

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**.

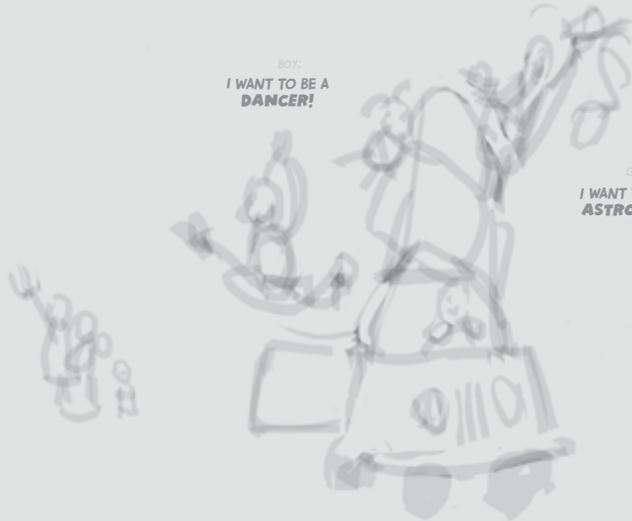
YOU CAN LEARN MORE ABOUT THAT IN THE **CARTOON INTRODUCTION TO ECONOMICS**.



... 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!**



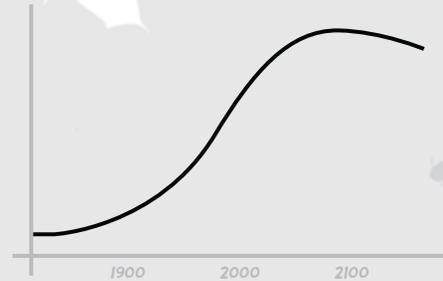
WEALTHIER FAMILIES TEND TO HAVE FEWER CHILDREN...

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

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



... 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?**





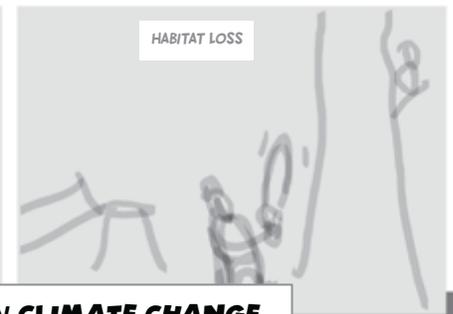
STORY #2 IS ABOUT THE ENVIRONMENTAL IMPACT OF ALL THIS GROWTH AND DEVELOPMENT.

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,



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.

