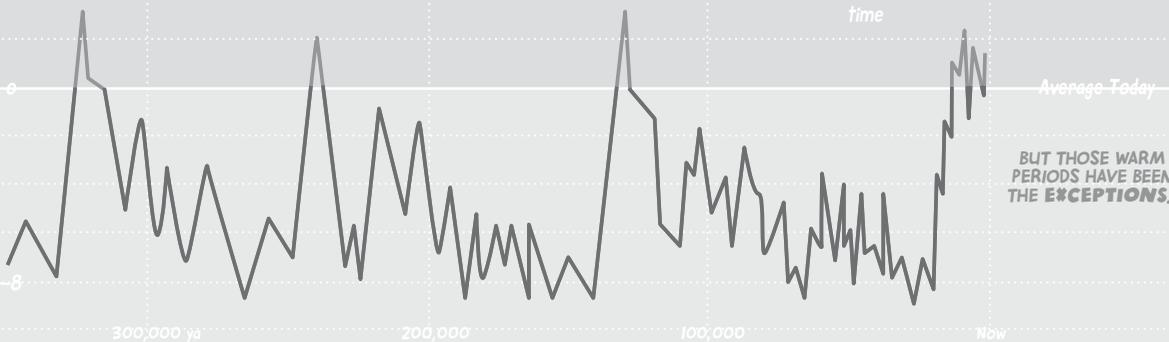
GRAPH BASED ON PETIT ET AL., 1999

OVER THE PAST 400,000
YEARS THERE HAVE BEEN
WARM PERIODS...

... INCLUDING THE
PAST 10,000
YEARS.

stepping
over the
peaks

looking
at the
current
time



BUT THOSE WARM
PERIODS HAVE BEEN
THE EXCEPTIONS.

**THESE ICE CORES SHOW THAT EARTH HAS USUALLY BEEN
4-8 C (7-14F) COLDER THAN IT IS NOW.**

NOTE, ADD THE DEGREE SYMBOL.

THOSE SMALL
TEMPERATURES
CHANGES...

... WERE
ENOUGH TO
PUT CHICAGO
UNDER A MILE
OF ICE.

I VOTE TO CREDIT THE
GRAPH WITH SOMETHING
LIKE THIS:

CHECK OUT THE
GLOSSARY TO LEARN
MORE ABOUT IT.

THE MYSTERY OF THE ICE AGES...

A RETURN TO
19TH CENTURY
GEOLOGISTS FROM
THE TOP OF THE LAST
SPREAD:

I WONDER WHY THERE
AREN'T **GLACIERS**
HERE ANYMORE?

AND DON'T SAY
PREHISTORIC
GIANTS!

... WAS MOSTLY SOLVED BY THE SERBIAN MATHEMATICIAN
MILUTIN MILANKOVITCH DURING THE FIRST WORLD WAR.

THE **REAL MYSTERY**
IS WHY WE'RE FIGHTING
THIS **DUMB WAR!**

HE STUDIED THE **DETAILS** OF
THE EARTH'S **ORBIT** AROUND THE SUN...

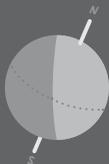
IT ORBITS
ONCE A YEAR...

... BUT AS IT DOES
IT **MEANDERS** AND
WOBBLES A BIT.

PLAYING WITH TOP,
SHOWING THE KID THE TOP.

... INCLUDING THE **TILT** OF THE EARTH, WHICH CAUSES **WINTERS** AND **SUMMERS**.

IN **JULY** THE
NORTHERN
HEMISPHERE GETS
MORE SUN...



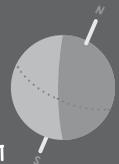
... AND THE SOUTHERN
HEMISPHERE IS **DARK**
AND **COLD**.

APRIL



OCTOBER

IN **JANUARY** THE
NORTHERN HEMISPHERE IS
DARK AND COLD...



... AND THE SOUTHERN
HEMISPHERE GETS
MORE SUN.

NOT TO SCALE.

IT TURNS OUT THAT THE TILT **VARIABLES** OVER TENS OF THOUSANDS OF YEARS.

AND NOW, IN **ASTRONOMY NEWS**, THE TILT OF THE EARTH IS **23.4 DEGREES** AND SLOWLY GETTING **WEAKER**.

WE'LL HAVE AN UPDATE IN **9,000 YEARS**.

OR THIS COULD BE CROLL GIVING TECHNICAL DETAILS,



WHEN THE TILT IS STRONGER, **SEASONS ARE STRONGER...**

MY HEAD IS ON FIRE, MY FEET ARE FREEZING!

CHARACTER HERE, TILTED OVER

ALT.

OUT OF THE **FRYING PAN...**



MY FEET ARE ON FIRE, MY HEAD IS FREEZING!



ALT.

...AND INTO THE **FREEZER**.

...AND WHEN THE TILT IS WEAKER, **SEASONS ARE WEAKER.**

I'M GETTING COOKED A MORE EVEN AMOUNT ALL AROUND...

CHARACTER HERE, TILTED OVER LESS, THIS WILL BE A HAND DRAWING.



...NO MATTER WHAT TIME OF YEAR IT IS,



TWO OTHER ORBITAL VARIATIONS ALSO AFFECT THE STRENGTH OF THE SEASONS.

THEY'RE THE **MILANKOVITCH CYCLES.**

MM TO KID,

PERHAPS HOOLA HOOPS FOR BOTH MM AND KID

MM WIGGLING, NOT SAYING IT, BUT WIGGLING HIS HIPS.,

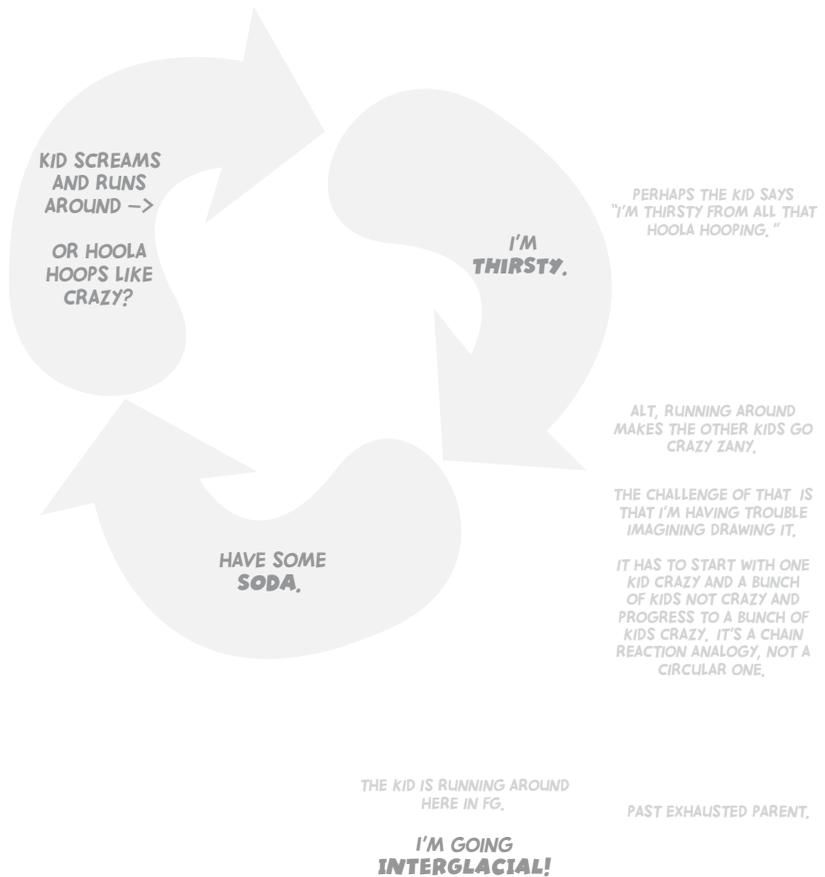
THE MILANKOVITCH CYCLE THEORY SAYS THAT THESE ORBITAL VARIATIONS...

THEY'RE WIGGLES AND JIGGLES!

MM DANCES AROUND WIGGLING AND JIGGLING,

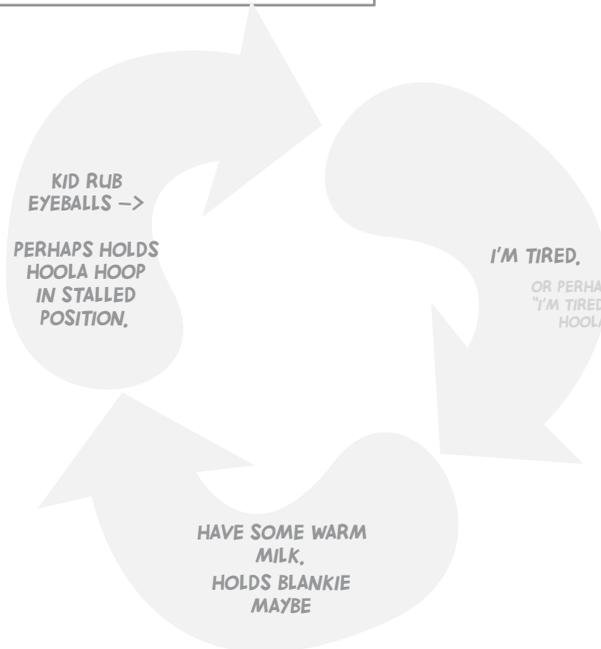
OR HOOLA HOOPING!

... TRIGGER POSITIVE FEEDBACK LOOPS THAT BRING US OUT OF THE ICE AGES...



THIS MIGHT BE A GOOD PLACE FOR A FOOTNOTE ABOUT "POSITIVE FEEDBACK"... COULD SAY "POSITIVE FEEDBACK LOOPS AMPLIFY"

... AND SEND US **BACK INTO THEM.**



Y SAYS:

PERHAPS HOW YAWNING IS CONTAGIOUS BUT I'M NOT SURE THAT COMMUNICATES THE FEEDBACK EFFECT, IT'S GOT TO BE CUMULATIVE,

MAYBE THE KID FALLS ASLEEP AND THE PARENT MAKES SOME SORT OF QUIP ABOUT

TOO BAD THIS WON'T LAST AS LONG AS AN ICE AGE,

KID ASLEEP HERE IN FG

IN OTHER WORDS, THE MILANKOVITCH CYCLES ARE THE PACEMAKER OF THE ICE AGES!

