

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.



I WANT TO BE A **DANCER!**

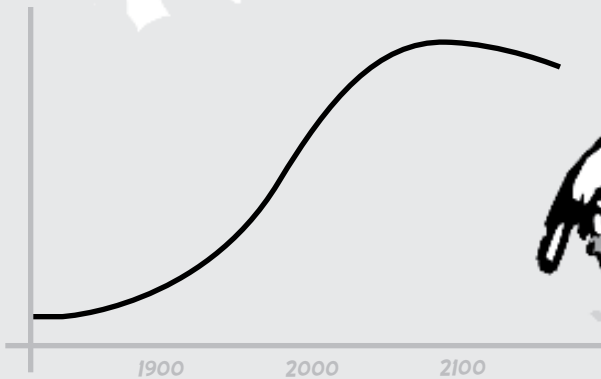
I WANT TO BE AN **ASTRONAUT!**

WEALTHIER FAMILIES
TEND TO HAVE FEWER CHILDREN...

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.



ENOUGH
ALREADY!

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



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

IT SEEMS **TOO**
GOOD TO BE
TRUE!



BUT 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?

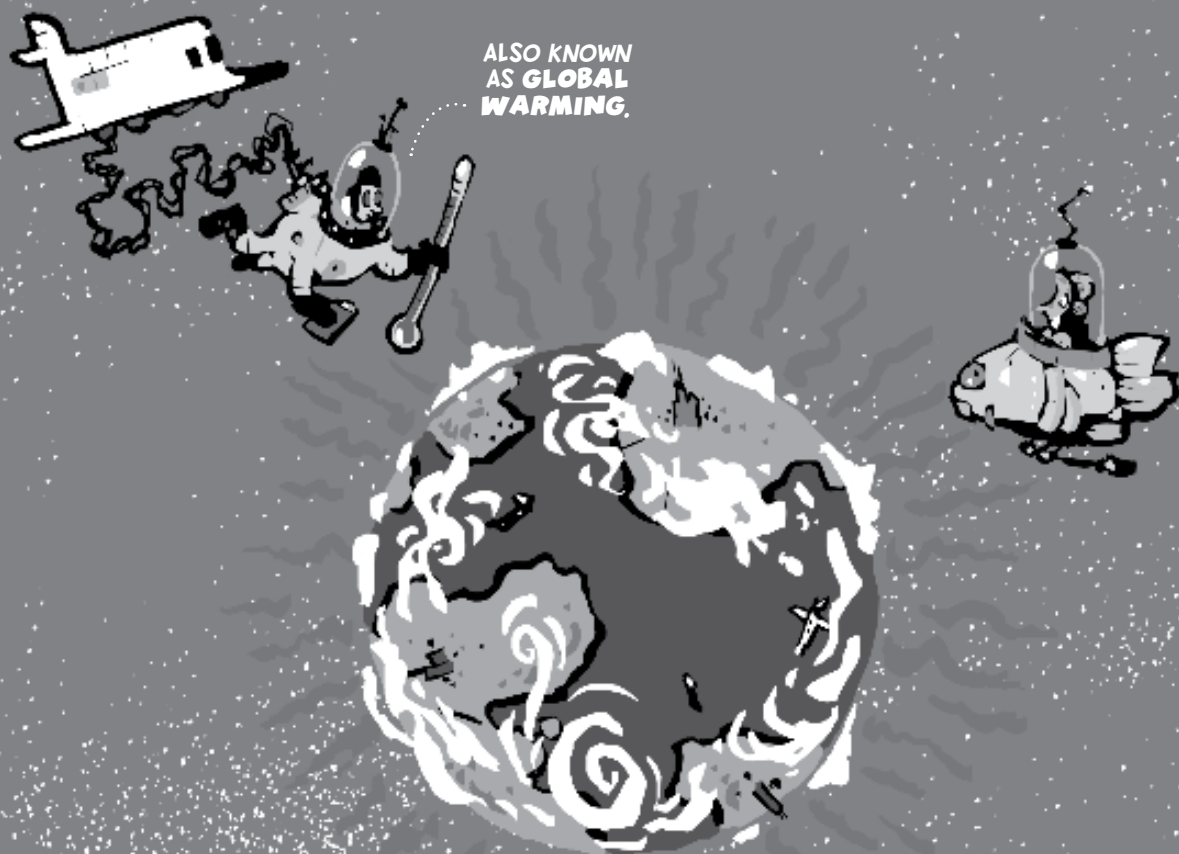
THE INVISIBLE HAND OF
FREE-MARKET ECONOMICS
ISN'T LIKELY TO FIX **THIS...**

... NOT WITHOUT
SOME **HELP!**

ENVIRONMENTAL CONCERNS COVER ALL SORTS OF TOPICS.



THIS BOOK FOCUSES ON CLIMATE CHANGE.



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 BETTER 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.

LIST OF THREATS:

VIOLENT VIDEO GAMES

NATIONAL DEBT

TERRORISM

ASTEROIDS

BIRD FLU

STUPIDITY

JUNK FOOD

POLLUTED DRINKING WATER.

BAD SPEELING

POVERTY

SPACE ALIENS

REALITY T.V.

HOW DOES THIS
ONE COMPARE?

CLIMATE CHANGE

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

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

CLIMATE CHANGE COULD
TURN THE EARTH INTO AN
ALIEN PLANET.

HOW DO YOU KNOW IT
WON'T BE AN **AWESOME**
ALIEN PLANET?



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.**

**MOSTLY AS A RESULT OF
BURNING FOSSIL FUELS AND
DEFORESTATION.**

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

**I THINK IT WILL WORK TO
KEEP THE HORSE AND THE CAR
CARRYING TRUCK, BUT AND
THEN I CAN HAVE THE LOGGER
IN FRONT OF THE TRUCK
CHOPPING DOWN A TREE AS IF
HE'S PAVING THE WAY FOR A
NEW ROAD.**

1950s



2000s

THIS BOOK IS ABOUT THE **SCIENCE**
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 HOW CLIMATE CHANGE MIGHT
AFFECT **LIFE ON EARTH**...

PART TWO:
PREDICTIONS

...AND **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 21–28C
(69–82F)...

...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 LIKE YOUR
PERSONALITY.

WEATHER IS
LIKE YOUR
MOOD.

...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 PLANET EARTH

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 50 MILLION
TIMES OLDER THAN
GRANDPA.

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...

SCIENTIST OR
DAD TO YOUNG
CHILD, OF AFRICAN
DESCENT

GRANDPA IS T-ING UP TO
PLAY GOLF HERE.

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



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

4.6 bya Now

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

BOB.

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

ROD.

YOU AND YOUR
JOKES ARE SO
PRIMITIVE!

HARRIET

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.

WHAT DO YOU
CALL A SINGLE-CELLED
ORGANISM **SMEARED ON**
THE WALL?

ART.

WILL YOU TWO
SHUT UP!

I'M TRYING TO
CONCENTRATE!

HAROLD

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

EUREKA!

AMOEBA 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.**

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.

IN CHAPTER 4 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,

MOSTLY WATER
AND CARBON,

HOW ABOUT IF THIS IS BROCCOLI FROM THE PREVIOUS PAGE, BUT DO COW'S EAT BROCCOLI?

MOSTLY WATER
AND CARBON,

MOSTLY WATER
AND 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...

DRAWING NOTE: 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.
NC.SU.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

AMOEBAE IN SCHOOL,
UNDERWATER:

SCARY TEACHER
SCARING THEM

THE SUN GENERATES
VISIBLE LIGHT...

...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 CFC'S 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)**.

NOTE THROUGHOUT NEED TO SUBSCRIPT
THE 2 IN CO₂,

... AND WE CAN TAKE HEART FROM THE **PROGRESS**
WE'VE MADE IN REPAIRING THE OZONE HOLE,

[SCIENTIST #1:

PRESIDENT REAGAN
HELPED PHASE OUT CFCs
AND THE OZONE LAYER IS
RECOVERING,

SCIENTIST #2:

IF ONLY GLOBAL
WARMING WERE
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.**

**YORAM NEEDS TO
WORK ON THIS
TIMELINE.**

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

4.6 bya

Now

**YORAM NEEDS TO
WORK ON THIS
TIMELINE.**

**BOY, I COULD REALLY
USE SOME ICED TEA!**

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

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

THREE PEOPLE FLOATING IN THE WATER (MAYBE NEAR A
BOBBING SIGN SAYING "NORTH POLE", AND MAYBE THEY'RE
ON COOL FLOATING THINGS LIKE AN INNER TUBE WITH
THE HEAD OF A DUCK/DINOSAUR/ETC AND ONE OF THOSE
FLOATING CHAISE LOUNGE THINGS WHERE YOU CAN STRETCH
YOUR LEGS OUT AND THERE'S A PILLOW FOR YOUR HEAD).
ANYWAY, THERE COULD BE TWO PEOPLE AND A SCIENTIST
LOUNGING AROUND LIKE THIS

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

4.6 bya

Now

GIANT SCORPIONS!
GIANT COCKROACHES!
GIANT CROCODILES!

SCARED LOOKING VELOCIRAPTOR
CREEPED OUT BY THE BUGS.

**GOOD THING THAT WAS
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

CARBONIFEROUS MEANS
"COAL BEARING"

**...BECAUSE SOME OF THE
ORGANISMS THAT **DIED** THEN
GOT BURIED...**

"OUR" DINOSAURS DIDN'T APPEAR UNTIL ABOUT 230M YEARS AGO... BU; IT'S "SHORTLY
" ON GEOLOGIC TIME SCALES!])

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

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

AMOEBAS HAVING A
FUNERAL

DOUG.

AMOEBAS HAVING A
FUNERAL

**...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.

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

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

FILLING UP CAR,

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...)

DURING THE LAST 100 MILLION YEARS...

4.6 bya

4 bya

3 bya

2 bya

1 bya

100 mya

80 mya

60 mya

40 mya

20 mya

Now

... 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 CONTINENT HERE

ONE CONTINENT 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.

100 mya

Now

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

... BUT CALM IS A RELATIVE TERM.

NO **SNOWBALL EARTHS...**

... AND NO **TROPICAL NORTH POLES!**

YORAM NEEDS TO DOUBLE-CHECK THIS FRAME.