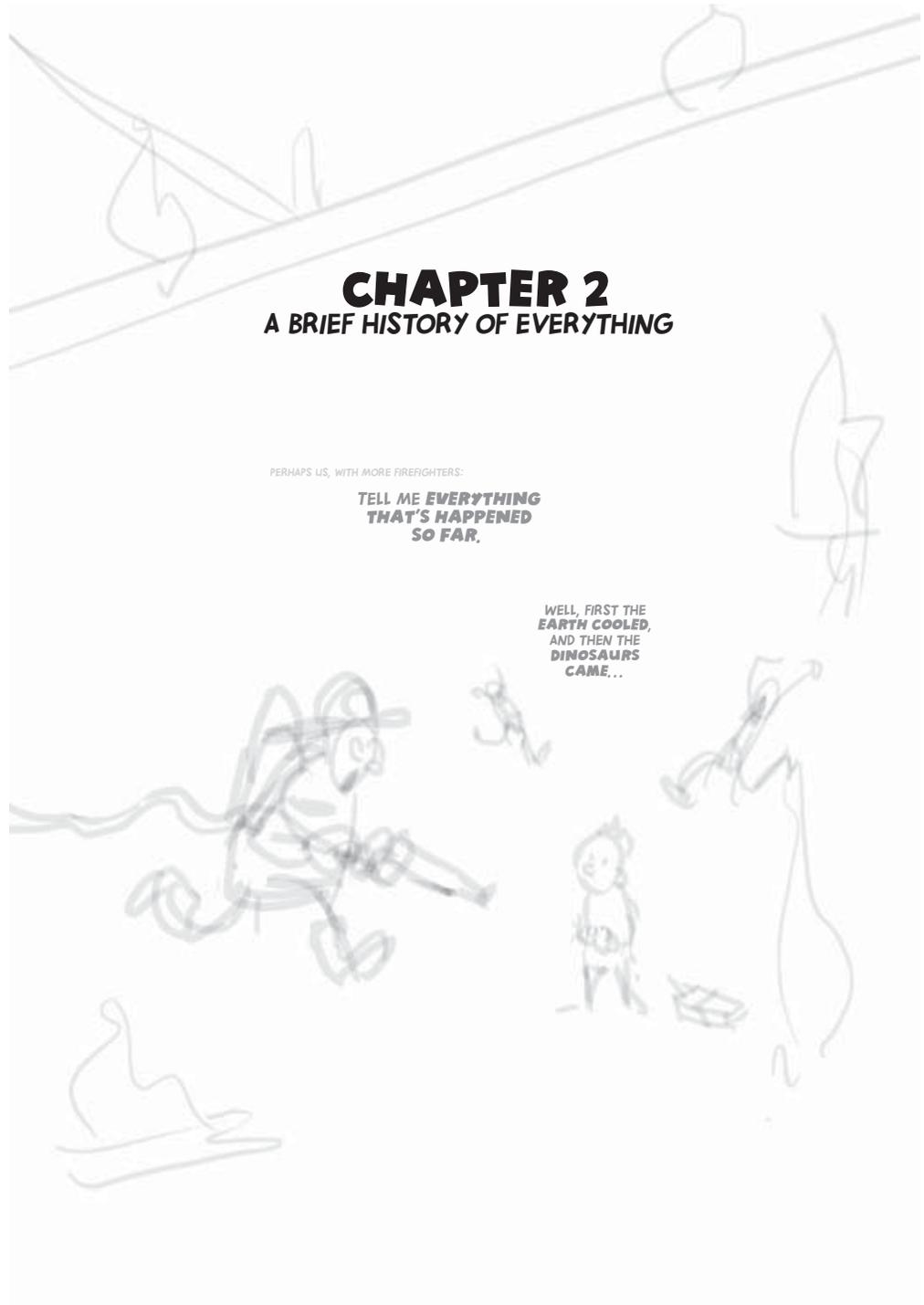
CHAPTER 2

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.

4.6 bya 4 bya 3 bya 2 bya 1 bya Now

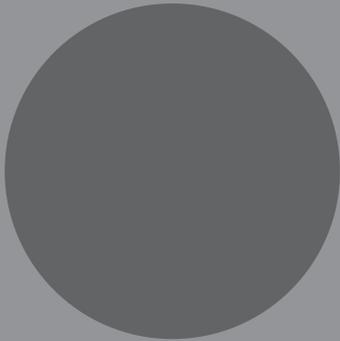
THAT'S A
LONG TIME!

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.

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!

AMOEBIA LEAPS OUT OF A
BATHTUB AND RUNS AROUND
OUTSIDE.

HUSBAND
SAYS:

EEK! 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'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.

I VOTE TO PUT THIS IN THE GLOSSARY UNDER 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,

ABOUT 60% WATER AND 20% CARBON,

ABOUT 60% WATER AND 20% CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER AND CARBON,

MOSTLY WATER, MOST OF THE REST IS CARBON,

MOSTLY WATER, MOST OF THE REST IS 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?

SCIENTIST #2

WELL, DUH,

PERHAPS IN ASTRONAUT SUITS,

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...

AMBOBAS 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 GUY'S 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).

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.

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.

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

PERHAPS ON THE PLANET, A TINY TINY FACTORY EMITS THE CFC'S AND A TINY TINY CAR EMITS THE CO2

PERHAPS THE LINES ARE SAID BY SCIENTISTS IN ASTRONAUT COSTUMES.

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...



THIS SNOWBALL EARTH IS FREEZING!

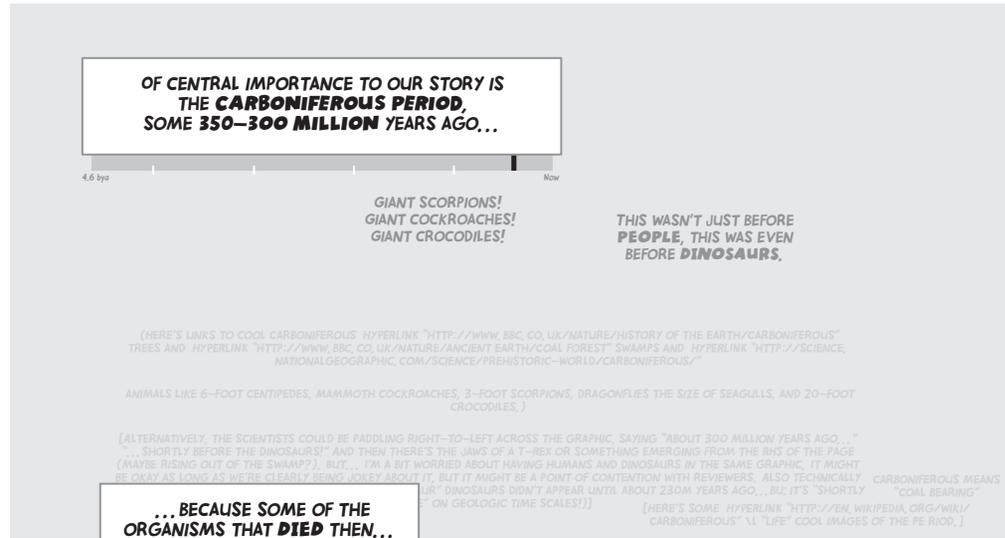
GOOD THING THERE WEREN'T ACTUALLY PEOPLE BACK THEN!