COULD BE A ROCK BAND, WITH MM AS DRUMMER,

START ROCK BAND/ MARCHING BAND ANALOGY HERE,

I SET THE RHYTHM,

MM IS THE DRUMMER FOR THE BAND

LET'S SEE HOW IT WORKS IN **CLOSER DETAIL.**

FOR A **SIMPLIFIED VERSION** OF THE MILANKOVITCH STORY...

MILANKOVITCH:

IF YOU WANT THE
FULL STORY YOU CAN
READ MY **626-PAGE**
BOOK!

... **IMAGINE WE'RE IN CANADA** DURING A **GLACIAL PERIOD.**

LIKE THE ONE
THAT PEAKED
20,000 YEARS
AGO.

MAYBE INCLUDE A MAP OF WHAT THE EARTH LOOKED LIKE AT THE PEAK OF THE
LAST ICE AGE?

[HTTP://WWW.SCOTESE.COM/IMAGES/LGM.JPG](http://www.scotese.com/images/lgm.jpg)

THE MILANKOVITCH CYCLES EVENTUALLY CREATE
CONDITIONS WITH **STRONG SEASONS.**

HOT HOT
SUMMERS.

LOTS OF MELTING ICE
AND SNOW.

COLD COLD
WINTERS.

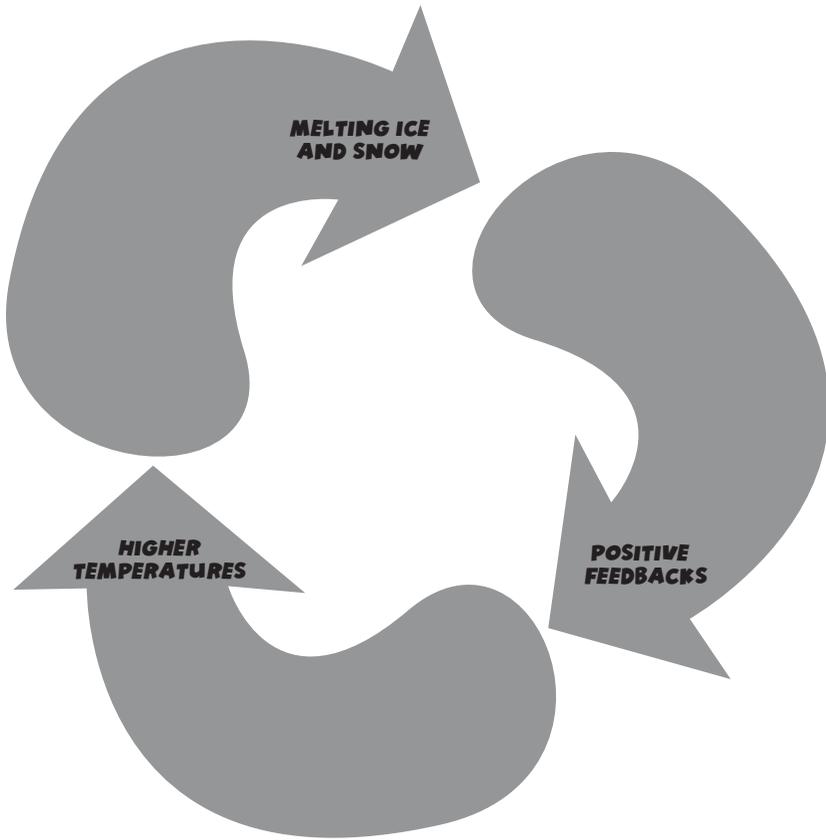
BUT THERE ISN'T ENOUGH
NEW SNOW TO KEEP UP
WITH THE SUMMER MELT.

THAT CAUSES **ICE AND SNOW** TO GIVE WAY TO **LAND AND WATER.**

SOME GAG ABOUT BEING IN CANADA WITH LESS
SNOW.

NOW WE CAN
PLANT **MAPLE**
SYRUP TREES!

AMPLIFYING THIS MILANKOVITCH EFFECT ARE POSITIVE FEEDBACK LOOPS...



... LIKE THE ALBEDO EFFECT.

ICE AND SNOW **REFLECT** LOTS OF SUNLIGHT BACK INTO SPACE.

THIS IS A BALD GUY!!:
(I LOVE THIS!)

WITH FULL HEAD OF HAIR!!!:

LAND AND WATER **ABSORB** MORE SUNLIGHT, WARMING THE PLANET.

ROCK STAR HAIR!!!
COULD BE DIFFERENT MEMBERS OF THE BAND... COULD BE ONE OF OUR SCIENTISTS IS BALD, ANOTHER HAS BIG HAIR.

IN THIS WAY THE MILANKOVITCH CYCLES, COMBINED WITH POSITIVE FEEDBACK LOOPS, CREATE AN INTERGLACIAL PERIOD.

SHOW MM DRUMMER LEADING THE BAND HERE.

THESE ARE FANS ATTENDING THE CONCERT, SO YOU SEE THE BAND AND THE AMPS ON-STAGE, AND THE CONVERSATION HERE IS THE CLASSICAL CONVERSATION BETWEEN PEOPLE WHO CAN'T HEAR EACH OTHER:

IT SURE IS **HOT** AND **LOUD** IN HERE,

WHAT???

FINGERS IN EARS,

TO SEE HOW IT WORKS IN THE OTHER DIRECTION,
IMAGINE WE'RE IN THE MIDDLE OF AN **INTERGLACIAL PERIOD**.

LIKE THE ONE
WE'RE IN **NOW**.

SCIENTISTS OUTSIDE THE MUSIC VENUE, BUYING TICKETS OR WAITING IN LINE OR
WHATEVER? WITH A MARQUEE SAYING:

TONIGHT:

MILANKOVITCH AND THE FEEDBACKS

WE COULD EVEN ADD SOME ADDITIONAL BAND NAMES TO THE MARQUEE, LIKE TWO OF
MY FAVORITES FROM AROUND SEATTLE:

EXTRA FINE SHREDDED LETTUCE
THE UNI-BROS

THE MILANKOVITCH CYCLES EVENTUALLY CREATE
CONDITIONS WITH **MILD SEASONS**.

**MILD
SUMMERS.**

NOT MUCH MELTING ICE
AND SNOW.

**MILD
WINTERS.**

BUT STILL COLD
ENOUGH FOR SNOW
IN PLACES LIKE
CANADA,

SKIING?

THAT CAUSES **ICE AND SNOW** TO SLOWLY REPLACE **LAND AND WATER**.

WHAT'S MORE CANADIAN
THAN **MAPLE SYRUP**?

ICE HOCKEY?

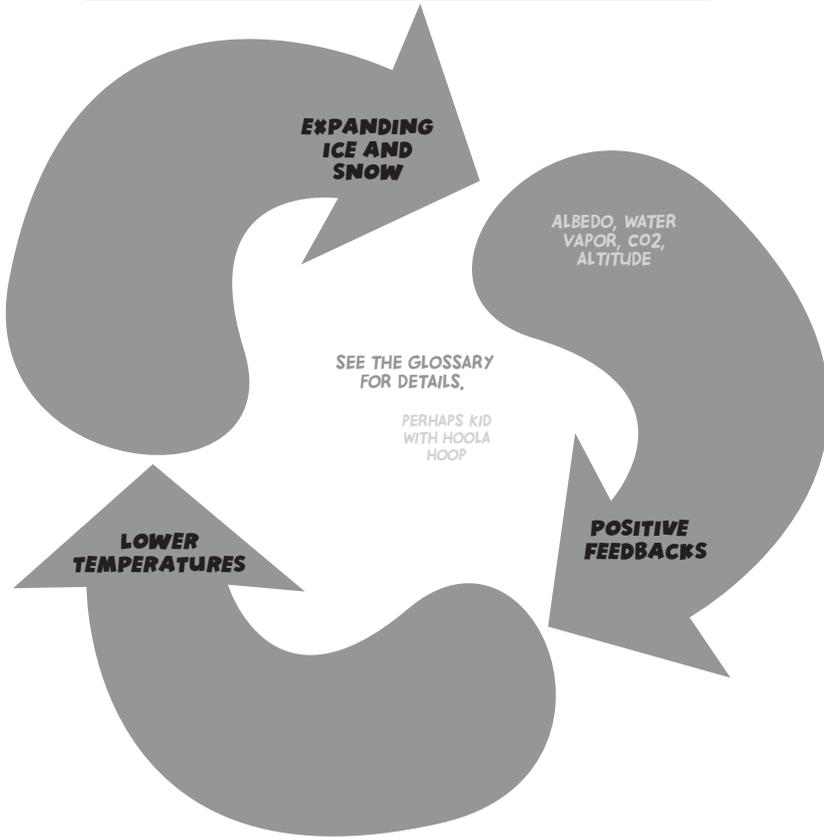
NOW THE **ALBEDO EFFECT** WORKS IN THE **OTHER DIRECTION...**

LAND AND WATER THAT **ABSORB** LOTS OF SUNLIGHT...

... GET COVERED WITH ICE AND SNOW THAT **REFLECT** SUNLIGHT, COOLING THE PLANET.

BALD GUY AGAIN,

... AS DO OTHER **POSITIVE FEEDBACK LOOPS.**



ALL THIS BRINGS UP A **PRETTY OBVIOUS QUESTION.**

GIVEN THAT WE'RE **CURRENTLY** IN AN **INTERGLACIAL PERIOD...**

... SHOULD I WORRY ABOUT THE **NEXT ICE AGE?**

WHAT??

THE **ANSWER**, ACCORDING TO THE NATURAL PROGRESSION OF THE MILANKOVITCH CYCLES, IS THAT **WE ARE DUE FOR ANOTHER ICE AGE...**

OH NO, I BETTER STOCK UP ON HEATING OIL!

ROCK FAN AGAIN:

... BUT NOT FOR AT LEAST **30,000 YEARS**.

AH, **NEVER MIND!**

OTHER ROCK FAN

A MORE IMMEDIATE CONCERN IS THE **HUMAN INFLUENCE** ON THE ATMOSPHERE AND THE CLIMATE.