LOOK, I'VE CALMED DOWN!

WOW, WHAT WERE YOU LIKE BEFORE?

SCIENTIST

KID GOING BONKERS

100 mya

Now

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...

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.

100 mya

Now

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

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!

DON'T
FORGET THIS
CHARACTER
NEEDS
RELATIVELY
DARK SKIN,

DINOSAUR

MAMMOTH

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

THAT'S ONLY 2,000
TIMES OLDER THAN
GRANDPA,

LADY GAGA
OR SCIENTIST

CHARACTERS FROM
PAGE 2,

GRANDPA GRUMPILY
PULLING HIS GOLF BAG

RETURN
TO KID AT
BEGINNING,

... 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?**

[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

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

ON THE BEACH, SCIENTIST SAYS THIS TO SUNBATHER.

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...

Falling
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 LIKE
**COUNTING TREE
RINGS.**

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

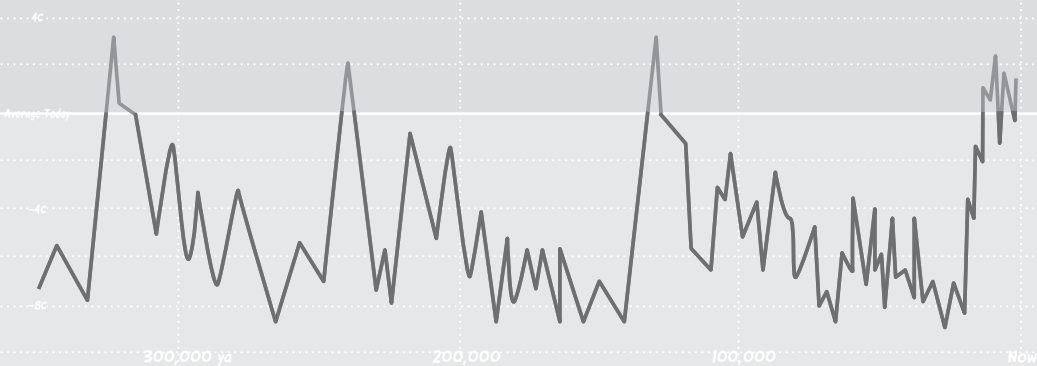
OVER THE PAST 400,000
YEARS THERE HAVE BEEN
WARM PERIODS...

stepping
over the
peaks

... INCLUDING THE
**PAST 10,000
YEARS.**

looking down
and Right at the
current time

BUT THOSE WARM
PERIODS HAVE BEEN
THE **E#CEPTIONS.**



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

THOSE **SMALL
TEMPERATURES
CHANGES...**

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

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

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



... AND THE SOUTHERN
HEMISPHERE GETS
MORE SUN.

OCTOBER

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**.

OR THIS COULD
BE CROLL GIVING
TECHNICAL DETAILS.



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

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!

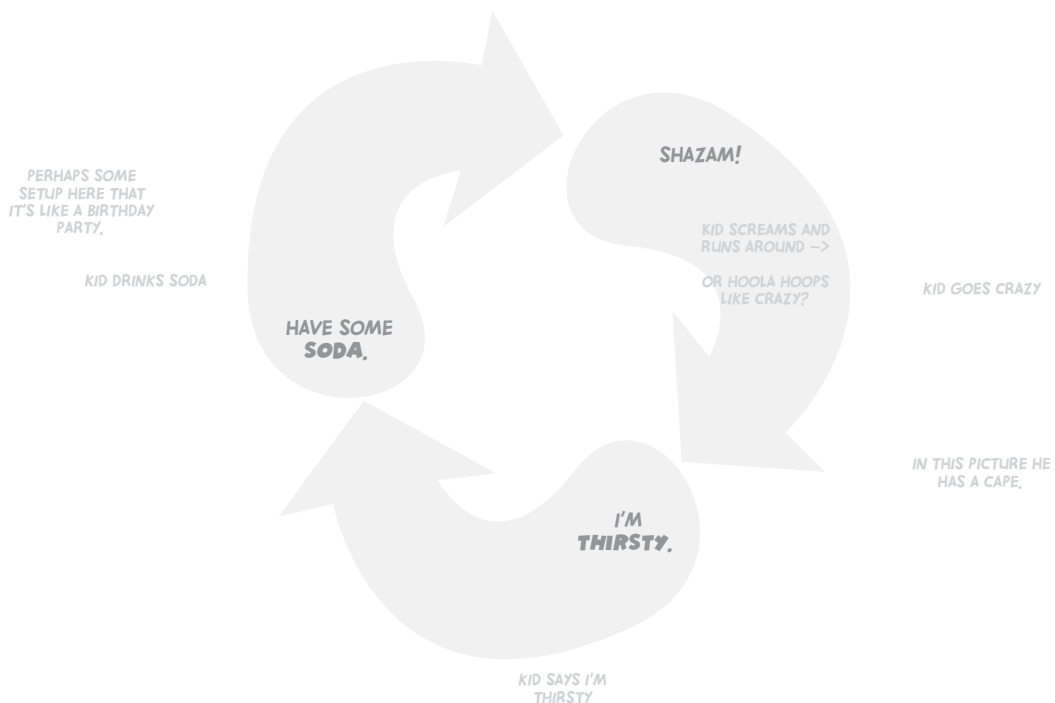
... SET THE **RHYTHM** FOR THE ICE AGES...

START ROCK BAND/ MARCHING BAND
ANALOGY HERE,

I'M THE PACEMAKER,

MM IS THE DRUMMER FOR THE BAND

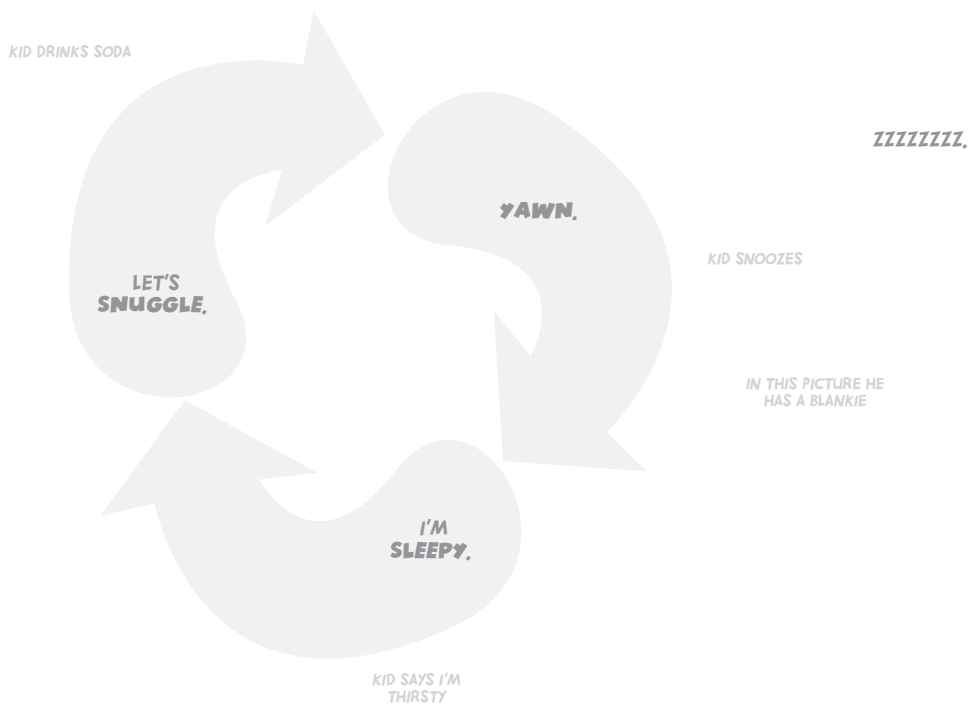
... BY TRIGGERING **POSITIVE FEEDBACK LOOPS,**



**SOMETIMES THOSE POSITIVE FEEDBACK LOOPS BRING THE EARTH
OUT OF AN ICE AGE...**

**I'M GOING
INTERGLACIAL!**

**...AND SOMETIMES THEY SEND US
BACK INTO ONE.**



LET'S SEE HOW IT WORKS IN CLOSER DETAIL.

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

FOR MORE DETAILS,
SEE **ICE AGES** IN
THE GLOSSARY...

...OR READ MY
626-PAGE BOOK!

MILANKOVITCH:

...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 THE MILANKOVITCH CYCLES ARE THINGS LIKE THE ALBEDO EFFECT...

ICE AND SNOW
REFLECT LOTS OF
SUNLIGHT BACK INTO
SPACE,

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

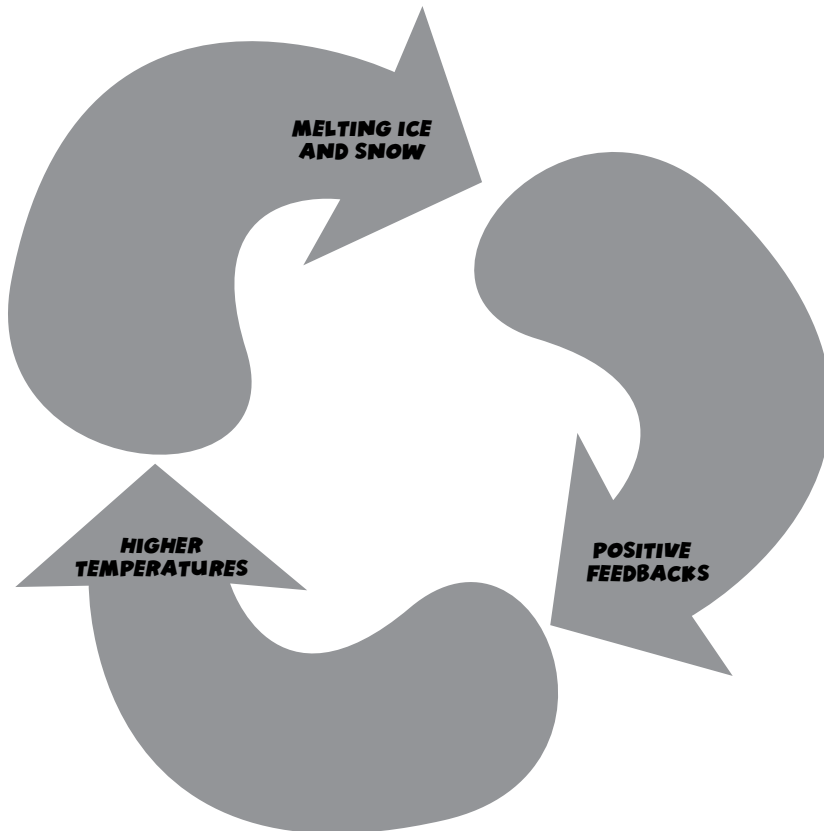
WITH FULL HEAD OF
HAIR!!!!:

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,

... AND OTHER POSITIVE FEEDBACK LOOPS.