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!



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

AMOEBAS HAVING A FUNERAL

DOUG.



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?

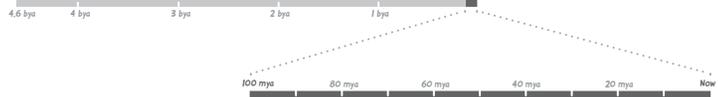
(GOOGLE "SINCLAIR GAS" AND YOU'LL SEE THE DINO IMAGE, THAT'S KIND OF WHAT I'M THINKING...)

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...



... 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?

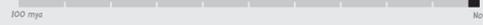
ONE CONTENENT HERE

ONE CONTENENT HERE

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,

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



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...

... 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...

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

SO THE CHICKEN AND THE DINOSAUR HAVE THE SAME GESTURE,

... AND HELLO TO THE CHICKEN.

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

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.**

EVERYONE ELSE CALLS THEM **ICE AGES.**

THIS PICTURE HAS A HUGE GLACIER AND WOOLY MAMMOTHS,

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

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...

Time
SNOW
GOT
COMPRESSED,
TRAPPING ANCIENT AIR
IN ANCIENTICE.

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

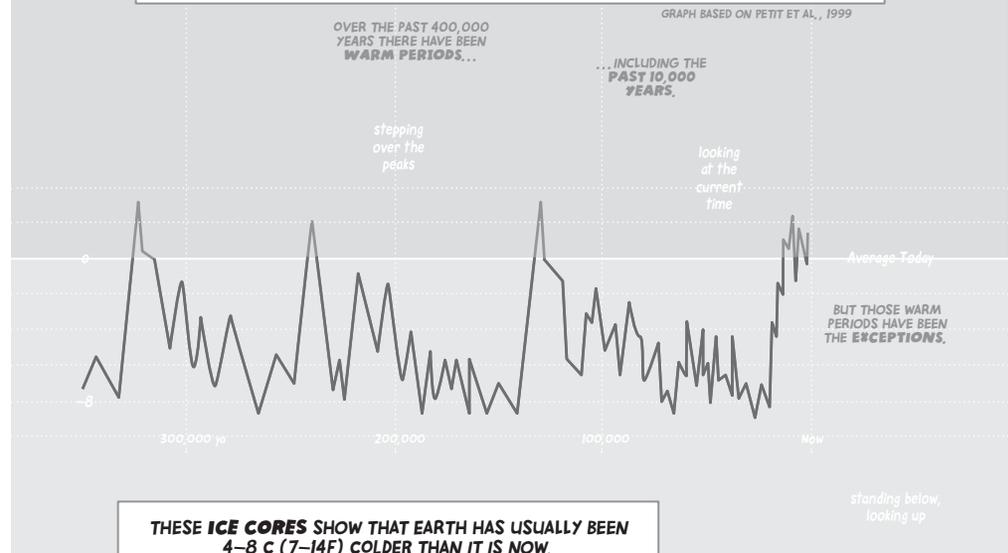
I'VE GOT A 6-FOOT **COD!**

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**.



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...

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

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

... AND THE SOUTHERN
HEMISPHERE GETS
MORE SUN.

OCTOBER

APRIL

NOT TO SCALE.

IT TURNS OUT THAT THE TILT **VARIES**
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!

MY FEET ARE
ON FIRE,
MY HEAD IS
FREEZING!

CHARACTER HERE,
TILTED OVER



ALT,
OUT OF THE
FRYING
PAN...

ALT,
... AND INTO
THE FREEZER.

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

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

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

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



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...

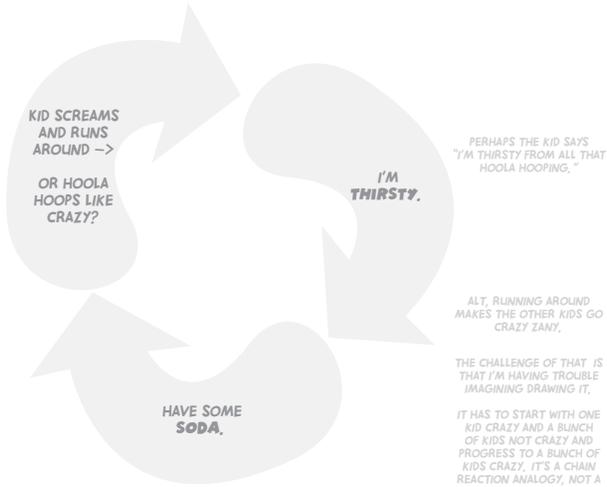
THEY'RE WIGGLES AND JIGGLES!

MM DANCES AROUND WIGGLING AND JIGGLING,

OR HOOLA HOOPING!

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

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



WE'RE STILL BRAINSTORMING ABOUT THE BEST ANALOGY TO USE HERE TO GET ACROSS THE IDEA OF FEEDBACK.