ABOUT THAT **HEATING OIL...**

SCIENTIST FROM BEHIND THE TWO OF THEM,

ROCK FAN

CHAPTER 4

CARBON DIOXIDE

MIGHT BE FUN TO PULL APART THIS TEXT
SO THAT THE ZEROS LOOK A BIT LIKE GAS
MOLECULES. COULD BE A SIMPLE SIGHT GAG,
I'D MAKE SURE TO USE THE RIGHT NUMBER OF
ZEROS, BUT THERE'S TOO MANY ZEROS HERE
TO COUNT ANYWAY.

WITH EVERY BREATH OF
AIR YOU INHALE ABOUT
10,000,000,000,000,000,000,000
GAS MOLECULES...

... INCLUDING ABOUT
2,100,000,000,000,000,000,000
MOLECULES OF O₂...

... AND ABOUT
4,000,000,000,000,000,000
MOLECULES OF CO₂.



ALT.

PERHAPS ZEROS ENTER A
CHARACTER'S OPEN MOUTH.

WHAT WE CALL **AIR** IS ACTUALLY A MIXTURE THAT'S ABOUT **21% OXYGEN...**

CREATED OVER THE EONS BY ALL THAT PHOTOSYNTHESIZING **GREEN STUFF.**

REMEMBER TO DEPICT IN PICTURE, IN OCEANS AND ON LAND.

... AND ABOUT **78% NITROGEN.**

A NITROGEN DAY RALLY HERE WITH LOTS OF PUNS ABOUT ATMOSPHERIC NITROGEN, N₂:

I'M INTO N₂

N₂ DEEP

N₂ THE DRAGON

N₂ THE NTH POWER

THE **REMAINING 1% INCLUDES WATER VAPOR...**

[MAYBE HAVE A KID AT A BLACKBOARD SHOWING $21+78=99$, AND IT'S RAINING OUTSIDE?] OR MAYBE SOMETHING ABOUT EVAPORATION AND THE WATER CYCLE?]

... AND SMALL AMOUNTS OF OTHER GASES SUCH AS **CARBON DIOXIDE (CO₂).**

IT'S **ODORLESS, COLORLESS, AND INVISIBLE...**

... AND IT'S THE FOCUS OF THIS CHAPTER!

**IN THE EARLY 1950S A CHEMIST NAMED
CHARLES DAVID KEELING...**

CALL ME DAVE,

**... FIGURED OUT A WAY TO ACCURATELY MEASURE
THE CONCENTRATION OF CARBON DIOXIDE IN AIR.**

HOW ABOUT SOMETHING LIKE HE'S GOT TWO BALLOONS ON A
SCALE OR IS COMPARING TWO BALLOONS OR TWO BAGS OR TWO
SAMPLES AND HE SAYS:

D1: WHAT'S THE CO₂ DIFFERENCE BETWEEN THESE
TWO SAMPLES?

D2: ONE IN A MILLION!

**STARTING IN 1958, KEELING AND HIS COLLEAGUES MADE DAILY MEASUREMENTS
OF CO₂ AT THE MAUNA LOA OBSERVATORY IN HAWAII...**

Y BRAINSTORM:

MIGHT BE USEFUL FOR A
CALLBACK WHEN WE DO
OCEAN ACIDIFICATION,
PERHAPS A LINE LIKE
"SORRY, KID, NOT EVER."

C'MON DAD, LET'S
GO TO THE **BEACH!**

WEARING SNORKELING GEAR

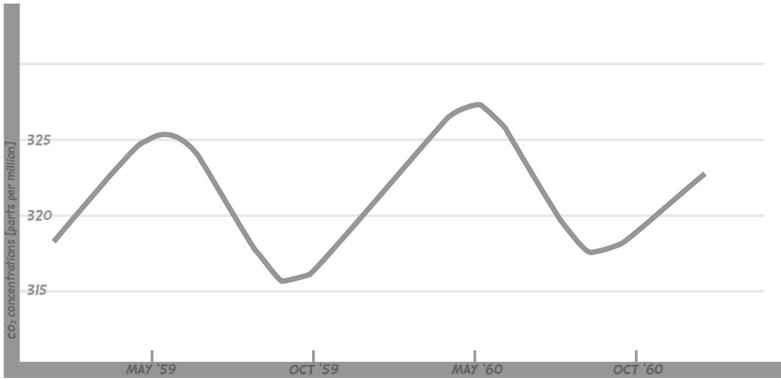
SORRY, KID,
NOT NOW.

... AND THE RESULTS MADE HIM FAMOUS.

WELL, NOT **ROCK STAR**
FAMOUS...

... MORE LIKE
NICHE FAMOUS.

KEELING MADE TWO BIG DISCOVERIES. FIRST, HE DISCOVERED AN ANNUAL CYCLE IN CO2 CONCENTRATIONS.



DJ
(RASTAFARIAN):
DUDE, IT'S LIKE THE PLANET IS BREATHING!

D2 (SCIENTIST OR BUSINESS TYPE):

OKAY, HIPPIE, TAKE IT EASY.

THIS CYCLE IS RELATED TO THE SEASONS...

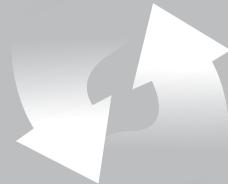


LOOK AT PAGE #!

HOLDING TILT GRAPHIC FROM PREVIOUS CHAPTER, BUT THE PICTURE WILL HAVE THE SUN SHINING ON IT.

...AND TO THE CARBON CYCLE...

LOOK AT PAGE 7!



HOLDING CARBON ARROW FROM PREVIOUS CHAPTER,

...AND TO THE FACT THAT MOST OF THE LAND ON EARTH IS IN THE NORTHERN HEMISPHERE.

LOOK AT A MAP!



MORE LAND MEANS MORE GREEN STUFF.

THIS WILL BE HAND DRAWN, WITH STRONGER CONTRAST BETWEEN LAND AND SEA

PLUS CLEAR EQUATOR AND HIGHLIGHT OF NORTH V SOUTH

DURING THE NORTHERN HEMISPHERE **WINTER**,
CO₂ GETS "EXHALED" INTO THE ATMOSPHERE...

... THANKS TO PROCESSES LIKE THE
DECOMPOSITION OF FALLING LEAVES,



OF COURSE, WINTER
IN THE NORTH IS
**SUMMER IN THE
SOUTH...**

... BUT THE SOUTH IS LESS
IMPORTANT BECAUSE THERE'S
NOT MUCH LAND.

THEN DURING THE NORTHERN HEMISPHERE **SUMMER**,
CO₂ GETS "INHALED" OUT OF THE ATMOSPHERE...

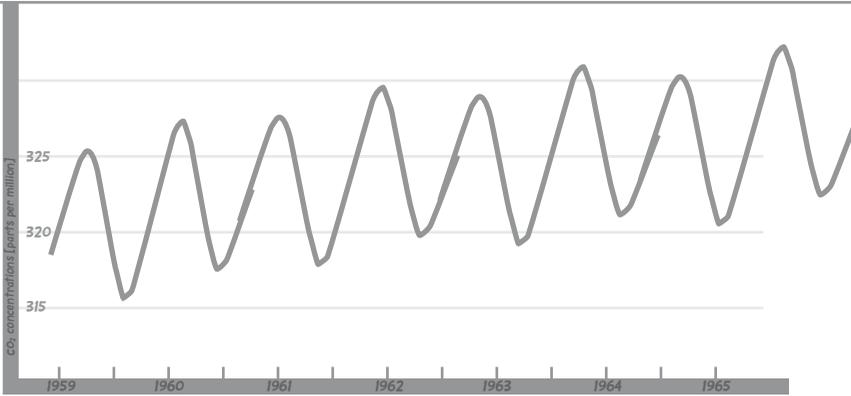
... BY **INCREASED PHOTOSYNTHESIS.**



ALL THE **GREEN
STUFF** GROWING IN
THE **NORTH...**

... SWAMPS THE IMPACT
OF THE SOUTHERN
HEMISPHERE WINTER.

KEELING'S SECOND BIG DISCOVERY WAS THAT CO₂ CONCENTRATIONS IN THE ATMOSPHERE WERE INCREASING OVER TIME.



SOME GAG HERE ABOUT IT GOING UP.

KEELING'S MEASUREMENTS CONTINUED FOR YEARS AND THEN DECADES...

[MAYBE SHOW HIM BEFORE BLACKBOARD OR SOMETHING WITH THIS [HYPERLINK](http://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt) "FTP://FTP.CMDL.NOAA.GOV/CCG/CO2/TRENDS/CO2_ANNMEAN_MLO.TXT" DATA GOING DOWN THE PAGE: "YEAR / AVERAGE VALUE, 1960 / 317PPM, 1970 / 326PPM, 1980 / 339PPM, 1990 / 354PPM"]

PERHAPS HE GETS A BEARD AS HE GROWS OLDER,

PERHAPS JUST TRUDGING UP THE SIDE OF MONA KEA...

... AND AFTER HIS RETIREMENT HIS SON STEPPED INTO HIS SHOES.