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 UNIBROZ

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!

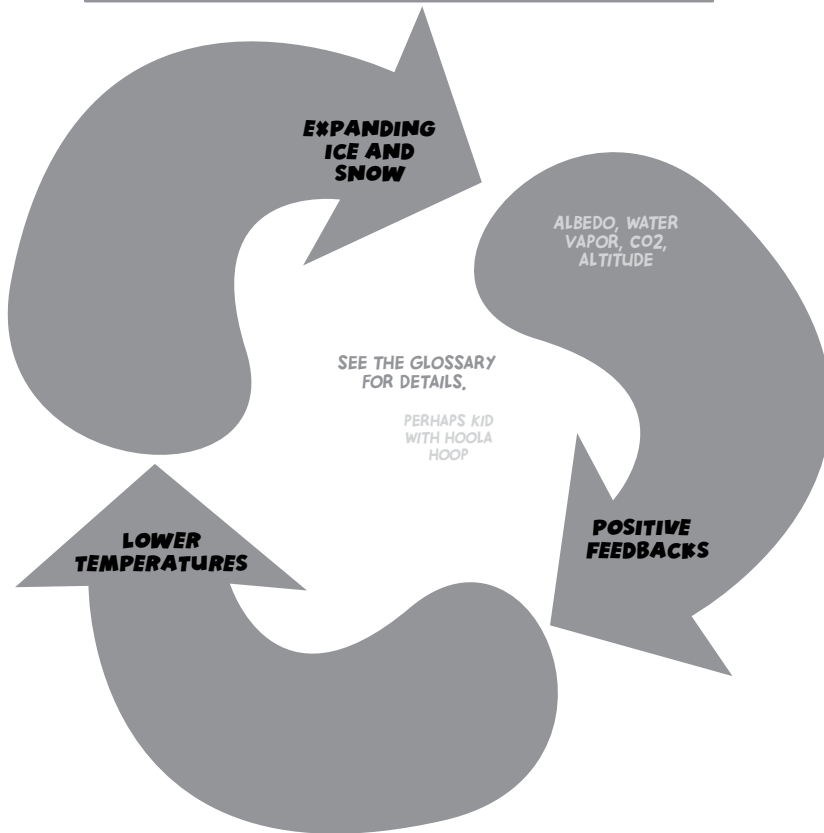
NOW THE **ALBEDO EFFECT** WORKS IN THE **OTHER DIRECTION...**

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??

I'M NOT SURE WHAT THIS "WHAT" IS
DOING HERE?

THE **ANSWER** IS THAT MOTHER NATURE **IS**
GEARING UP 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.

UM, ABOUT THAT
HEATING OIL...

SCIENTIST FROM
BEHIND THE TWO OF
THEM,

ROCK FAN

CHAPTER 4

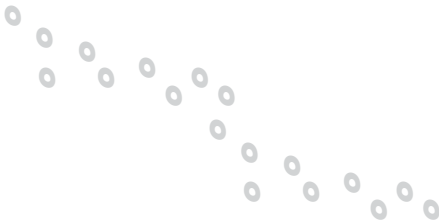
CARBON DIOXIDE

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

...AND ABOUT
4,000,000,000,000,000,000,000
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 **TINY AMOUNTS**, MEASURED IN **PARTS PER MILLION (PPM)**,
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:

WHAT'S THE
CO₂ DIFFERENCE
BETWEEN THESE
TWO SAMPLES?

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."

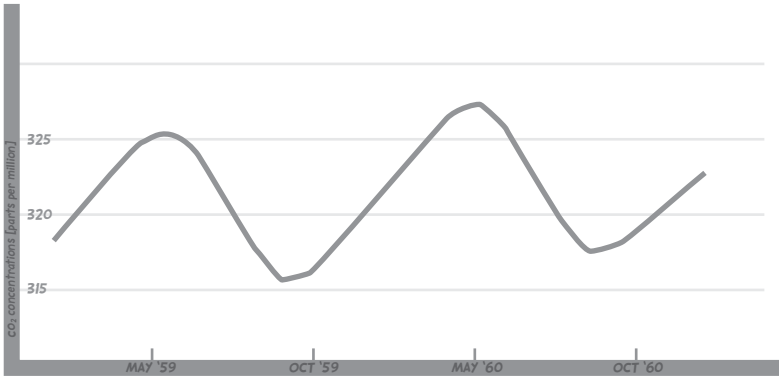
WEARING SNORKELING GEAR

... 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**...



LOOK AT
PAGE #!

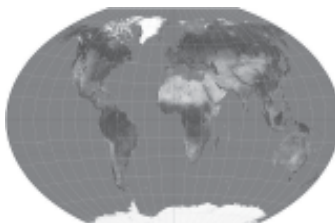
...AND TO THE **CARBON CYCLE**...



LOOK AT
PAGE 7!

...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,

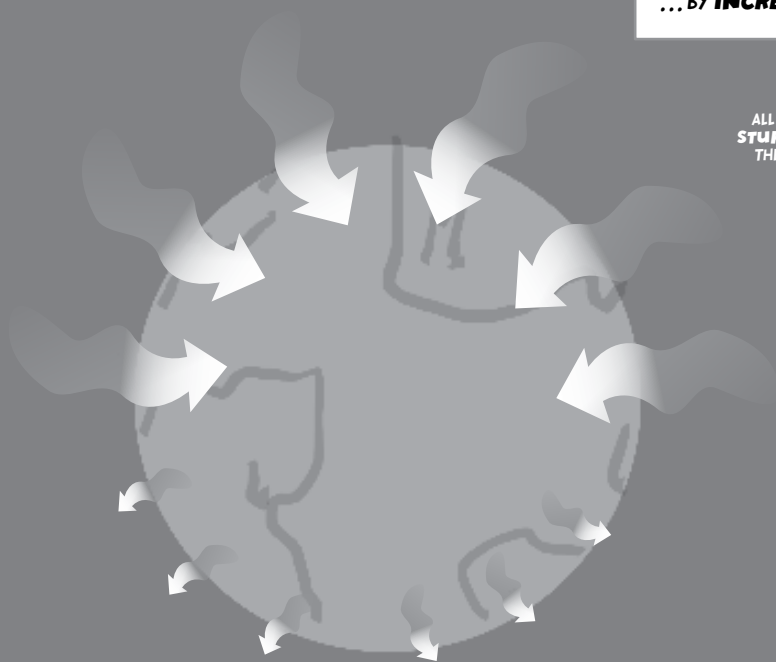


OF COURSE, WINTER
IN THE NORTH IS
**SUMMER IN THE
SOUTH...**

... 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...

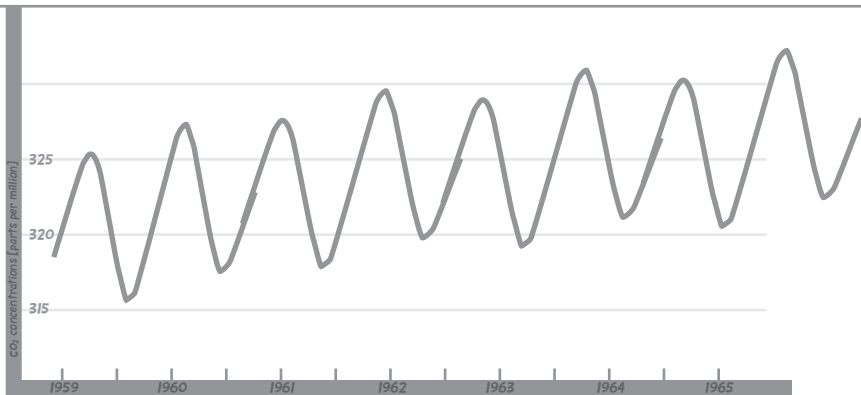
... BY **INCREASED PHOTOSYNTHESIS.**



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.

WHEN KEELING STARTED IN 1958, THE INCREASE WAS ABOUT **1 PART PER MILLION (PPM) PER YEAR**.

EVERY INCREASE OF **1 PPM** EQUALS **7.8 BILLION TONS** OF CO₂...

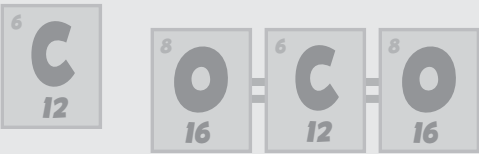
...OR **2.1 BILLION TONS** OF CARBON...

...BECAUSE THERE'S **1 TON** OF CARBON ATOMS...

HOLDING THIS UP,

...IN EVERY **3.67 TONS** OF CO₂ MOLECULES.

HOLDING THESE UP,



KEELING'S MEASUREMENTS CONTINUED FOR **YEARS** AND THEN **DECADES**, 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!**

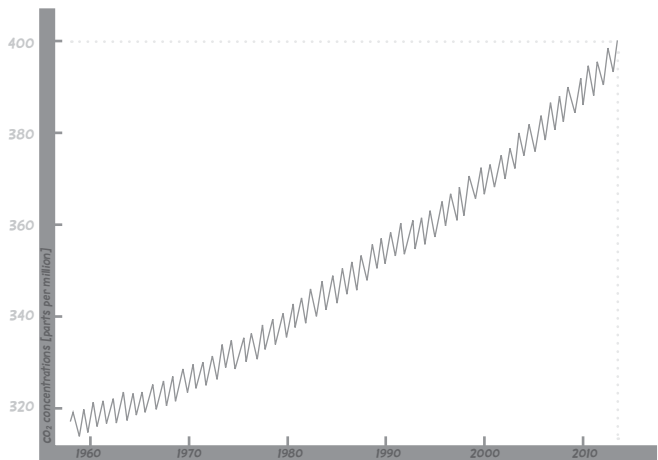
THIS TIME IT'S THE DAD IS GRANDPA AGE, THE SON IS DAD AGE, AND THE LINES ARE VIRTUALLY THE SAME:

SORRY, DAD, NOT NOW.