WE'RE PRETTY CERTAIN IT SHOULD HAVE A KID GETTING MORE AND MORE EXCITED ON THIS PAGE, AND LESS AND LESS EXCITED ON THE OPPOSITE PAGE, HOWEVER, EXACTLY WE'RE NOT CERTAIN YET WHAT SHOULD BE THE SOURCE OF THE FEEDBACK.

IF ANYONE HAS ANY BRAINSTORMS, WE'D LOVE TO HEAR THEM!

PERHAPS THE KID SAYS "I'M THIRSTY FROM ALL THAT HOOLA HOOPING."

ALT, RUNNING AROUND MAKES THE OTHER KIDS GO CRAZY ZANY,

THE CHALLENGE OF THAT IS THAT I'M HAVING TROUBLE IMAGINING DRAWING IT.

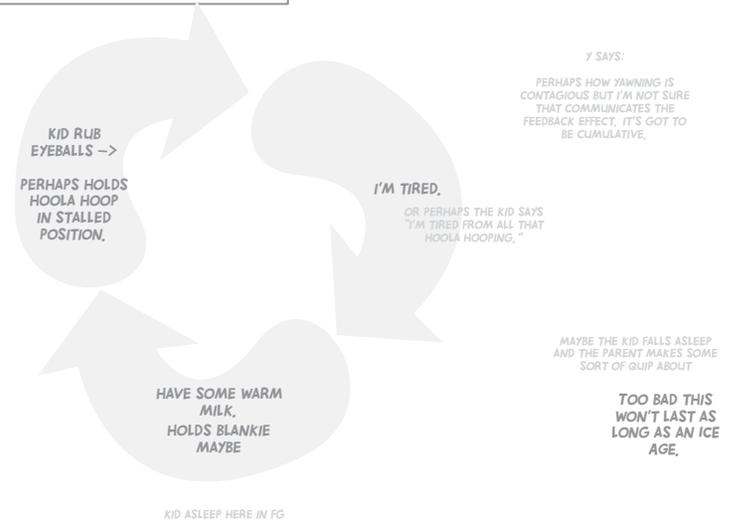
IT HAS TO START WITH ONE KID CRAZY AND A BUNCH OF KIDS NOT CRAZY AND PROGRESS TO A BUNCH OF KIDS CRAZY, IT'S A CHAIN REACTION ANALOGY, NOT A CIRCULAR ONE.

THE KID IS RUNNING AROUND HERE IN FG,

I'M GOING INTERGLACIAL!

PAST EXHAUSTED PARENT,

... 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.

I'M TIRED,

OR PERHAPS THE KID SAYS "I'M TIRED FROM ALL THAT HOOLA HOOPING,"

MAYBE THE KID FALLS ASLEEP AND THE PARENT MAKES SOME SORT OF GUIF 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.

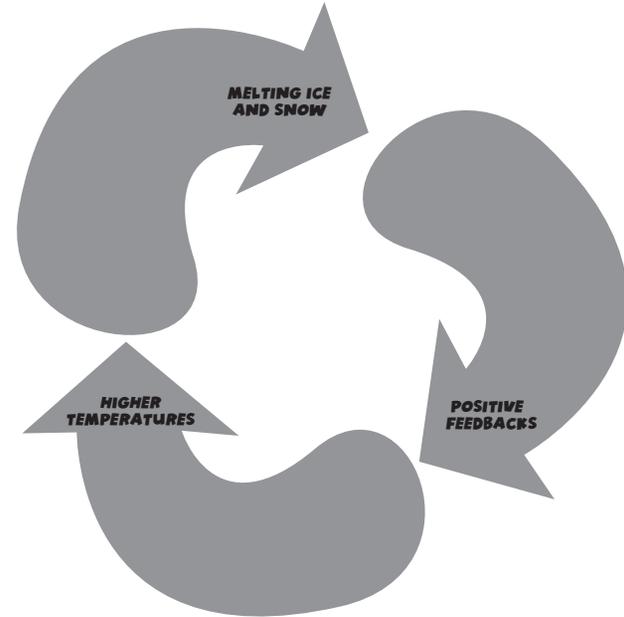
BUT THERE ISN'T ENOUGH NEW SNOW TO KEEP UP WITH THE SUMMER MELT.

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!

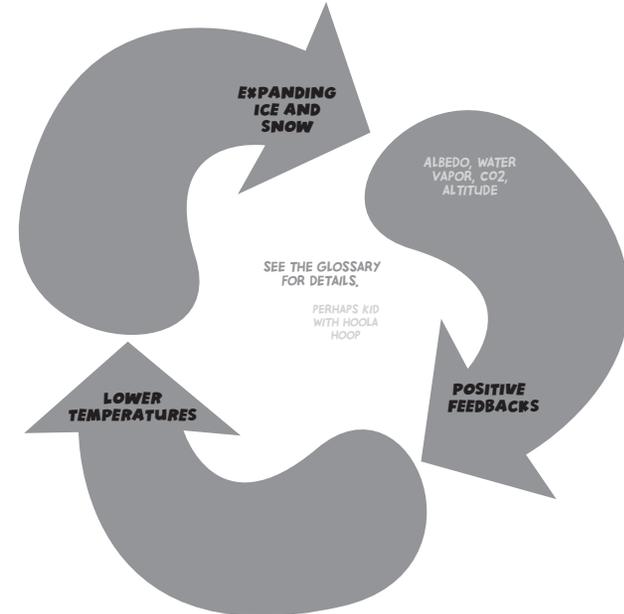
NOW THE **ALBEDO EFFECT** WORKS IN THE **OTHER DIRECTION**...