THIS TIME IT'S THE DAD IS GRANDPA AGE,
THE SON IS DAD AGE, AND THE LINES ARE
VIRTUALLY THE SAME:

**C'MON SON, LET'S
GO TO THE BEACH!**

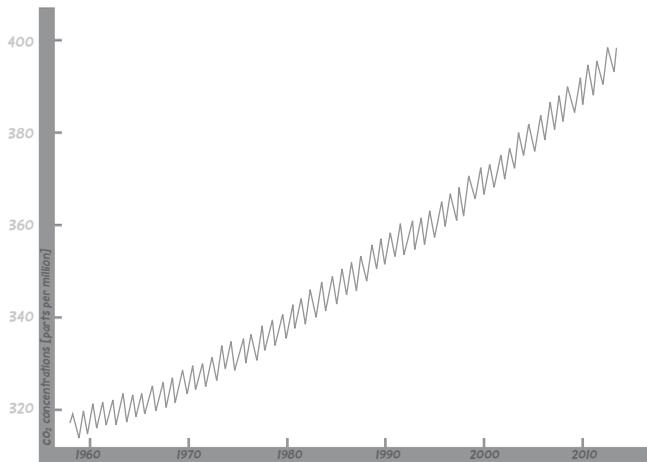
THIS TIME IT'S THE DAD IS GRANDPA AGE,
THE SON IS DAD AGE, AND THE LINES ARE
VIRTUALLY THE SAME:

WITH SNORKLE AND FINS,

**SORRY, DAD,
NOT NOW.**

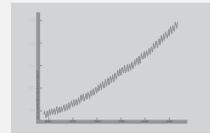
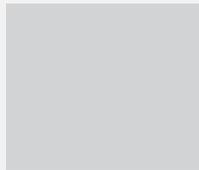
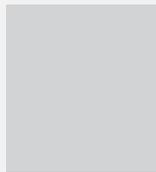
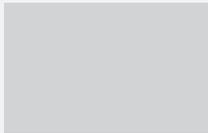
[MAYBE THE BLACKBOARD CONTINUES DOWN THE PAGE,
AND RALPH IS SAYING "2000 / 370PPM, 2010 / 390
PPM"]

THE GRAPH OF THE DAILY MEASUREMENTS THAT THEY AND THEIR COLLEAGUES HAVE MADE SINCE 1958 IS CALLED THE **KEELING CURVE**...



SOME GAG HERE:
UP AND UP AND UP IT GOES,
HOW HIGH?
NOBODY KNOWS,

... AND IT IS NOW ONE OF THE **MOST FAMOUS IMAGES** IN THE WORLD.



MUSEUM WITH THE MONA LISA
AND MONDRIAN
AND THE SCREAM
AND THE KEELING CURVE

IT'S ALSO ONE OF THE CENTRAL PIECES OF **EVIDENCE** IN THIS BOOK.

WHAT'S CAUSING
THE INCREASE?

WHAT'S GOING TO
HAPPEN BECAUSE OF IT?

WHAT CAN WE
DO ABOUT IT?

PERHAPS ENDING WITH A
FAVORITE ART CRITICISM
QUERY:

WHAT DOES IT
MEAN?

IS THIS GAG BETTER WITH
ONLY THIS?

OR ADD Y'S
BRAINSTORM:

WHAT IS IT
TELLING US?

THOSE **INCREASING CO2 LEVELS** ARE CLOSELY CONNECTED TO TWO HUMAN ACTIVITIES:
BURNING FOSSIL FUELS AND DEFORESTATION.

FELLOW WITH A CHAINSAW CUTTING DOWN TREES AND SAYING

AND SOMETIMES
**BOTH AT THE
SAME TIME!**

ABOUT **HALF** OF THAT EXTRA CO2 GETS ABSORBED BY **PLANTS**
AND BY OTHER **CARBON SINKS** SUCH AS THE **OCEANS...**

WE'LL COME BACK TO THIS
IN CHAPTER 8, ON **OCEAN
ACIDIFICATION.**

... BUT THE REST **STAYS IN THE ATMOSPHERE,**
PUSHING UP THE KEELING CURVE.

CO2 IN THE
ATMOSPHERE NOW
AVERAGES ABOUT
**400 PARTS PER
MILLION...**

... AND IS **INCREASING** BY
ABOUT **2 PPM PER YEAR.**

HERE'S HOW THE **CARBON CYCLE** IS AFFECTED BY THE **8 BILLION TONS** OF CARBON EMITTED BY HUMAN ACTIVITY **EACH YEAR**:

PLANES

ABOUT **3,6 BILLION TONS** REMAIN IN THE **ATMOSPHERE...**

119.6
BILLION
TONS

122.6
BILLION
TONS

90.6
BILLION
TONS

92.2
BILLION
TONS

... ABOUT **1,4 BILLION TONS** ARE ADDED TO THE **OCEANS...**

SHIPS

CARS

... AND ABOUT **3,0 BILLION TONS** ARE ABSORBED BY **PLANTS AND SOILS.**

SCIENTIST IN CAR WITH TRAILER THAT HAS A PLANT ON IT PERHAPS,

HUMAN EMISSIONS ARE A **SMALL FRACTION** OF THE NATURAL CYCLE, BUT OVER TIME IT **ADDS UP.**

INHALE MORE THAN
YOU EXHALE...

... AND PRETTY SOON
YOUR LUNGS WILL
EXPLODE.

HIPPIES FROM THE PREVIOUS SPREAD

SCIENTISTS HAVE ALSO PUT THE KEELING CURVE IN **HISTORICAL CONTEXT...**

WHAT DID CO2 CONCENTRATIONS LOOK LIKE **BEFORE 1958?**

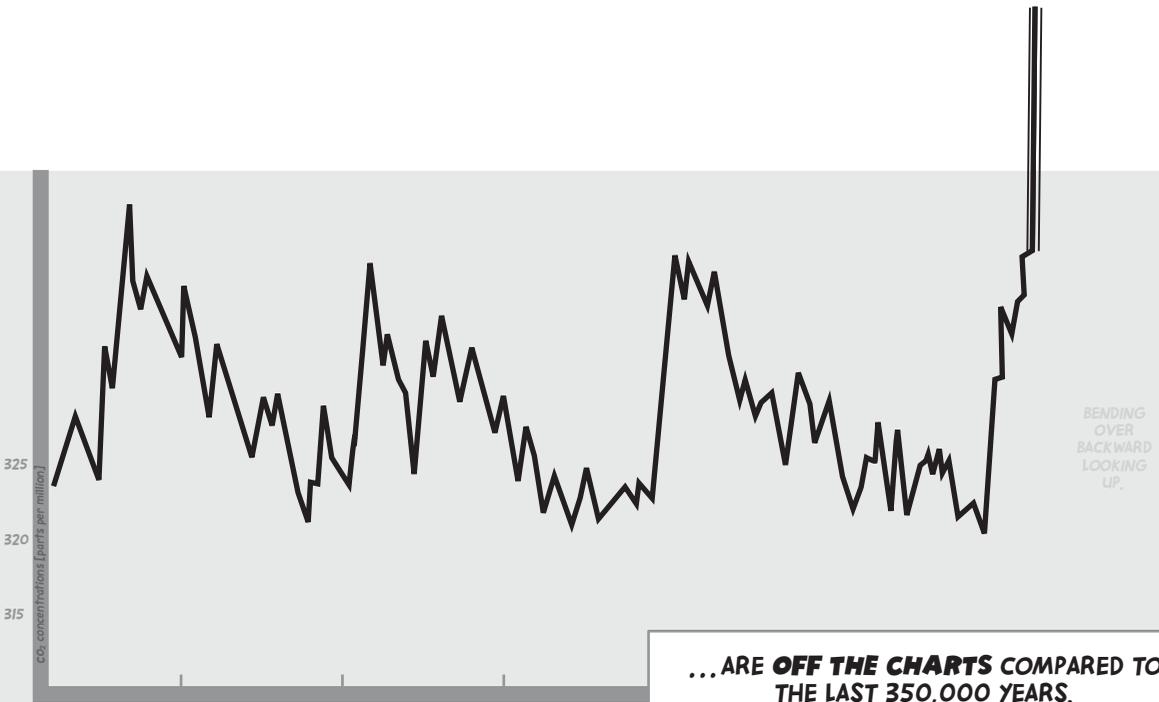
LOOKING LEFT,

...BY STUDYING THE AMOUNT OF CO2 TRAPPED **IN ICE CORES.**

WE LEARNED ABOUT THESE IN **CHAPTER 3,**

HOLDING ICE CORE,

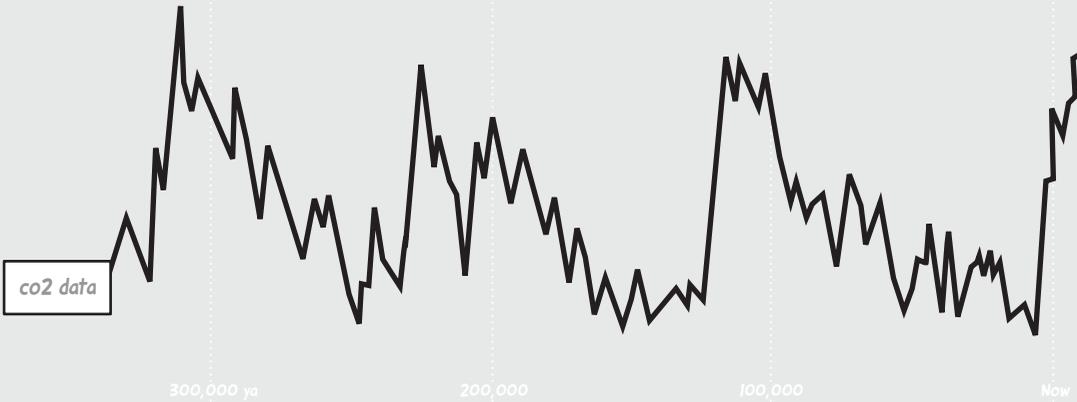
AS YOU CAN SEE, **TODAY'S LEVELS...**



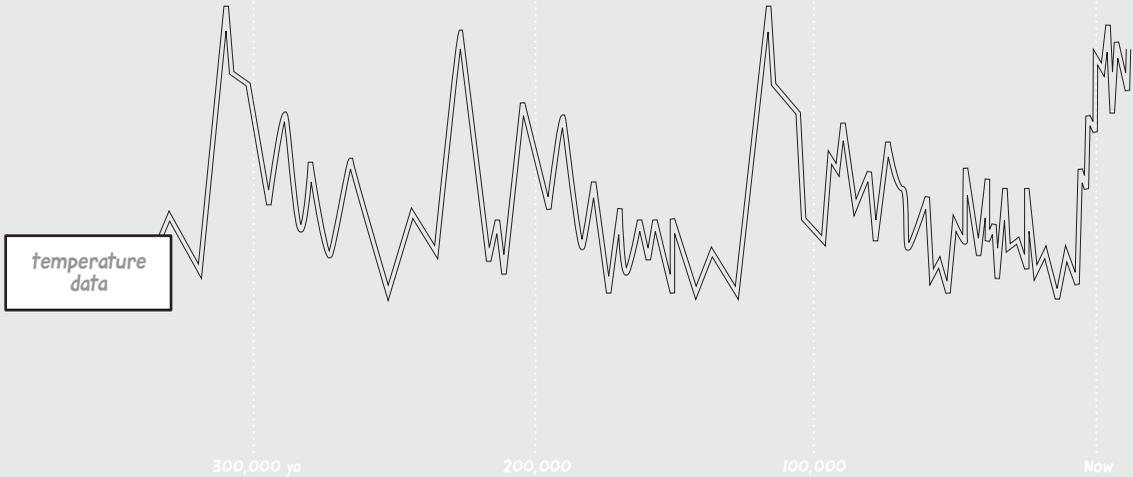
...ARE **OFF THE CHARTS** COMPARED TO THE LAST 350,000 YEARS.