WITH SNORKLE AND FINS.

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

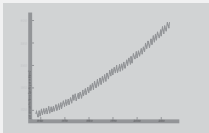
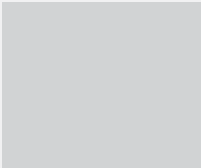
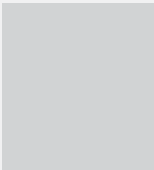
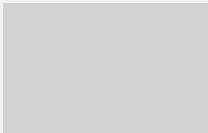
THE GRAPH OF THE DAILY MEASUREMENTS THAT THEY AND THEIR COLLEAGUES
HAVE MADE SINCE 1958 IS CALLED THE **KEELING CURVE**.



IN 2013, WE'RE AT **400 PPM**
AND INCREASING BY ABOUT
2 PPM PER YEAR.

I'D MUCH PREFER HAVING A CHARACTER
SAY THIS AND POINT WITH A STICK THAN
PUT THIS TEXT IN AN ARROW.

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

... AND ONE OF THE CENTRAL PIECES OF **EVIDENCE** IN THIS BOOK.

PERHAPS ENDING WITH A
FAVORITE ART CRITICISM
QUERY:

WHAT DOES IT
MEAN?

IT MEANS THAT
HUMAN ACTIVITY IS
CHANGING THE PLANET!

IN THE 19TH CENTURY THE MAJOR SOURCE OF HUMAN CO₂ EMISSIONS WAS **DEFORESTATION...**

CLEARING TREES TO MAKE ROOM FOR FARMS AND CITIES...

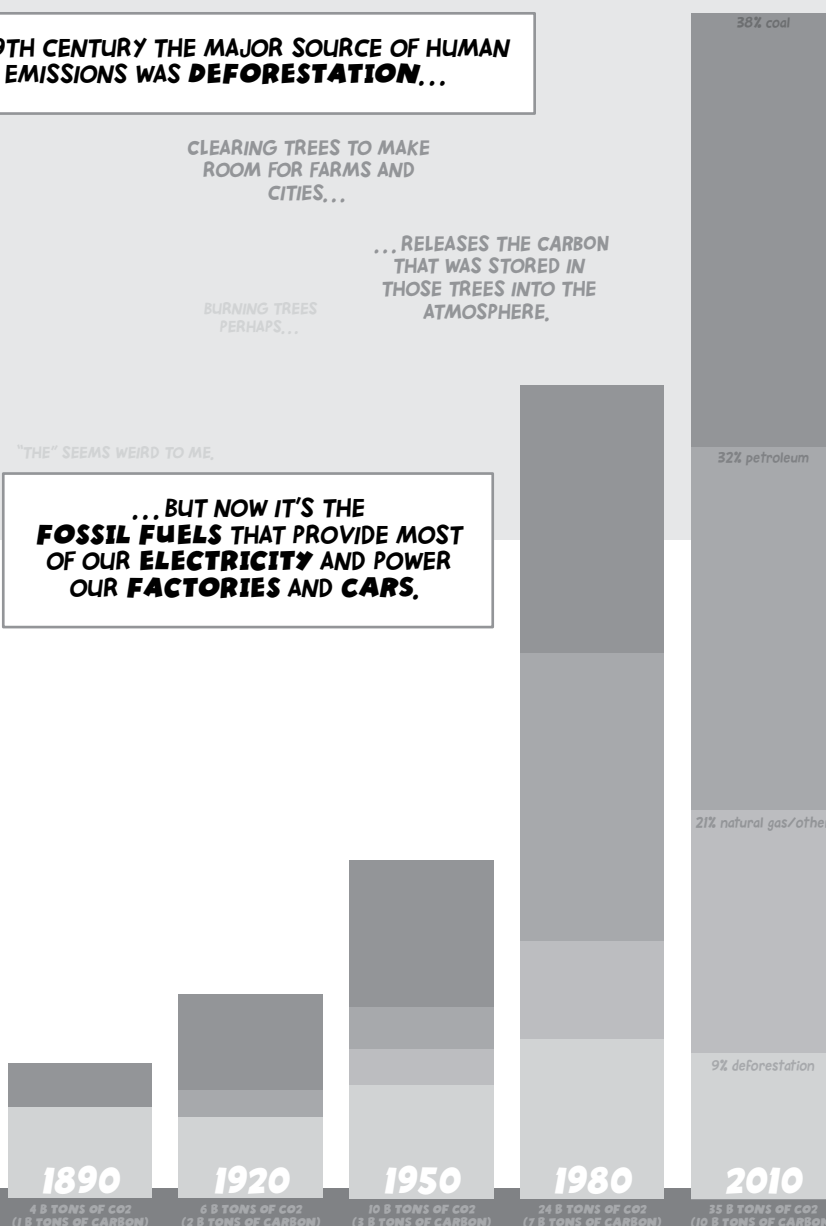
...RELEASES THE CARBON THAT WAS STORED IN THOSE TREES INTO THE ATMOSPHERE,

BURNING TREES PERHAPS...

SMOKE CONTINUES OVER HERE,

"THE" SEEMS WEIRD TO ME,

...BUT NOW IT'S THE **FOSSIL FUELS** THAT PROVIDE MOST OF OUR **ELECTRICITY** AND POWER OUR **FACTORIES** AND **CARS**.



BY 2010 WE WERE BURNING THROUGH 44,000 GALLONS OF PETROLEUM **EVERY SECOND**.

ABOUT **HALF** OF THAT EXTRA CO₂ GETS ABSORBED BY **PLANTS...**

FORESTS STILL COVER ABOUT 1/3 OF THE EARTH'S LAND,

WE'LL COME BACK TO THIS IN **CH 15**.

...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.

NOTE THAT IN SEPTEMBER WE NEED TO REVISIT THESE NUMBERS.

HERE'S HOW THE **CARBON CYCLE** IS AFFECTED BY
THE **10 BILLION TONS** OF CARBON EMITTED
BY HUMAN ACTIVITY **EACH YEAR**:

PLANES

ABOUT
4 BILLION TONS
REMAIN IN THE
ATMOSPHERE...

119.6
BILLION
TONS

122.6
BILLION
TONS

90.6
BILLION
TONS

92.2
BILLION
TONS

...ABOUT
3 BILLION TONS
ARE ADDED TO THE
OCEANS...

A FACTORY

SOME CARS

SHIPS

...AND ABOUT
3 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.

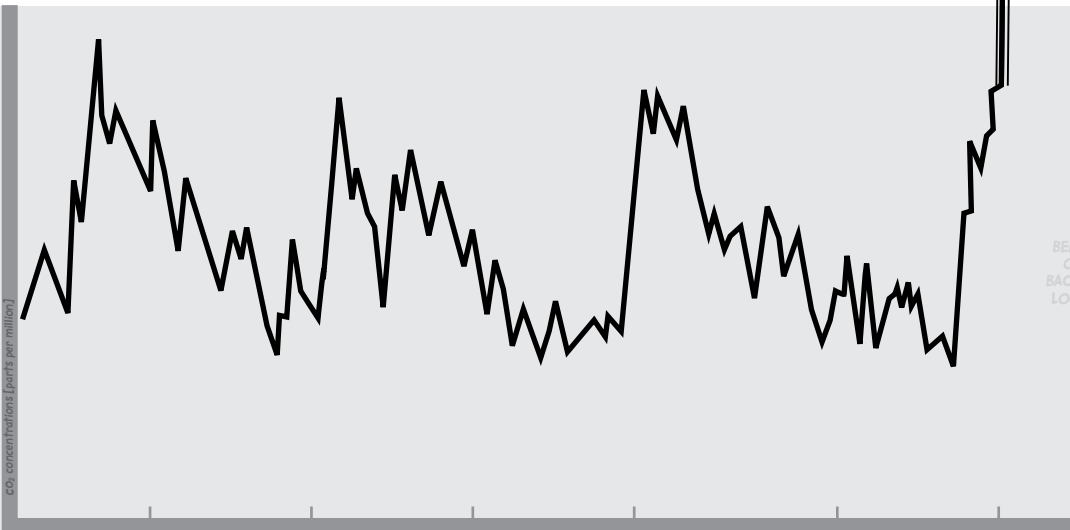
LITTLE CHARACTERS OR ARROWS CAN POINT THESE OUT:

≈1900: 300 PPM
≈2013: 400 PPM

400

300

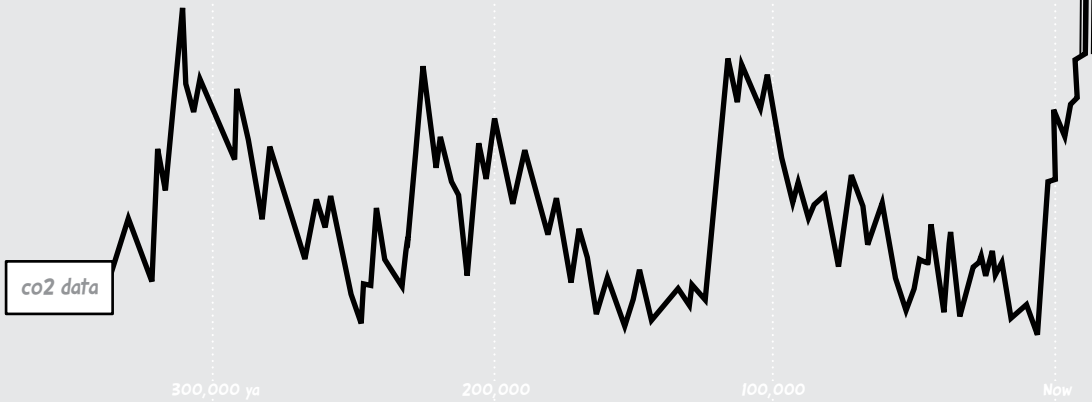
200



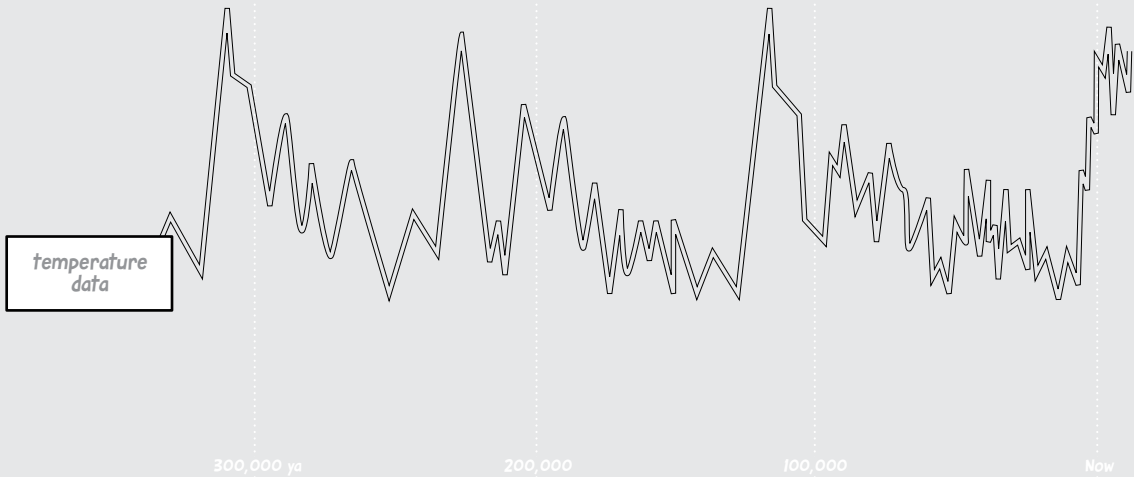
BENDING OVER BACKWARD LOOKING UP,

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.

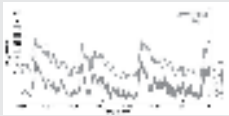


IT'S **OBVIOUS** THAT CO2 AND TEMPERATURE HAVE BEEN **CLOSELY RELATED**
FOR THE PAST 350,000 YEARS.

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** EXCEEDS **ENERGY OUT**, 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** EXCEEDS **ENERGY IN**, THE PLANET **COOLS DOWN**.

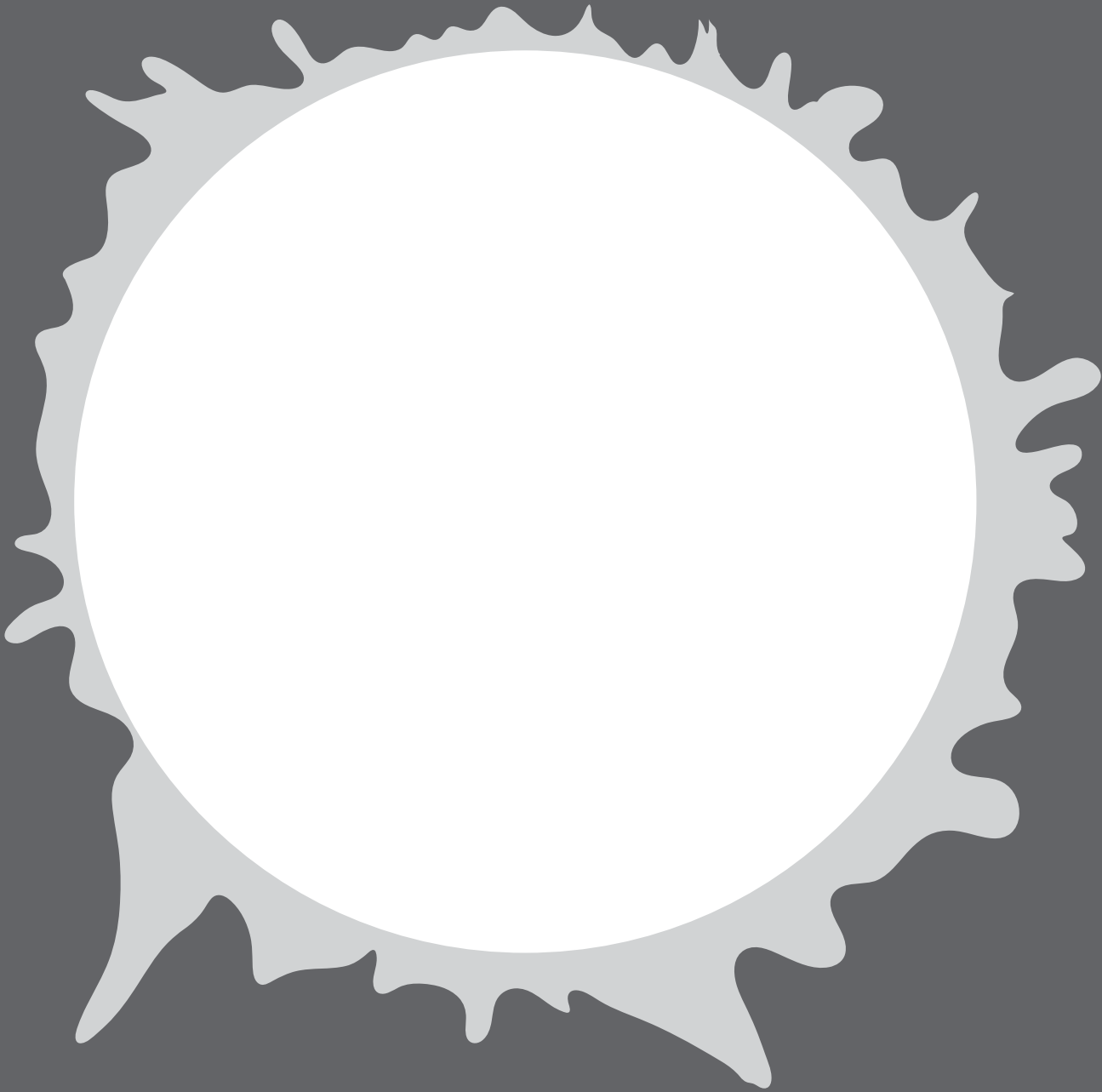
JUST LIKE YOUR HOUSE COOLS DOWN WHEN YOU OPEN A WINDOW,

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 YOU PICTURE
THE SUN AS A
BASKETBALL ON
ONE END OF A FULL-
SIZED COURT...

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

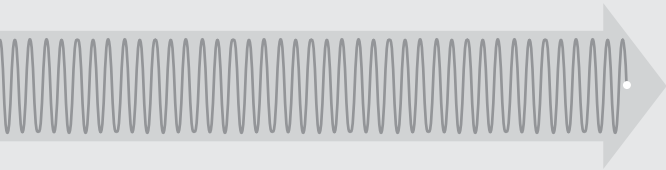
THE AMOUNT OF ENERGY
HITTING THE EARTH EACH
SECOND...

... 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.



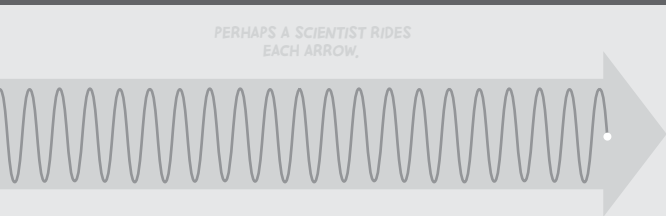
ENERGY FROM THE SUN INCLUDES **VISIBLE LIGHT**
AND OTHER TYPES OF **ELECTROMAGNETIC RADIATION**.



HIGH-ENERGY
ULTRAVIOLET
(**UV**) **RADIATION**
HAS VERY SHORT
WAVELENGTHS.

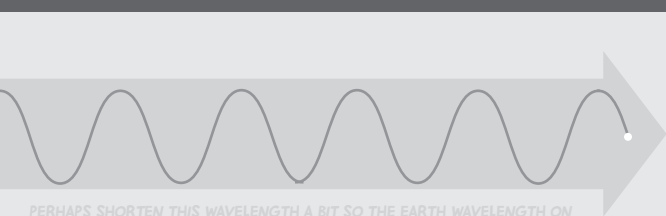
COULD DO A SILLY ICON OR
SUPERHERO FOR THE DIFFERENT
KINDS OF RADIATION.

IT'S PARTIALLY
BLOCKED BY THE
OZONE LAYER.



VISIBLE LIGHT
WAVELENGTHS
COVER THE WHOLE
RAINBOW...

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



LOW-ENERGY
INFRARED
RADIATION HAS
EVEN LONGER
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, FOR EXAMPLE, SOLAR ENERGY THAT IS **REFLECTED BACK INTO SPACE...**

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

IT'S THE
**ALBEDO
EFFECT!**

ABOUT **30%** 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**...

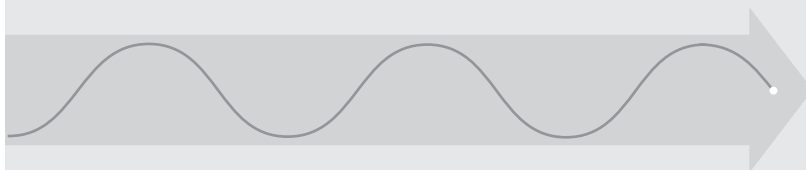
ASTRONAUT HERE



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

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

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 **THERMAL IMAGING** EQUIPMENT...

PLUMBER:
THERE'S A **LEAKY PIPE**
INSIDE THIS WALL...

POLICE OFFICER:
...AND A **MAN HIDING** IN YOUR
BASEMENT.

...OR HUDDLED NEAR A **HOT FIRE.**

YOU CAN'T **SEE**
INFRARED RADIATION,
BUT YOU CAN **FEEL** IT.

IN THE MORNING IT
WON'T BE **RED HOT**
ANYMORE...

...BUT IT WILL STILL BE
INFRARED HOT.

TELLING THIS
LIKE A GHOST
STORY

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

WATER VAPOR (H_2O)



CARBON DIOXIDE (CO_2)



METHANE (CH_4),



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!

A **GREENHOUSE** ALSO WORKS
BY **REDUCING ENERGY OUT.**

SEE THE GLOSSARY
FOR DETAILS.