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 **10,000,000,000,000,000,000,000,000** GAS MOLECULES...

... INCLUDING ABOUT **2,100,000,000,000,000,000,000,000** 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:

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

SORRY, KID, NOT NOW.

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

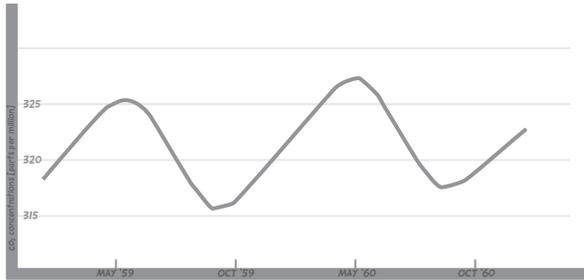
WEARING SNORKELING GEAR

... 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.



D1 (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...**

...AND TO THE **CARBON CYCLE...**

LOOK AT
PAGE #!

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

LOOK AT
PAGE #!

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!



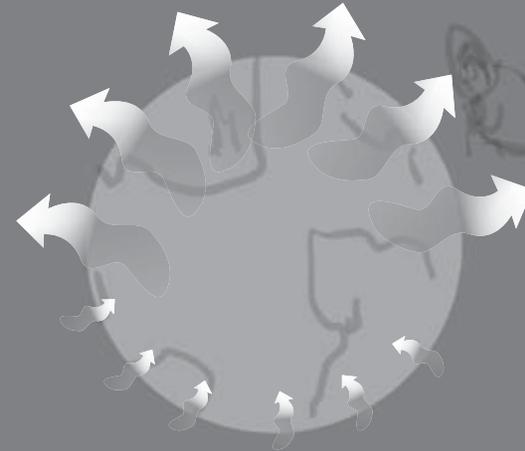
**MORE LAND MEANS
MORE GREEN
STUFF.**

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.

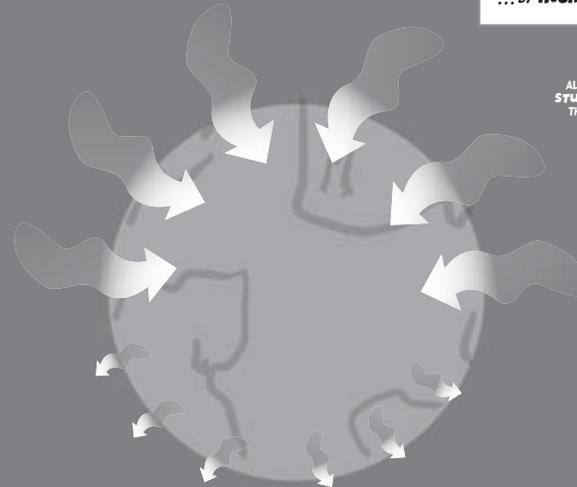


OF COURSE, WINTER
IN THE NORTH IS
**SUMMER IN THE
SOUTH...**

... 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...

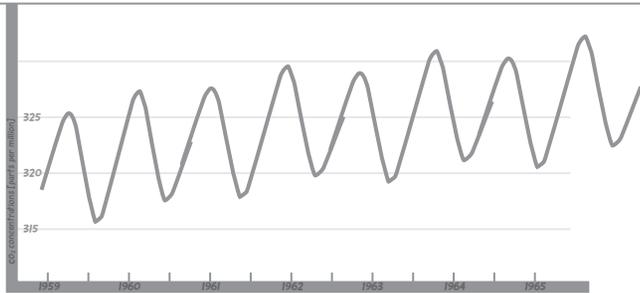
... BY **INCREASED PHOTOSYNTHESIS.**



**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
"FTP://FTP.CMDL.NOAA.GOV/CCG/CO2/TRENDS/CO2_AIR/MEAN_WLO.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!**

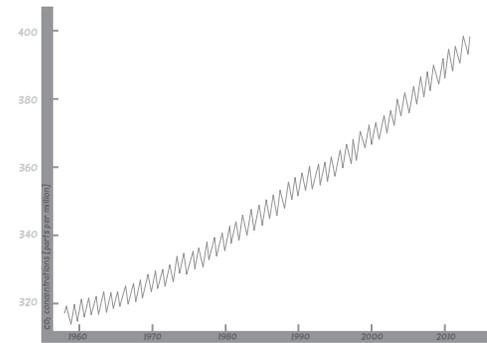
THIS TIME IT'S THE DAD IS GRANDPA AGE,
THE SON IS DAD AGE, AND THE LINES ARE
VIRTUALLY THE SAME:

WITH SNORKLE AND FINS.