JUST A NOTE THAT THE AXES HERE NEED A BIT OF WORK WITH LABELS AND TICKMARKS.

EVEN MORE AMAZING IS THE RELATIONSHIP BETWEEN THIS HISTORIC CO2 DATA...



...AND THE ICE CORE TEMPERATURE DATA FROM PAGE X.

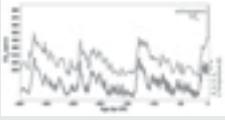


IT'S OBVIOUS THAT CO2 AND TEMPERATURE HAVE BEEN CLOSELY RELATED FOR THE PAST 350,000 YEARS.

**WHAT ARE THE ODDS
OF THAT HAPPENING
BY CHANCE?**

**LESS THAN ONE
IN A MILLION!**

THE CONNECTION BETWEEN CO2 AND TEMPERATURE IS SO STRONG THAT IT'S EASY TO GET CARRIED AWAY...



CO2 IS THE **DRIVING FORCE** BEHIND THE ICE AGES!

BE CAREFUL, **CORRELATION IS NOT CAUSATION.**

ON THE WALL

PERHAPS THE EXCITABLE KID

... SO DON'T FORGET WHAT WE LEARNED IN THE LAST CHAPTER.

THE **MILANKOVITCH CYCLES SET THE TEMPO** FOR THE ICE AGES,...

MM AS A DRUMMER SAYING:

AS WE'LL SEE IN THE NEXT CHAPTER, HOWEVER, CO2 HAS A MAJOR INFLUENCE ON THE PLANET'S TEMPERATURE.

... BUT THE CO2 FEEDBACK LOOP HELPS AMPLIFY THE MESSAGE!

AND THEN WE SEE THE AMPS AND STUFF IN THE NEXT FRAME AND A SCIENTIST OR SOMEBODY ELSE SAYS:

[AND THEN WE COULD HAVE SMALLISH AMPS LABELED "ALBEDO FEEDBACK" AND MAYBE "ALTITUDE FEEDBACK" AND A REALLY BIG AMP LABELED "CO2 FEEDBACK".

CHAPTER 5

ENERGY

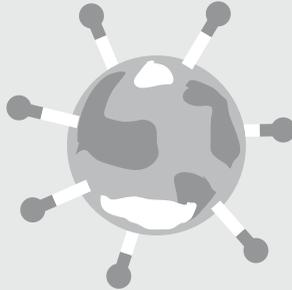
YOUR **BANK ACCOUNT**
DEPENDS ON **MONEY IN**
AND **MONEY OUT...**

...AND THE
EARTH'S TEMPERATURE
DEPENDS ON **ENERGY IN**
AND **ENERGY OUT.**

PERHAPS BANK TELLER AND
CUSTOMER DEPOSITING HUGE
BAG OF MONEY.

**IF YOU SPEND A YEAR MEASURING AIR TEMPERATURES
ALL OVER THE SURFACE OF THE PLANET...**

GLOBE WITH THERMOMETERS STICKING
OUT OF IT.



CURRENTLY ABOUT
14 C, 57 F.

**... WHAT YOU END UP WITH IS A GLOBAL AVERAGE
TEMPERATURE FOR PLANET EARTH.**

**IF YOU WANTED TO, YOU COULD
DO THE SAME THING FOR YOUR HOUSE.**

[MAYBE A KID PUTTING A
THERMOMETER IN A WEIRD
PLACE—CEILING? BATHROOM? AND
THE PARENT ASKS

**WHAT ARE YOU
DOING?**

MAYBE THE KID SAYS

ABOUT
**20 C,
68 F.**

THE TWO DOMINANT INFLUENCES ON GLOBAL AVERAGE TEMPERATURE ARE **ENERGY IN** AND **ENERGY OUT**.

IT'S TRUE FOR YOUR HOUSE AND IT'S TRUE FOR THE WHOLE PLANET,

WHEN **ENERGY IN** IS BIGGER, THE PLANET **WARMS UP...**

JUST LIKE YOUR HOUSE WARMS UP WHEN YOU TURN ON THE HEATER,

MAYBE TEENAGE BOY TURNS UP THE HEAT...

... AND WHEN **ENERGY OUT** IS BIGGER, THE PLANET **COOLS DOWN**.

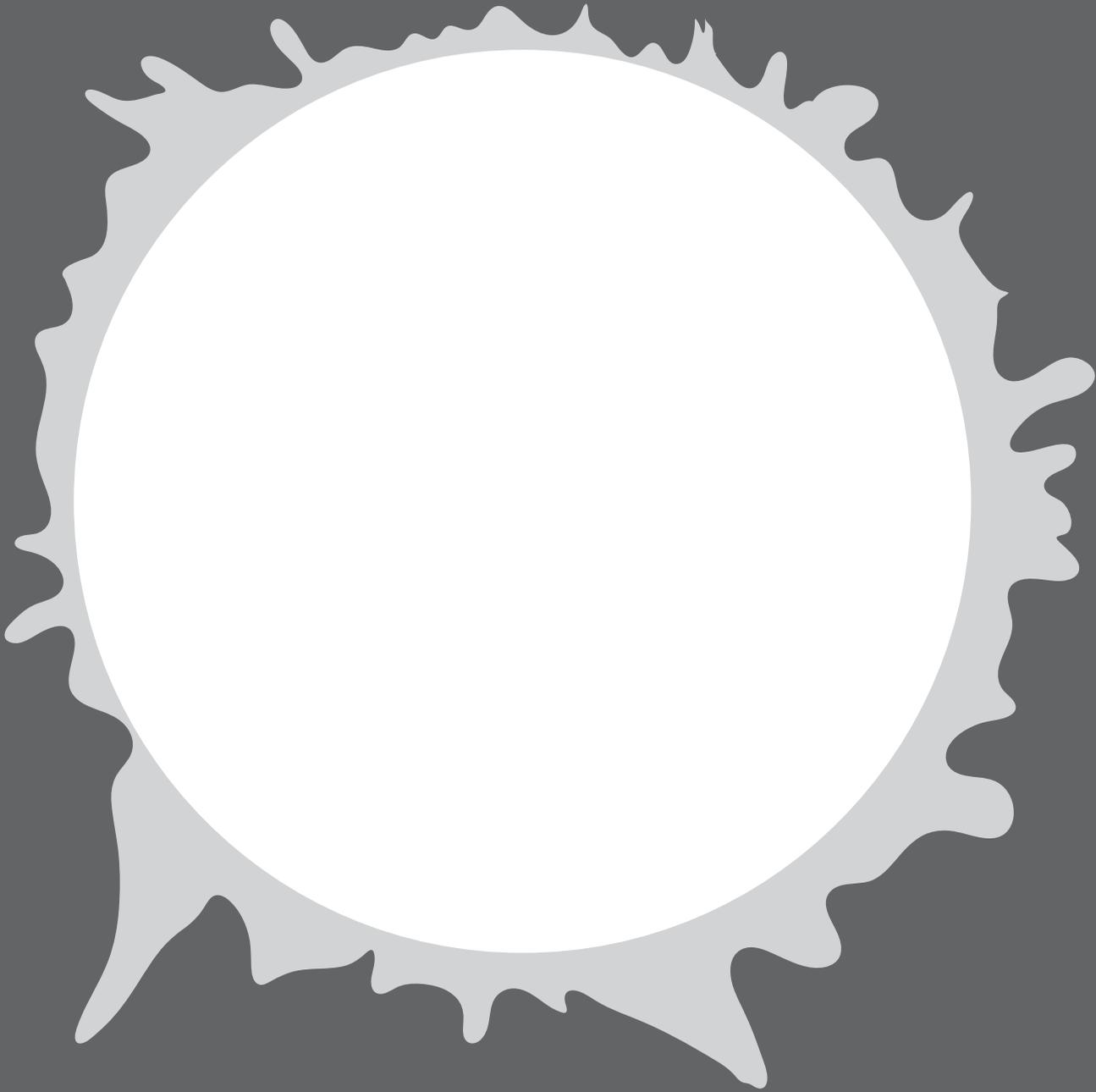
JUST LIKE YOUR HOUSE COOLS DOWN WHEN YOU OPEN A WINDOW,

SHOW ENERGY LEAVING HOUSE

MAYBE TEENAGE GIRL OPENS THE WINDOW, ANNOYING HER BROTHER...

SO TO UNDERSTAND GLOBAL TEMPERATURE WE NEED TO UNDERSTAND MORE ABOUT **ENERGY IN** AND **ENERGY OUT**.

ENERGY IN IS SIMPLE.



IF THE SUN WAS
A BASKETBALL
ON ONE END OF
A FULL-SIZED
COURT...

... THE EARTH
WOULD BE A
LARGE GRAIN OF
SAND UNDER THE
OTHER BASKET.

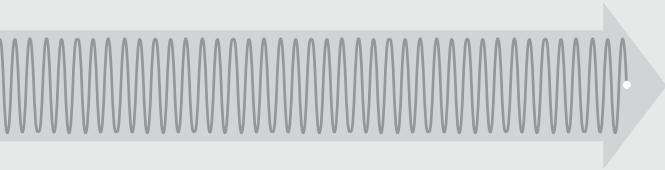
THE AMOUNT OF ENERGY
HITTING THE EARTH EACH
SECOND...

... IS EQUIVALENT TO
EACH PERSON ON
EARTH RUNNING **100**
HAIR DRYERS FOR A
WHOLE YEAR.