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 **-18°C (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
(462°C, 863°F) 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 5°C
(9°F).**

[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 2–4°C
(3.6–7.2°F).**

CHAPTER 6

SCIENCE

WHY SHOULD I
TRUST ~~you~~?

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

DON'T TRUST US.

THIS COULD BE THE DETECTIVE'S
LINE, IF HE'S A BIT SHADY.

(CLIMATE SCIENTIST FROM
THE BOTTOM OF PREVIOUS
PAGE):

**TRUST THE
SCIENTIFIC
METHOD.**

NANCY DREW, SHERLOCK HOLMES, POLICE DETECTIVES, THAT SORT OF THING, WE
COULD POTENTIALLY INTRODUCE THIS THEME ON THE INTRO PAGE OF THE CHAPTER,

DEPENDS ON HOW THE DRAWING GOES, MAYBE A CHARACTER WILL POP OUT.

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 THEN **REFINING** THEM **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'S THEORY
WORKS BETTER THAN
NEWTON'S.

THIS PROCESS NEVER ENDS...

EVEN **EINSTEIN** COULDN'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, 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 REMAINS ONE OF HUMANITY'S
MOST POWERFUL INVENTIONS**

(JUMPER2):

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

THE IDEAL WAY TO **TEST A HYPOTHESIS**
IS WITH A **CONTROLLED E*PERIMENT...**

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 **CHILLAXITROL** 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
E*PERIMENTS** 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...

... AND 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**,

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)

SOME OF THE **BEST EVIDENCE** COMES FROM
CLIMATE SCIENTISTS' **SUCCESSFUL PREDICTIONS** FROM DECADES PAST.

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

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

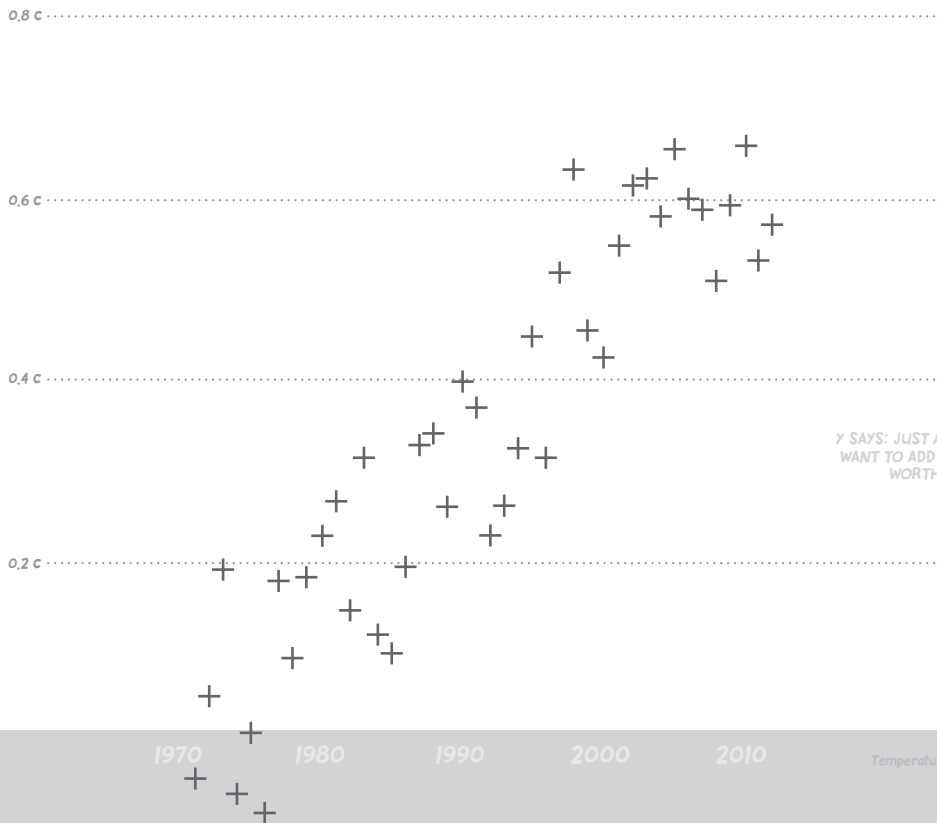
...BUT OUR
PREDICTIONS
WERE **GREAT**.

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

SINCE THE 1970S, GLOBAL TEMPERATURE INCREASES HAVE
AVERAGED ABOUT **0.15C (0.3F)** PER DECADE.

WE PREDICTED
0.2C (0.4F)...

...NOT BAD!



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

SCIENTIST FANNING SELF AND SWEATING.

THE COOK HAD ACCESS TO THE MURDER
WEAPON.

D2: EVERYONE KNEW SHE HATED HIM,

(ALT: SHE WAS ALWAYS TALKING ABOUT HOW
MUCH SHE LOATHED/HATED HIM,)

D3: NOBODY ELSE WAS IN THE KITCHEN THAT
MORNING,

D4 (OPTIONAL, BY THE COOK): IT WASN'T
ME, IT WAS QUEEN VICTORIA,

... 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,

OLD BRAINSTORMS:

SOMETHING FUNNY LIKE,

MORE WARMING ON MY HAIRY
HEAD...

THAN ON MY BALD ONE?

OR A GAG ABOUT THEIR FASHION,

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

YUP,

THOSE DETAILS ARE LIKE **FINGERPRINTS** AT A **CRIME SCENE.**

THIS HAS GOT
ANTHROPOGENIC
GLOBAL WARMING
WRITTEN ALL OVER IT,

D (DETECTIVE):

PEERING AT A
THERMOMETER
PERHAPS?

OR MAYBE STANDING
ON A BLOCK OF ICE
FLOATING IN THE SEA
AND EXAMINING IT
WITH A MAGNIFYING
GLASS,

DETECTIVE WORK IS ACTUALLY
A PRETTY GOOD ANALOGY...

UP HERE,

THE CONCLUSION IS
INESCAPABLE,

IT WASN'T ME,
IT WAS **QUEEN
VICTORIA**,

ONLY ONE PERSON
HATES THE BUTLER...

... **AND** HAS KEYS
TO THE KITCHEN...

... **AND** KNOWS HOW
TO MAKE A SOUP THIS
DELICIOUS,

FOOTMAN HERE,
OBSERVING THE
LEGS OF THE
BUTLER, WHICH ARE
STICKING UP OUT
OF A POT,

DEAD BUTLER HERE, HIS FEET STICK
OUT OF A POT,

DETECTIVE, PULLS A LADLE
OUT OF THE POT AND
TASTES IT...

COOK HERE,

ALT:

TURKEY DEATH
... **AND** KNOWS HOW TO
TRUSS A TURKEY,

... **AND 100 YEARS OF SCIENTIFIC DETECTIVE WORK HAS CONVINCED MOST SCIENTISTS
THAT GREENHOUSE GAS EMISSIONS ARE WARMING THE PLANET.**

WE'RE
CONVINCED.

WE'RE **NOT.**

2 MICROPHONES HERE, THERE'S AN INCREDIBLE LINE OF LAB COATED SCIENTISTS BEHIND ONE
MICROPHONE AND THERE'S TWO SCIENTISTS BEHIND THE OTHER MICROPHONE,

THIS ON JACKETS

IPCC
AAAS
AMS
ACS
ASA

THIS ON JACKET
NIPCC

THIS ON SIGN IN FRONT OF
CHARACTERS WITH DISTINCTIVE DRESS:

National Academies of Sciences

IPCC = INTERGOVERNMENT PANEL ON CLIMATE CHANGE; AAAS = AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE; AMS = AMERICAN METEOROLOGICAL SOCIETY; ACS = AMERICAN CHEMICAL SOCIETY;
ASA = AMERICAN STATISTICAL ASSOCIATION; NIPCC = NONGOVERNMENTAL INTERNATIONAL PANEL ON CLIMATE CHANGE

INCLUDES THE NATIONAL ACADEMIES OF THE U.S., BRAZIL, CANADA, CHINA, FRANCE, GERMANY, INDIA, ITALY, JAPAN, RUSSIA, THE U.K., AUSTRALIA, BELGIUM, THE CARRIBEAN, INDONESIA, IRELAND, MALASIA, NEW ZEALAND, SWEDEN.

OF COURSE, IT'S ALWAYS POSSIBLE THAT ALL THOSE SCIENTISTS ARE **WRONG**.

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

...AND SO IS **LUNG CANCER**.

IN A BAR, WITH DRINKS IN FRONT OF THEM,

SMOKING

AND THE KILLER REALLY WAS **QUEEN VICTORIA!**

DETECTIVE AT THE SAME BAR, PERHAPS WITH QUEEN VICTORIA IN HANDCUFFS, BUT I DOUBT IT.

BUT SO FAR **NOBODY** HAS BEEN ABLE TO IDENTIFY A **GOOD COMPETING THEORY** FOR GLOBAL WARMING...

IS IT CAUSED BY **SUNSPOTS?**

NO.

EL NINO?

NO.

MILANKOVITCH CYCLES?

NO.

BROCCOLI?

WHA?

GO THROUGH SOME OF THE COMPETING THEORIES:

KIDS

DETECTIVE CHARACTER INVOLVED HERE.

...AND THE CASE FOR **ANTHROPOGENIC CLIMATE CHANGE** HAS GOTTEN **STRONGER AND STRONGER**.

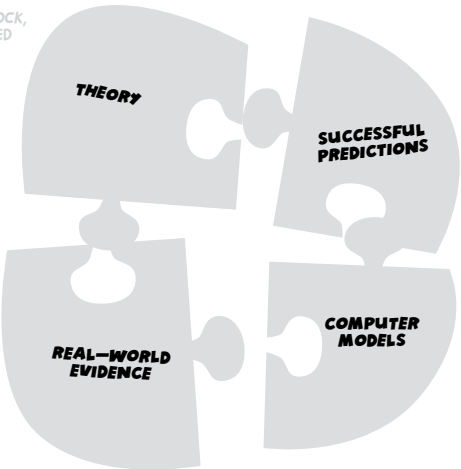
I'LL DRAW THIS BY HAND, AND THE PIECES WILL INTERLOCK, WITH THE REAL WORLD EVIDENCE PIECE BEING PLACED DOWN WITH THE OTHERS.

D (DETECTIVE):

IT'S ALL **COMING TOGETHER**.