SORRY, DAD,
NOT NOW.

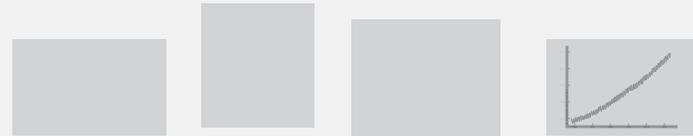
[MAYBE THE BLACKBOARD CONTINUES DOWN THE PAGE,
AND RALPH IS SAYING "2000 / 370PPM, 2010 / 390
PPM"]

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...**

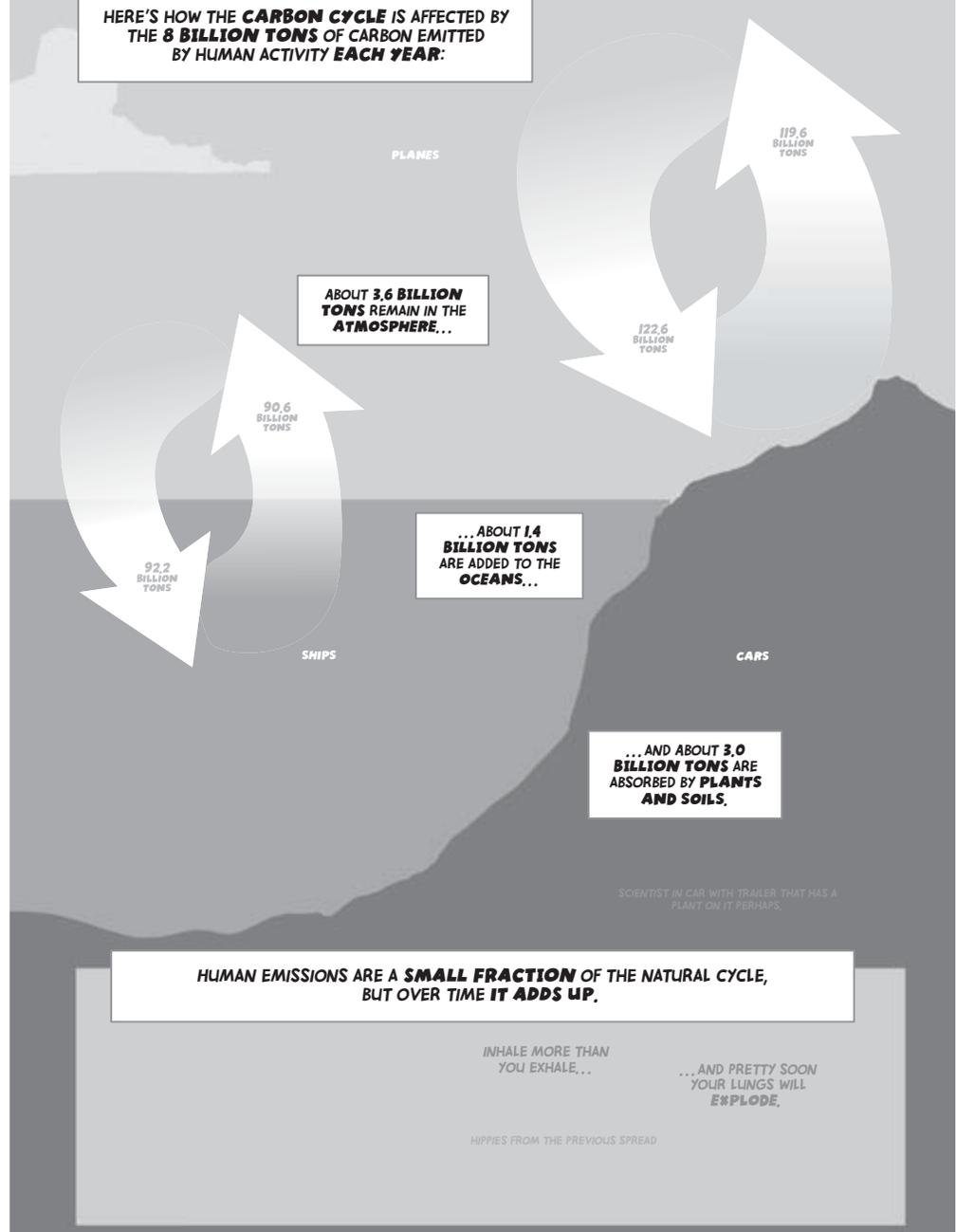
WE'LL COME BACK TO THIS IN CHAPTER #, ON **OCEAN ACIDIFICATION**.