HAIR DRYERS COULD FIT
WITH FAMILY ABOVE,
TEENAGE BROTHER IS VERY
ANNOYED AT TEENAGE
SISTER FOR RUNNING THE
HAIR DRIER,



**ENERGY FROM THE SUN INCLUDES VISIBLE LIGHT
AND OTHER TYPES OF ELECTROMAGNETIC RADIATION.**

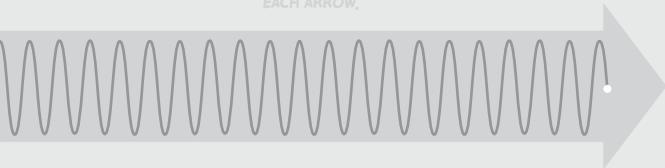


HIGH-ENERGY
**ULTRAVIOLET
(UV)** RADIATION
HAS THE SHORTEST
WAVELENGTHS.

COULD DO A SILLY ICON OR
SUPERHERO FOR THE DIFFERENT
KINDS OF RADIATION,

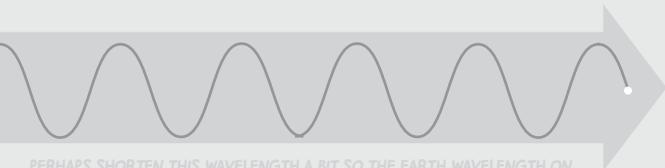
IT'S PARTIALLY
BLOCKED BY THE
OZONE LAYER,

PERHAPS A SCIENTIST RIDES
EACH ARROW,



VISIBLE LIGHT
WAVELENGTHS
COVER THE WHOLE
RAINBOW...

... FROM SHORTWAVE
VIOLET TO
LONGWAVE **RED**,



LOW-ENERGY
INFRARED
RADIATION HAS
THE LONGEST
WAVELENGTHS.

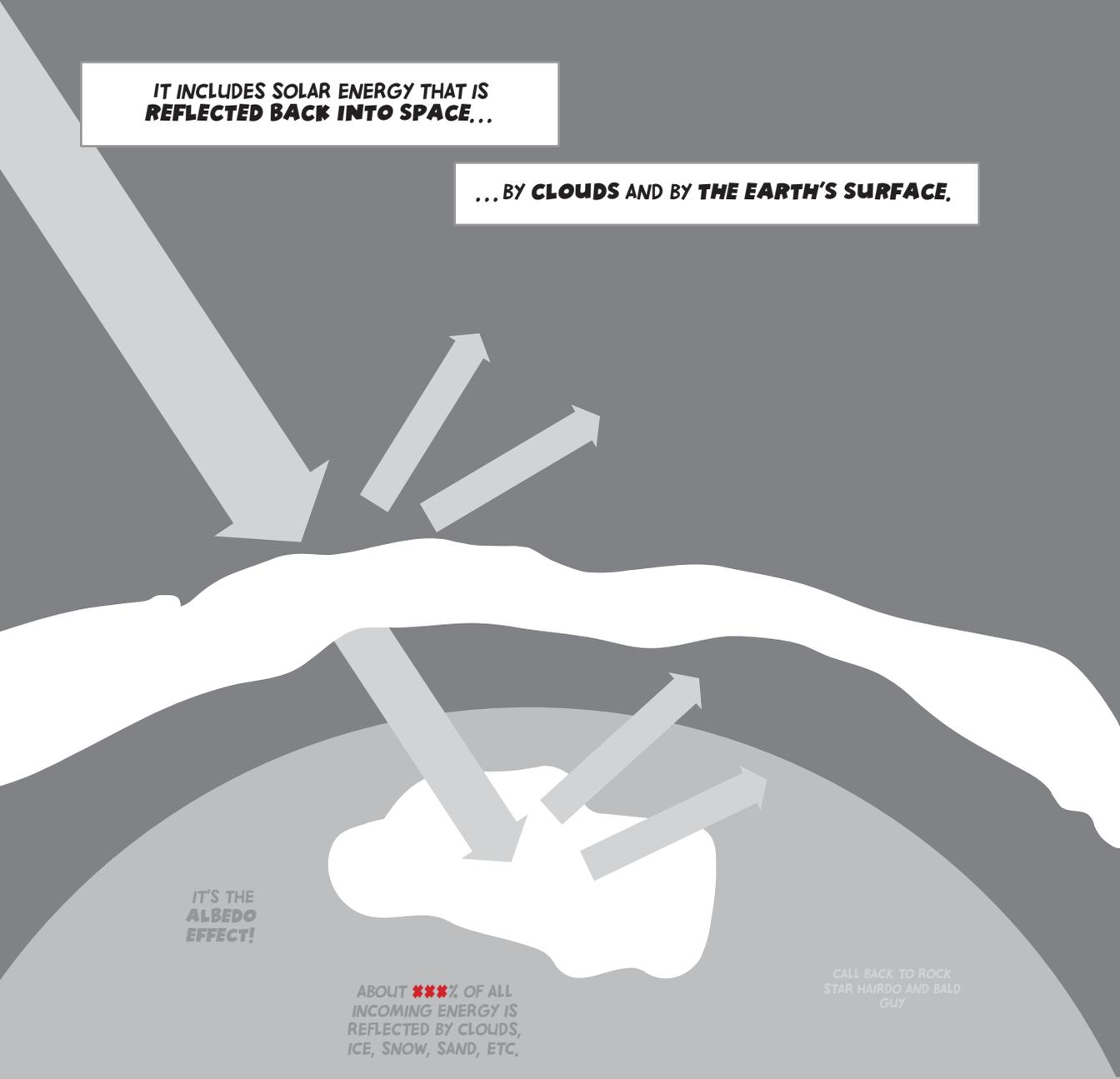
WE'LL COME BACK
TO THIS IN A
MOMENT,

PERHAPS SHORTEN THIS WAVELENGTH A BIT SO THE EARTH WAVELENGTH ON
THE NEXT PAGE CONTRASTS MORE,

ENERGY OUT IS MORE COMPLICATED.

IT INCLUDES SOLAR ENERGY THAT IS REFLECTED BACK INTO SPACE...

...BY CLOUDS AND BY THE EARTH'S SURFACE.



IT'S THE ALBEDO EFFECT!

ABOUT *****%** OF ALL INCOMING ENERGY IS REFLECTED BY CLOUDS, ICE, SNOW, SAND, ETC.

CALL BACK TO ROCK STAR HAIRDO AND BALD GUY

CHECK OUT THE GLOSSARY FOR MORE.

INCLUDING THIS TECHNICAL NOTE: IF YOU STUDY MORE CLIMATE SCIENCE, YOU'LL LEARN THAT REFLECTED SOLAR ENERGY IS USUALLY SUBTRACTED FROM ENERGY IN RATHER THAN BEING ADDED TO ENERGY OUT, WE'RE FOLLOWING A MORE INTUITIVE APPROACH, BUT OF COURSE BOTH WAYS ARE CORRECT

CRUCIALLY, ENERGY OUT **ALSO** INCLUDES RADIATION
GIVEN OFF BY THE EARTH ITSELF.

THE **EARTH** DOESN'T
EMIT AS MUCH ENERGY
AS THE **SUN**...

ASTRONAUT HERE



... BUT IT **DOES** EMIT
ENERGY.

THIS OUTGOING ENERGY IS IN THE **INFRARED** PART OF
THE ELECTROMAGNETIC SPECTRUM...

IN FACT, ITS
WAVELENGTHS ARE
LOWER ENERGY AND
LONGER THAN THOSE
FROM THE SUN,

CLOSEUP OF
ASTRONAUT FROM
THE PANEL ABOVE

... AND IS FAMILIAR TO ANYBODY WHO'S
USED **NIGHT-VISION GOGGLES**...

PERHAPS VERY DARK FRAME WITH GLIY
WITH NIGHT VISION GOGGLE, OTHER
SAYING:

WHAT YOU'RE SEEING IS THE
INFRARED RADIATION
GIVEN OFF BY THE THINGS
AROUND YOU,

... OR FELT THE WARMTH OF A **STOVE**.

A **HOT** STOVE IS
RED HOT...

... AND A **WARM** STOVE
IS **INFRARED HOT**.

I'M NOT SURE THIS ISN'T TOO CLEVER.

AND THAT BRINGS US TO **GREENHOUSE GASES**.

WATER VAPOR (H₂O)



CARBON DIOXIDE (CO₂)