I CAN DEFINITELY HAVE THE PIECES BLEED OFF THE PAGE, AND HAVE LOTS MORE OF THEM.

THAT'S DRAWING HEAVY WORK, SO I'LL POSTPONE IT.



**MOST GLOBAL WARMING DATA IS
GATHERED BY SCIENTISTS...**

FROM SPACE,

I'LL DRAW A SATELLITE HERE

IN THE OCEANS,

I'LL DRAW AN OCEAN BOAT
HERE

ON LAND,

I'LL DRAW A SCIENTIST
STANDING ON LAND AND
DRILLING INTO A GLACIER
HERE,

**... BUT IN FACT, THERE'S EVIDENCE OF GLOBAL
WARMING ALL AROUND US.**

**FLOWERS ARE
BLOOMING
EARLIER.**

**BIRDS ARE
MIGRATING
EARLIER.**

**ALLERGY SEASON
IS STARTING
EARLIER.**

THIS IS THE SAME
GRANDPARENT IN THE PANEL
BELOW,

MAN WITH HUGE BOX OF
KLEENEX AND KLEENEXES ALL
OVER THE GROUND,

**YOU MIGHT EVEN FIND PHENOLOGICAL EVIDENCE IN
YOUR OWN BACKYARD.**

**A PIED FLYCATCHER,
AND IT'S ONLY APRIL 10!**

[OR YB COULD FIND AN
ACCURATE DATE HERE,]

**SOME BIRDS HAVE
A NATURAL INSTINCT
TO MIGRATE...**

AND THEN A SCIENTIST STUDYING THE
HUMANS:

**...AND SOME HUMANS
HAVE A NATURAL INSTINCT
TO KEEP RECORDS.**

ONE GRANDPARENT
BIRDWATCHER

HER HUSBAND,

THIS ON A PIN OR A BUMPER
STICKER OR SOMETHING,

THESE DAYS, MUCH OF WHAT WE KNOW ABOUT CLIMATE CHANGE
IS INCORPORATED INTO **COMPUTER MODELS...**

I LOVE THIS:

ANOTHER FUN BRAINSTORM HERE COULD BE A BIG SIPHON CONNECTED TO AN ELECTRICAL CABLE, I.E., WE'RE TAKING THE BIRDS AND THE ICE SHEETS AND THE THEORETICAL EQUATIONS AND THE MILANKOVITCH CYCLES AND STUFFING THEM ALL INTO THIS GRINDER THAT IS CONNECTED TO A COMPUTER, AND THEN MAYBE WE COULD MOVE THE "OVERHEATED COMPUTER SHOWING AN OVERHEATED PLANET" IDEA DOWN TO THE BOTTOM OF THE PAGE.

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.**

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

VOLCANO HERE.

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

THE COMPUTER IS GETTING OVERHEATED HERE... PERHAPS A CHARACTER SAYS, *****\$&**

" YORAM PREFERS SOMETHING MORE NEUTRAL LIKE: **HEADS UP!**

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

**PART
TWO**
PREDICTIONS

CHAPTER 7

GLOBAL WARMING

NIX THESE DS; WE'LL HAVE TO COME UP WITH SOME OTHER OPENING GAG.
MAYBE THE 5 CHARACTERS ARE IN A TRAIN AND THEY'RE SHOVELING COAL
INTO THE ENGINE AND SWEATING AND SAYING

IS IT JUST ME... OR IS IT GETTING **HOT IN HERE?!**

PS, I VOTE NO ON TWO OF THE NOTES BELOW: I DON'T THINK WE SHOULD CALL
THE TRAIN BAU, AND I'M NOT KEEN ON THE TIED-TO-THE-TRACKS IDEA. (TOO
FATALISTIC IMHO.)

A TRAIN COMING DOWN THE TRACKS, LETTING OUT STEAM

NOW THAT WE'VE COVERED THE
BASIC SCIENCE OF CLIMATE CHANGE...

... LET'S TAKE A LOOK AT **WHAT MIGHT HAPPEN.**

THESE TWO PANELS COULD FEATURE A
SCIENTIST LOOKING INTO A MICROSCOPE ON
THE LEFT AND A SCIENTIST LOOKING INTO A
CRYSTAL BALL ON THE RIGHT.

THEN IN PART III WE'LL
LOOK AT **WHAT WE
CAN DO ABOUT IT.**

OF COURSE, LOTS OF THINGS **COULD**
HAPPEN IN THIS CENTURY AND BEYOND.

WE COULD DEVELOP
COLD FUSION...

...OR **CARBON-EATING
TREES...**

...OR **FLYING
WINDMILLS...**

...OR **PERPETUAL
MOTION MACHINES!**

ASIDE, WHISPERED:

ACTUALLY, THAT ONE
COULDN'T HAPPEN;
IT'S **IMPOSSIBLE.**

ONE **VERY UNLIKELY** POSSIBILITY IS THAT HUMAN CARBON EMISSIONS WILL STOP **COLD TURKEY**.

YOU CAN IGNORE THIS COMMENT IF YOU WANT, BUT I'M GOING TO GIVE CONTINUAL PUSH-BACK ABOUT ASSOCIATING HUMAN CARBON EMISSIONS WITH DRIVING AND GASOLINE. THAT'S WHAT EVERYBODY THINKS, BUT IT'S MUCH MORE ABOUT COAL AND ELECTRICITY.

SO IF I HAD MY DRUTHERS THIS WOULD BE A SCENE INSIDE A HOUSE, WITH ALIENS TELLING PEOPLE TO SHUT EVERYTHING DOWN, AND MAYBE THERE'S A WINDOW AND THROUGH THE WINDOW YOU CAN SEE A CAR AND AN ALIEN JUMPING ON THE HOOD OR PULLING PEOPLE OUT OF THE CAR OR STANDING IN FRONT OF THE CAR WITH A STOP SIGN OR SOMETHING ELSE FUN :) AND/OR MAYBE THEY'RE PUTTING A COVER ON A POWER PLANT EXHAUST STACK :)

YORAM, I'M THE ONE ARGUING TO TO ATTACH HUMAN EMISSIONS WITH COAL AND ELECTRICITY, (ALL SORTS OF DAY TO DAY ACTIVITIES), SO YOU DON'T GET TO ARGUE FOR IT :-)

THAT'S IT,
PARTY'S OVER.

SHUT EVERYTHING DOWN
RIGHT NOW.

A **MUCH MORE LIKELY** POSSIBILITY IS THAT **DEVELOPING COUNTRIES** LIKE CHINA AND INDIA WILL FOLLOW THE PATH BLAZED BY **DEVELOPED COUNTRIES** LIKE THE U. S.

FOSSIL FUELS TO POWER
HOMES, FACTORIES, AND
MOTOR VEHICLES...

...AND **DEFORESTATION**
TO CLEAR LAND FOR FARMS,
ROADS, AND BUILDINGS.

WE CALL THIS PATH **BUSINESS AS USUAL.**

WHAT IF WE **DIDN'T**
DO MUCH TO REDUCE
CARBON EMISSIONS?

THAT WOULD BE
BUSINESS AS
USUAL.

THE KEY FACT ABOUT
BUSINESS AS USUAL
IS THAT IT WOULD MAKE
CO2 EMISSIONS **EXPLODE**.

MAYBE AN OVERLOADED 3RD WORLD TYPE TRUCK DRIVES ONTO THE
PANEL AT THE LEFT AND THEN RIGHT ABOUT HERE EXPLODES, SENDING
THE PASSENGERS FLYING AROUND?

OR SOME OTHER SILLY AND SIMPLE EXPLOSION.

THE TRUCK COULD FIRST APPEAR ON THE PREVIOUS PAGE.

ALTERNATELY, A BOMB IS LIT ON THE PREVIOUS PAGE, OR SOMETHING
ELSE THAT'S SENSITIVE TO HUMAN LIFE :-)

TO SEE WHY, LET'S DIVIDE THE WORLD'S 7 BILLION PEOPLE INTO
FIVE CHINA—SIZED CHUNKS.

SITTING DOWN TO A TABLE, WITH PLACECARDS THAT
SAY:

RICH WORLD
CHINA
INDIA
REST OF ASIA
EVERYONE ELSE

1.4 BILLION
NAPKINS, PLEASE.

MAITRE D TO WAITER.

THE RICH WORLD MAKES UP **JUST ONE** OF THOSE FIVE CHINAS...

5 TABLES HERE, WITH THE RICH WORLD HIGHLIGHTED
SOMEHOW... THIS IS JUST A SETUP FOR THE NEXT
PANEL'S WONDERFUL GAG.

... BUT AT THE START OF THE 21ST CENTURY IT WAS RESPONSIBLE FOR ABOUT
HALF OF THE WORLD'S FOSSIL FUEL CONSUMPTION.

ONE CAKE IN FRONT OF THE RICH, AND ONE CAKE IN FRONT OF THE
REST,... A WHOLE CAKE, IN THE PROCESS OF BEING DELIVERED.)

Y FEELS IT'S IMPORTANT THAT THE WAITER SAYS THIS LINE:

ONE CAKE FOR
you...

... YOU ALL CAN **SHARE**
THE SECOND CAKE.

UNDER BUSINESS AS USUAL, THE OTHER FOUR
CHINAS COULD **CATCH UP BY 2100.**

THANKS TO RAPID
ECONOMIC GROWTH...

... WE CAN NOW AFFORD
MORE CAKE!

D (MAYBE
WAITER?):

**THAT'S 150%
MORE CAKE.**

A BAKER DELIVERS 3 MORE CAKES FOR A TOTAL OF 5 AT THE TABLE,
IE, WE USED TO HAVE 2 CAKES, NOW WE HAVE FIVE.

**MEANWHILE, POPULATION GROWTH IS LIKELY TO
ADD ANOTHER 2 CHINAS TO THE PLANET.**

WE'RE GOING TO
NEED **TWO MORE**
PLACE SETTINGS,

**NOW IT'S 250%
MORE CAKE.**

A BAKER DELIVERS 2 MORE CAKES FOR A
TOTAL OF 7 IN THIS PANEL,

TWO MORE DINERS, WAITER PUTS IN FRONT OF THEM TWO
MORE PLACECARDS THAT SAY:

AFRICA

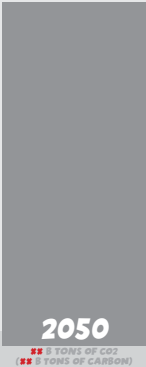
AND

MORE ASIA

SURE ENOUGH, **BUSINESS AS USUAL** EMISSIONS ARE PROJECTED TO RISE ABOUT **250%** OVER THE COURSE OF THIS CENTURY...