... 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**:



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

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

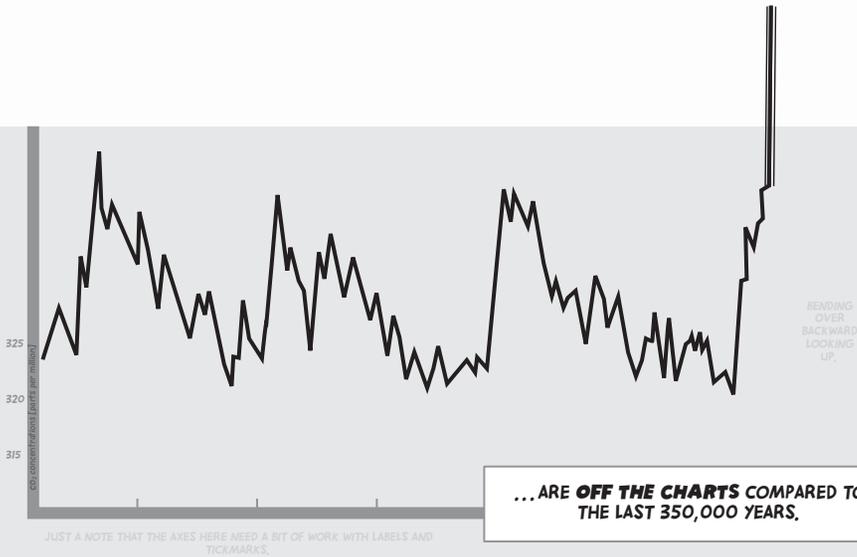
LOOKING LEFT,

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

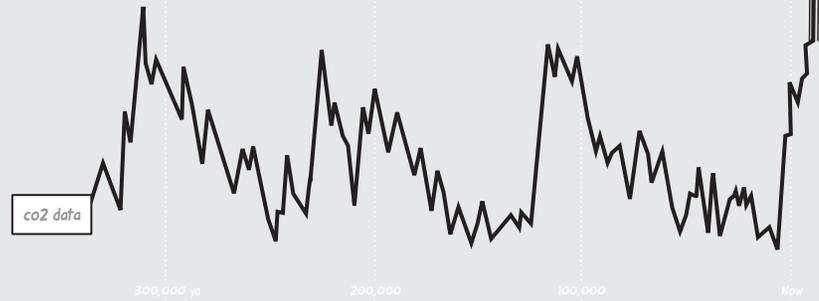
WE LEARNED ABOUT THESE IN CHAPTER 3.

HOLDING ICE CORE,

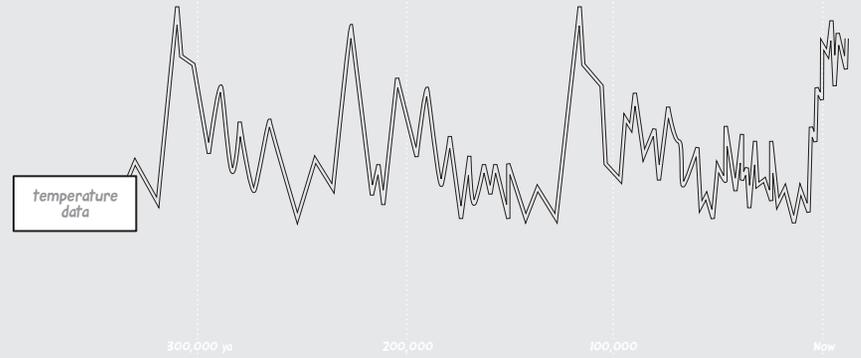
AS YOU CAN SEE, **TODAY'S LEVELS...**



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



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

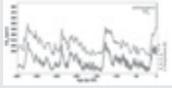


IT'S **OBVIOUS** THAT CO2 AND TEMPERATURE HAVE BEEN **CLOSELY RELATED** FOR THE PAST 350,000 YEARS.