METHANE (CH₄),



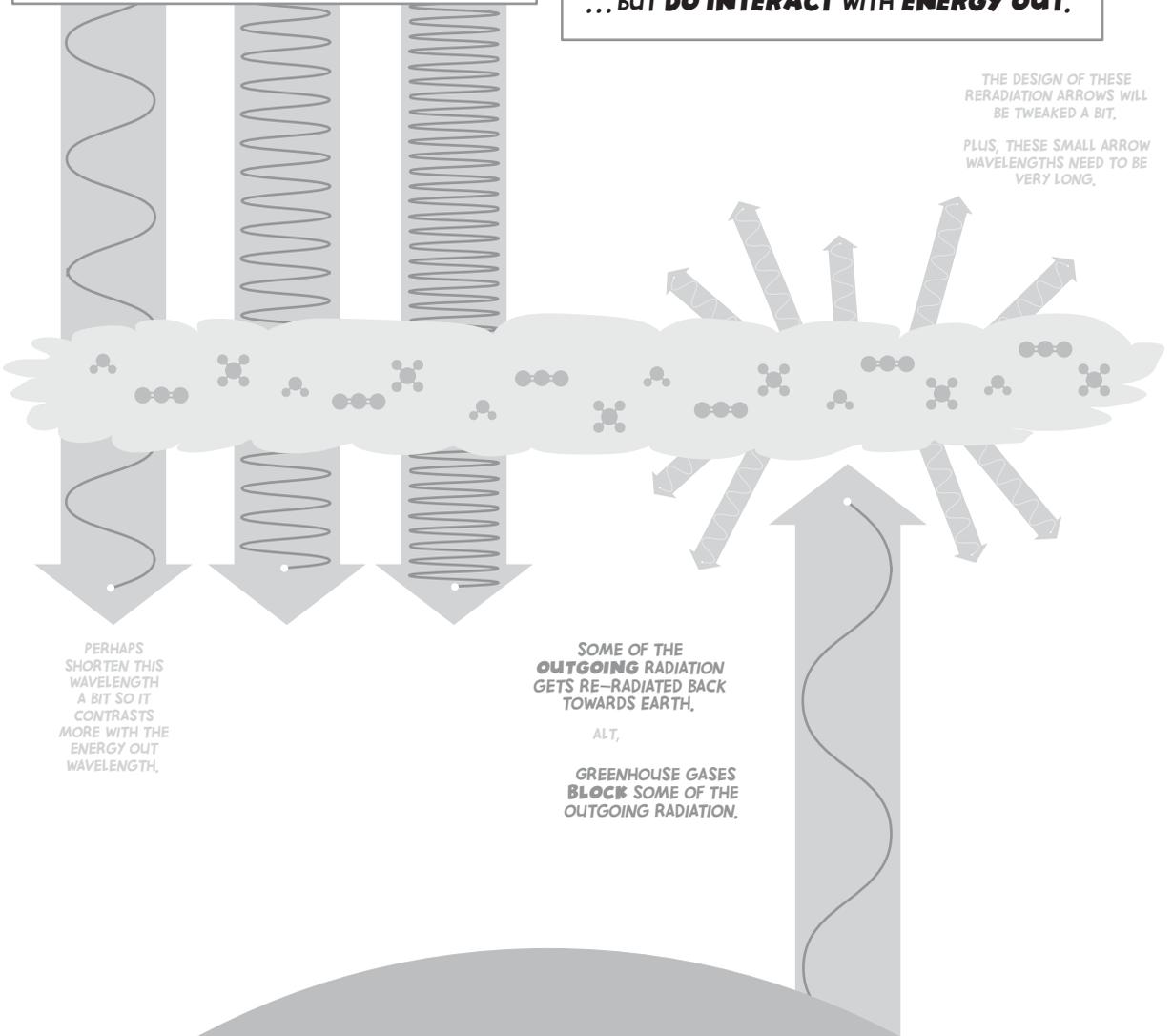
PLUS OTHERS THAT ARE LESS IMPORTANT.

WHAT MAKES THEM **GREENHOUSE GASES** IS THAT THEY **DON'T INTERACT MUCH WITH ENERGY IN...**

... **BUT DO INTERACT WITH ENERGY OUT.**

THE DESIGN OF THESE RERADIATION ARROWS WILL BE TWEAKED A BIT.

PLUS, THESE SMALL ARROW WAVELENGTHS NEED TO BE VERY LONG.



PERHAPS SHORTEN THIS WAVELENGTH A BIT SO IT CONTRASTS MORE WITH THE ENERGY OUT WAVELENGTH.

SOME OF THE **OUTGOING RADIATION** GETS RE-RADIATED BACK TOWARDS EARTH.

ALT,

GREENHOUSE GASES **BLOCK** SOME OF THE **OUTGOING RADIATION**.

BY REDUCING ENERGY OUT,
GREENHOUSE GASES **WARM THE PLANET.**

JUST LIKE
INSULATION WARMS
UP YOUR **HOUSE,**

OR A **BLANKET**
WARMS UP YOUR
BODY.

WE'D LIKE TO TRY TO THINK
OF SOMETHING SILLY HERE!

IN THE 1800S SCIENTISTS FIGURED OUT THAT THIS GREENHOUSE EFFECT HAS A MAJOR IMPACT ON THE EARTH'S TEMPERATURE...

THE **ACTUAL** SURFACE
TEMPERATURE IS ABOUT
14 C (57 F)...

WEARING EARLY 19TH
CENTURY VERSION OF
JEANS

... BUT **WITHOUT**
GREENHOUSE GASES IT
WOULD BE **-18C (0 F).**

WEARING EARLY 19TH
CENTURY VERSION OF A
PARKA

... AND TODAY SCIENTISTS KNOW THAT SIMILAR GREENHOUSE EFFECTS EXIST ON OTHER PLANETS.

VENUS HAS **70 TIMES**
MORE ATMOSPHERIC
CO₂ THAN EARTH...

... AND THAT'S A BIG REASON
THE SURFACE TEMPERATURE
(462C, 863F) IS HOT ENOUGH
TO **MELT LEAD!**

THE GREENHOUSE EFFECT ON VENUS IS OF COURSE
NOT CAUSED BY HUMANS...

OR BY
MARTIANS!

OR BY
**PREHISTORIC
GIANTS!**

MARTIAN HERE,

GEOLOGIST
HERE, OR
GIANT.

... AND WE'VE ALREADY SEEN THAT THERE'S
A NATURAL GREENHOUSE EFFECT ON EARTH TOO.

DURING THE **ICE AGES**,
CO₂ LEVELS VARIED BETWEEN
ABOUT **180PPM**
AND **280PPM...**

... AND DURING **HOTHOUSE
EARTH PERIODS**, THEY WERE
MUCH MUCH HIGHER.

HAVE WE REALLY GOTTEN THE IDEA OF PPM
ACROSS BY THIS POINT? JUST ASKIN.

VISUAL CALLBACK TO HOTHOUSE EARTH IMAGE
FROM CHAPTER 2.

**BUT WE'VE ALSO SEEN THAT HUMANS HAVE BEEN
ADDING LOTS OF GREENHOUSE GASES TO THE ATMOSPHERE.**

SINCE THE START OF THE
INDUSTRIAL REVOLUTION IN
THE LATE 1700S...

... WE'VE INCREASED CO₂ LEVELS
TO 400PPM.

THE SWEDISH CHEMIST **ARRHENIUS** WAS ONE OF THE FIRST TO RECOGNIZE THAT **HUMANS WERE BOOSTING THE GREENHOUSE EFFECT.**

THE DRAWING WILL SHOW THAT HE WAS IN THE LATE 1800S, (WITH HIS CLOTHES, AND MAYBE A FARMER WITH A HORSE.)

THIS IS GOING TO BE GREAT FOR FARMERS IN SWEDEN!

IN 1896 HE STUDIED WHAT WOULD HAPPEN IF WE **DOUBLED** CO2 CONCENTRATIONS...

... AND MADE A ROUGH CALCULATION OF THE **EVENTUAL INCREASE IN GLOBAL AVERAGE TEMPERATURE.**

WHAT IF WE WENT FROM **280 PPM...**

... TO **560 PPM?**

LOTS AND LOTS AND LOTS OF PAPERS WITH A PENCIL SCRIBBLING FURIOUSLY

ABOUT **5C,**
9F.

[HE'S GOT REAMS OF PAPER AND A PENCIL]

PERHAPS CRAWLING OUT FROM UNDER THE HUGE PILE OF PAPERS,

HIS ESTIMATE FROM 1896 CAME **REMARKABLY CLOSE** TO THE RANGE THAT CLIMATE SCIENTISTS TALK ABOUT TODAY.

THEY'VE GOT ALL THESE FANCY COMPUTERS

ABOUT **2-4C,**
3.6-7.2F.

CHAPTER 6

SCIENCE

WHY SHOULD I
TRUST **you?**

(ARRHENIUS, HERE, CARRY OVER
FROM THE PREVIOUS PAGE)

DON'T TRUST US.

(CLIMATE SCIENTIST FROM
THE BOTTOM OF PREVIOUS
PAGE):

**TRUST THE
SCIENTIFIC
METHOD.**

**THE SCIENTIFIC METHOD INVOLVES
DEVELOPING HYPOTHESES...**

NEWTON UNDER THE APPLE
TREE, MAYBE WITH $F=MA$
OR $F=GM \frac{M}{R^2}$.

**... TESTING THOSE HYPOTHESES
AGAINST THE REAL WORLD...**

ASTRONAUT:

NEWTON'S THEORY
OF GRAVITY WORKS
ON THE MOON!

BUT WITH THINGS LIKE **GPS**
IT'S A LITTLE BIT OFF.

FANCY
SATELLITE

... AND REFINING THOSE HYPOTHESES BASED ON THE DATA.

EINSTEIN, WITH A BLACKBOARD BEHIND HIM THAT HAS $E=MC$,
 $E=MC^2$, AND $E=MC^3$, WITH THE SECOND CIRCLED AND THE
OTHERS CROSSED OUT.

AT **SUPER HIGH SPEEDS**,
EINSTEIN WORKS BETTER
THAN **NEWTON**.

THIS PROCESS NEVER ENDS...

**EVEN EINSTEIN COLDN'T
UNITE GRAVITY AND
QUANTUM MECHANICS.**

PERHAPS ON THE CHALKBOARD $E=MC^2$
ON ONE SIDE AND SOME QUANTUM
SQUIBBLES ON THE OTHER, WITH A GAP
IN THE MIDDLE AND A STUMPED EINSTEIN
HOLDING HIS HEAD IN HIS HANDS.

NOT SURE, AND I'M NOT INSPIRED
AT THE MOMENT, BUT I HOPE THIS
PHILOSOPHICAL TYPE MATERIAL CAN
FEEL AS VISCERAL AND IMMEDIATE AS
POSSIBLE.

THIS IS A LITTLE QUIBBLE, MAYBE WE'LL
GET BACK TO IT, MAYBE NOT...
BUT MENTIONING QUANTUM FEELS A
BIT BRAINY TO ME AND I WONDER IF WE
COULD SAY SOMETHING THAT INCLUDES
THE FACT THAT OUR DESCRIPTIONS OF
BIG THINGS DON'T OVERLAP WITH OUR
DESCRIPTIONS OF REALLY TINY THINGS...

NOT SURE, AND I'M NOT INSPIRED
AT THE MOMENT, BUT I HOPE THIS
PHILOSOPHICAL TYPE MATERIAL CAN
FEEL AS VISCERAL AND IMMEDIATE AS
POSSIBLE.

... AND IT NEVER PRODUCES "ABSOLUTE TRUTH"...

(JUMPER1):

THE THEORY OF
GRAVITY IS **JUST
A THEORY.**

**... BUT THE SCIENTIFIC METHOD IS STILL ONE OF
THE MOST POWERFUL TOOLS WE HAVE,**

(JUMPER2):

IT'S THE BEST THING
TO **LOOK AT** BEFORE
YOU **LEAP.**

**THE IDEAL WAY TO TEST A THEORY
IS WITH A CONTROLLED EXPERIMENT...**

KID'S SCIENCE PROJECT WITH PLANTS

I GAVE LOTS OF WATER
TO THESE PLANTS...

... AND NO WATER TO
THESE ONES,

LET'S SEE WHICH
ONES SURVIVE,

MEDICINE TESTING:

I GAVE **CHILLA*ITROL**
TO THESE **HYPERACTIVE**
KIDS...

I'D PREFER SOMETHING
FUNNIER THAN DIABETICS,

... AND NOT TO
THESE ONES,

LET'S SEE WHICH
ONES CAN
CONCENTRATE
BETTER,

PERHAPS ADD:

I GAVE THE CARTOON
INTRODUCTION TO
CLIMATE CHANGE TO
THESE STUDENTS...

... AND NOT TO
THESE ONES,

LET'S SEE WHO
DOES BETTER ON
THE TEST!

... BUT THAT'S NOT ALWAYS POSSIBLE,

FOR EXAMPLE, YOU CAN'T DO **CONTROLLED EXPERIMENTS** ABOUT **SMOKING...**

I GAVE **ADDICTIVE NICTONE STICKS** TO THESE KIDS...

... AND NOT TO THESE ONES.

EVIL MAD SCIENTIST,

... OR ABOUT **CLIMATE CHANGE.**

I **DOUBLED THE CO2** ON THIS PLANET...

... BUT NOT ON THIS ONE.

EVIL ALIEN TYRANT,

SCIENTISTS HAVE NONETHELESS MADE PROGRESS ON THESE ISSUES.

IN FACT, THE SCIENTIFIC HISTORIES OF **SMOKING** AND **CLIMATE CHANGE** ARE SIMILAR.

WHAT POSSIBLE SIMILARITIES COULD THERE BE?

PERSON SMOKING ON A DIRTY MOTORCYCLE,

THE SCIENTIFIC LINK BETWEEN *SMOKING* AND *CANCER* HAS GROWN STRONGER AND STRONGER OVER TIME...

1957:

THE WEIGHT OF THE EVIDENCE [SUGGESTS] THAT EXCESSIVE SMOKING IS ONE OF THE CAUSATIVE FACTORS IN LUNG CANCER,

1964:

CIGARETTE SMOKING IS CAUSALLY RELATED TO LUNG CANCER IN MEN [AND PROBABLY WOMEN, TOO].

2004:

25 MILLION AMERICANS ALIVE TODAY WILL MOST LIKELY DIE OF A SMOKING-RELATED ILLNESS,

SURGEONS GENERAL FROM DIFFERENT YEARS,

PERHAPS PRESS CONFERENCE WITH SIGN ON PODIUM THAT SAYS THE DATES,

... AND A SIMILAR TREND IS EVIDENT IN THE SCIENTIFIC LINK BETWEEN *GREENHOUSE GAS EMISSIONS* AND *CLIMATE CHANGE*.

IPCC 1995:

THE BALANCE OF EVIDENCE SUGGESTS A DISCERNABLE HUMAN INFLUENCE ON GLOBAL CLIMATE,

IPCC 2001:

THERE IS NEW AND STRONGER EVIDENCE,

IPCC 2013:

IT IS **EXTREMELY LIKELY** THAT HUMAN ACTIVITIES HAVE CAUSED **MORE THAN HALF** OF THE OBSERVED INCREASE IN GLOBAL AVERAGE SURFACE TEMPERATURE SINCE THE 1950S,

PERHAPS SPELL OUT IPCC, OR JUST EXPECT PEOPLE TO LOOK IN THE GLOSSARY WHEN THEY SEE "IPCC":

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

OF COURSE, AS WITH ANY SCIENTIFIC THEORY,
IT MAY BE WRONG.

WHOOPS, **GLOBAL
WARMING IS ACTUALLY
CAUSED BY BROCCOLI...**

... AND SO IS
LUNG CANCER.

**BUT NOBODY HAS BEEN ABLE
TO IDENTIFY A GOOD COMPETING THEORY...**

GO THROUGH SOME OF THE COMPETING THEORIES:

IS IT **SUNSPOTS?**

NO.

IS IT **EL NINO?**

NO.

**COSMIC
BACKGROUND
RADIATION?**

NO.

BROCCOLI?

WHA?

COULD BEAT THE "PREHISTORIC GIANTS" GAG HERE.

... AND THE EVIDENCE HAS GOTTEN **STRONGER YEAR AFTER YEAR.**

SOME OF THE MOST IMPRESSIVE EVIDENCE COMES FROM CLIMATE SCIENTISTS' SUCCESSFUL PREDICTIONS.

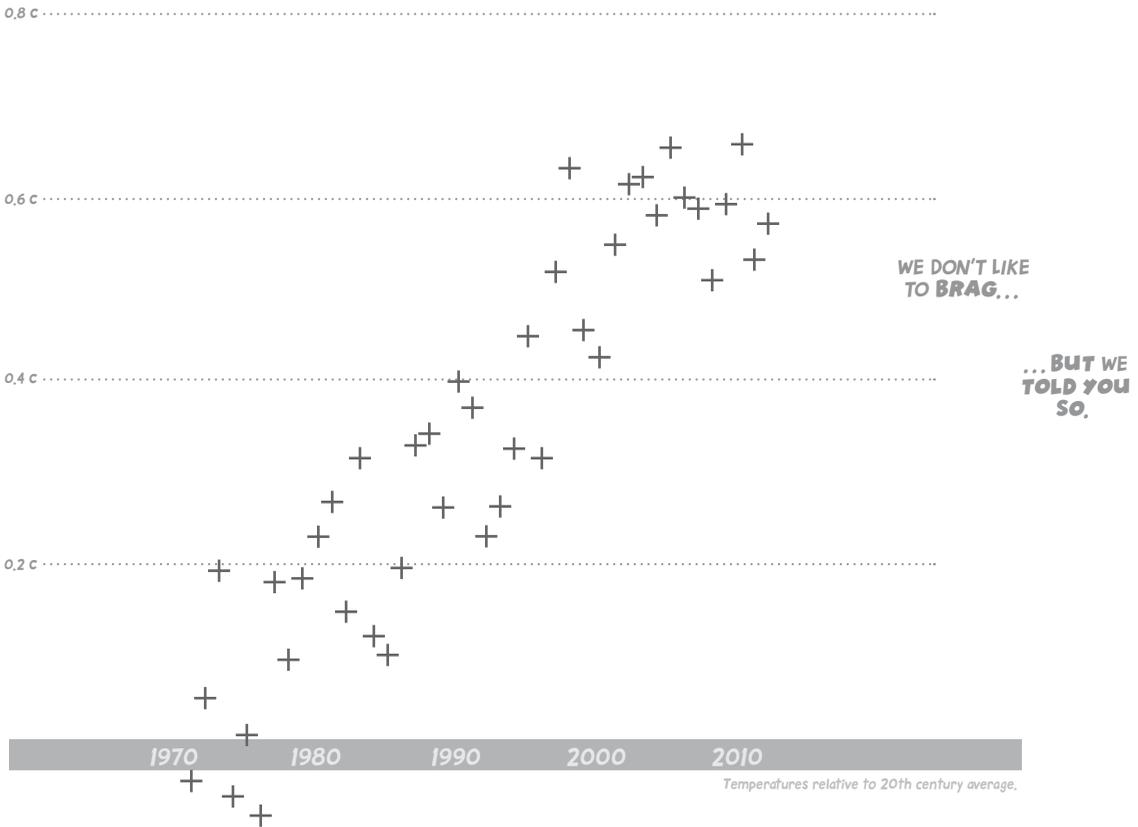
(1970S SCIENTISTS, IN 1970S CLOTHES AND GLASSES AND HAIRSTYLES: AFROS AND BEARDS &C):

WE PREDICT THAT RISING TEMPERATURES WILL BECOME **OBVIOUS** BY THE TURN OF THE CENTURY.

OUR **FASHION SENSE** WAS **TERRIBLE...**

... BUT OUR PREDICTIONS WERE **GREAT.**

SINCE THE 1970S, GLOBAL TEMPERATURE INCREASES HAVE AVERAGED ALMOST **0.2C (0.4F) PER DECADE.**



NOTE:
PERHAPS WE NEED TO ADD DATA FROM A FEW DECADES EARLIER

AND CLIMATE SCIENTISTS HAVEN'T JUST BEEN
RIGHT ABOUT THE BIG PICTURE...

SCIENTIST
FANNING SELF AND
SWEATING...

... THEY'VE ALSO BEEN **RIGHT ABOUT LOTS OF THE DETAILS.**

MORE WARMING
AT **NIGHT** THAN
DURING THE
DAY?

YUP.

MORE WARMING
NEAR THE POLES
THAN **NEAR THE**
EQUATOR?

YUP.

LESS ENERGY
ESCAPING INTO THE
STRATOSPHERE
AND INTO **SPACE?**

YUP.

SOMETHING FUNNY
LIKE,

MORE WARMING ON
MY HAIRY HEAD...

THAN ON MY BALD
ONE?

OR A GAG ABOUT
THEIR FASHION.

**MANY OF THESE PREDICTIONS
COME FROM **COMPUTER MODELS...****

CRYSTAL BALL CONNECTED TO
COMPUTER

Y FUN BRAINSTORM:

MAYBE WE COULD HAVE AN "OVERHEATING" COMPUTER THAT'S
DISPLAYING A SCREEN IMAGE OF AN "OVERHEATING" PLANET?

**... WHICH DO A PRETTY GOOD JOB OF SIMULATING
EVERYTHING FROM THE **ICE AGES...****

CHECK OUT
CHAPTER 3.

... TO **VOLCANIC ERUPTIONS.**

VOLCANO HERE.

SHORT-TERM COOLING
FOR A FEW YEARS, BUT
NO LONG-TERM IMPACT.

**AND THESE COMPUTER MODELS
PROVIDE THE BEST INDICATION
OF WHAT'S COMING **IN THE
DECADES AHEAD.****

WE WANT TO EMPHASIZE THIS,
PERHAPS WITH A FINAL NARRATOR
PANEL, THAT HAS THEM BITING THEIR
TEETH (SIMILAR GESTURES TO "ABOUT
THAT HEATING OIL.")