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.**

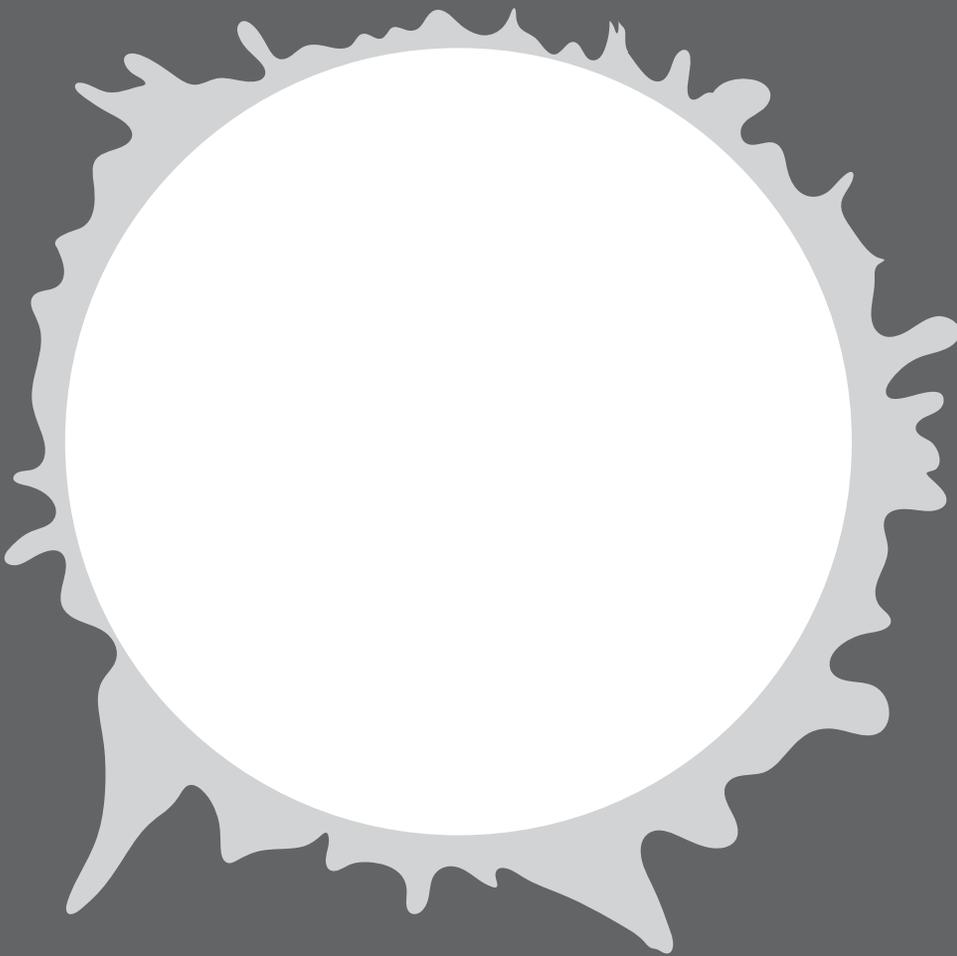
JUST LIKE YOUR HOUSE COOLS
DOWN WHEN YOU OPEN A
WINDOW.

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,

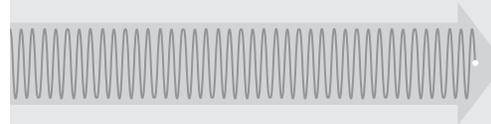
THE AMOUNT OF ENERGY
HITTING THE EARTH EACH
SECOND...

... 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 GUY 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.

ALY,

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)**...

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

WEARING EARLY 19TH CENTURY VERSION OF JEANS

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...**

WHAT IF WE WENT FROM **280 PPM...**
... TO **560 PPM?**

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

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

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 $F=GM$ IM $2/R^2$.

**... 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.

THIS IS A LITTLE QUIBBLE, MAYBE WE'LL
GET BACK TO IT, MAYBE NOT...

BUT MENTIONING QUANTUM FEELS A
BIT BRANNY 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...

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.

... 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 **CHILLASITROL** 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].

SURGEONS GENERAL FROM DIFFERENT YEARS, PERHAPS PRESS CONFERENCE WITH SIGN ON PODIUM THAT SAYS THE DATES.

2004:

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

... 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.**

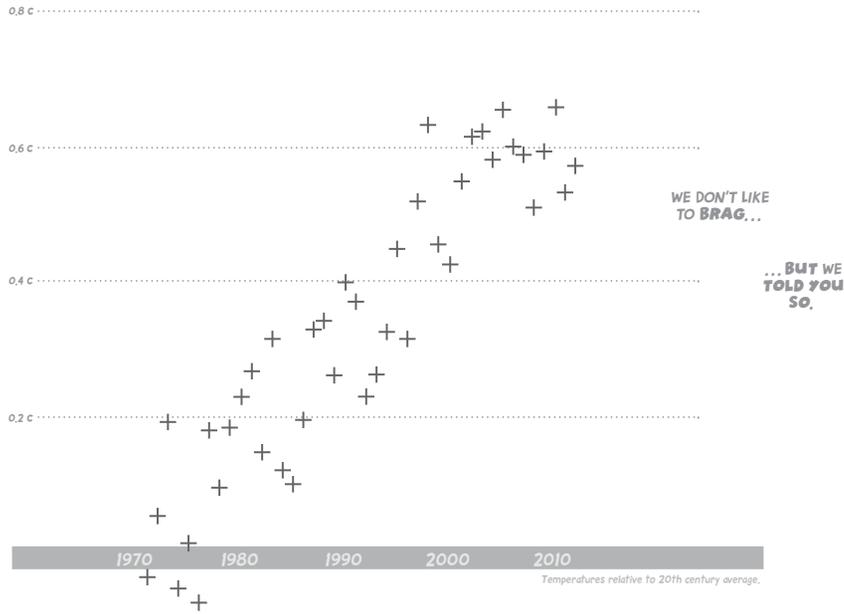
(1970S SCIENTISTS, IN 1970S CLOTHES AND GLASSES AND HAIRSTYLES: AFROS AND BEARDS & C):

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.")