THE CHINA CHARACTERS ARE DRIVING CARS, AND USING THE DISHWASHER AND ETC,

PERHAPS CONTRIVE A WAY TO TIE THESE IN WITH THE GRAPHS ON CHAPTER 4 PAGE 8... MAYBE THE BEST WAY TO DO THAT IS JUST WITH A DRAWING,



... PUSHING ATMOSPHERIC CO₂ CONCENTRATIONS UP NEAR **1000 PPM**.

PERHAPS THERE'S A PLANE ZOOMING UP HERE, JUST FOR FUN

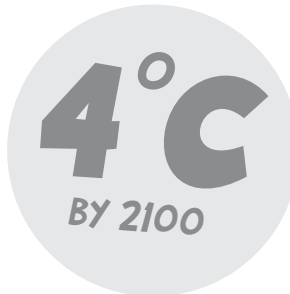
CO₂ CONCENTRATIONS HAVEN'T BEEN THAT HIGH FOR **MILLIONS OF YEARS**.

ONE OF THE SCIENTISTS UNDERNEATH, LYING ON THEIR STOMACH ON THE GRASS OR WHATEVER, USING BINOCULARS TO LOOK TO THE LEFT (I.E., IN THE DIRECTION OF MILLIONS OF YEARS AGO).

WORDSMITH, I DON'T LIKE THIS ASSIVE LANGUAGE. HOW ABOUT SOMETHING LIKE "AS A RESULT, BY 2100, GLOBAL TEMPERATURES WILL LIKELY BE ABOUT 4C HIGHER," OR:
"WHICH MEANS WE SHOULD EXPECT GLOBAL TEMPERATURES TO RISE ABOUT 4C IN THE NEXT CENTURY.

**THE RESULTING GLOBAL TEMPERATURE CHANGE BY 2100
IS LIKELY TO BE ABOUT 4C (7F).**

FORTUNE TELLER IMAGE HERE, RECALLS
PICTURE AT THE TOP OF CHAPTER I



I WONDER IF THERE'S SOME WAY TO USE THE CRYSTAL
BALL A BIT MORE CLEVERLY HERE, WITH A DRAWING
INSIDE IT OF PEOPLE SWEATING OR SOMETHING. ...
ON THE OTHER HAND WE WANT TO USE THE NUMBER
TO GOOD EFFECT TOO, SO I'LL PLAN TO PLAY AROUND
WITH IT IN LAYOUTS.

ALT; THEY COULD RISE A BIT LESS... OR A BIT MORE...

IT COULD BE A BIT LESS...

FORTUNE TELLER WAFFLES HERE,

**MAYBE ONE
DEGREE LESS.**

...IT COULD BE MORE...

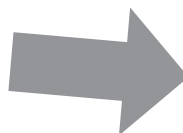
**MAYBE AS MUCH AS
TWO OR THREE
DEGREES MORE.**

MEH,

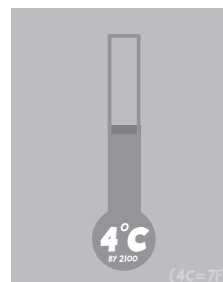
**WE'LL COME BACK
TO UNCERTAINTY
IN CHAPTER II.**

**... BUT THIS NUMBER MAKES A GOOD STARTING POINT FOR
UNDERSTANDING THE CHANGES THAT ARE COMING.**

THREE SCIENTISTS HOLD THESE THREE THINGS.



THEN ON THE SPREAD AFTER NEXT, THIS CAN
TURN OUT TO BE A BOOK,



MAYBE USE THE
THERMOMETER IMAGE
IN THE PICTURES
SOMEWHERE, PERHAPS
HERE,

IT MIGHT BE TEMPTING TO THINK OF **4C**
AS **NO BIG DEAL...**

WINTERS WILL BE A BIT WARMER,
SO I'LL **PAY LESS** FOR
HEATING...

... AND SUMMERS WILL
BE A BIT WARMER, SO I'LL
PAY MORE FOR AIR
CONDITIONING.

WHY ALL THE
FUSS?

... OR, ALTERNATELY, AS A **BIG BIG DEAL...**

IN MOST PLACES, THE
AVERAGE SUMMER IN 2100...

... WILL BE **HOTTER THAN THE
HOTTEST SUMMER OF THE
20TH CENTURY.**

... BUT NEITHER OF THESE IS THE **BEST WAY TO THINK ABOUT IT.**

THE TWO PEOPLE FROM THE FRAMES ABOVE
(PRESUMABLY A SKEPTIC-ISH PERSON
AND AN ALARMIST-ISH PERSON) BEING
QUIZZICAL:

HUH?

HOW ABOUT IN THIS FRAME THE NARRATOR
SCIENTIST PREPARES TO OPEN IT...

4°C
BY 2100

THE **BEST** WAY TO THINK ABOUT 4C IS AS A KIND OF **SHORTHAND**.

IT'S LIKE THE **TITLE**
OF A BOOK...

...AND YOU SHOULD BE
CAREFUL ABOUT **JUDGING A**
BOOK BY ITS COVER.



BOOK WITH 4 ON IT.

THERE ARE LOTS OF OTHER
CLIMATE-RELATED SHORTHANDS...

TITLES ON SPINES:

350 PPM
600PPM
1000 PPM
RCP 2,6
RCP 4,5
RCP 6,0
RCP 8,5
COLD TURKEY
WARM TURKEY
GOOSE EGG
CHICKEN LITTLE
FOWL WEATHER (!)

...AND ALL OF THEM ATTEMPT TO SUMMARIZE
LOTS OF DIFFERENT CHANGES IN LOTS OF DIFFERENT PLACES.

READ ME THE CHAPTER
ABOUT **SEA LEVEL**
RISE IN ASIA.

ONE CHAPTER A NIGHT AND
WE'LL BE DONE BY THE TIME
YOU **GO TO COLLEGE.**



BOOK WITH 4 ON IT.

PARENT READING
TO SMALL CHILD AT
NIGHT TIME;

OPENING UP THE
BOOK HERE.

FOR EXAMPLE, A GLOBAL INCREASE
OF 4C (7F) WOULD LIKELY WARM
OCEANS BY ONLY 3C (5F)...

...**LAND AREAS** BY AN AVERAGE OF 5C (9F)...

PERSON SWIMMING IN THE
OCEAN,

SAME PERSON GETTING OUT OF
THE OCEAN WALKING ON THE
BEACH, SAYING:

OUCH OUCH OUCH OUCH,

... AND THE **ARCTIC** BY A WHOPPING 8C (15F).

**LESS ICE MEANS
LESS REFLECTION
OF SOLAR ENERGY.**

**IT'S THE ALBEDO
EFFECT!**

ALBEDO GUY REAPPEARS HERE

AND THAT'S JUST THE **TIP OF THE ICEBERG.**

Welcome to the **Arctic Circle**

an emerging epicenter of industry and trade
akin to the Mediterranean Sea.

IMHO WE CAN CUT THIS, HERE, WE'LL MAKE SURE TO BALANCE GOOD AND BAD
ELSEWHERE. THE POINT IS THERE ARE BIG CHANGES ALL OVER THE PLACE, AND
BESIDES, NO MORE ICEBERGS ISN'T NECESSARILY INTRINSICALLY BAD

DRAWING OF THE TITANIC SAILING COMFORTABLY

BOAT SAYS "TITANIC 2"

Well, there
**USED TO BE
ICEBERGS**
here.

THE FACT IS, A GLOBAL
INCREASE OF 4C (7F)
WOULD **TRANSFORM THE
ENTIRE WORLD...**

Welcome to
the **FERTILE
FARMLAND** of
BANGLADESH.

Well, there
**USED TO BE
FARMLAND**
here.

SCIENTISTS KNOW...

I LIKE THE SPIRIT OF THIS ONE A LOT, BUT I
WONDER IF IT NEEDS SOME WORDSMITHING.

... YOU GET MORE **FOREST FIRES**
WHEN IT'S **HOT AND DRY.**

The World's Deserts

WORLD MAP

HMMMM... LET'S TWEAK THIS OR THE FOREST
FIRE ONE...

NOW EVEN **BIGGER AND DRIER!**

Swim the
**GREAT
BARRIER
REEF.**

HURRY, THE OFFER
ENDS SOON!

Goodbye **FROSTBITE.**

... hello **HEATSTROKE.**

Greetings from
MINNESOTA...

... where winters **don't suck anymore!**

When it
comes to
Latitude,
50 is the
new 40.

Monsoons...

... JUST GOT **Monsoonier.**

SIBERIA

MAYBE: PRIME
FARMLAND FOR SALE

THE NEW
**AGRICULTURAL
HEARTLAND.**

... BECAUSE WHEN
THE CLIMATE CHANGES,
EVERYTHING CHANGES.

Y NOTE:

JUST A NOTE HERE THAT THE NEXT PAGE (INTRO TO THE WATER CHAPTER) ALSO HAS BREATHING SPACE AND OPPORTUNITIES FOR INTERESTING PICTURES, SO WE MIGHT NEED TO THINK ABOUT THE 2 OF THEM TOGETHER. AND MAYBE WE CAN EVEN COMBINE THEM IN SOME FUN WAY, E.G., THE WAVE IS ON THE LHS WITH ONE SCIENTIST ON IT AND THE OTHER SCIENTISTS ARE ON THE BEACH ON THE RHS? MAYBE THERE'S A RAINSTORM IN THE BACKGROUND? (SEE NOTES FOR THE NEXT CHAPTER, WHICH COVERS WATER/ICE/VAPOR, ABOUT HOW IT WOULD BE GOOD TO INCLUDE ALL OF WATER'S FORMS, LIQUID/GAS/SOLID.)

HOW ABOUT A HUGE WAVE LOOMING TO THE LEFT, CRESTING AND READY TO FALL ON THE SCIENTISTS.

MANY OF THOSE CHANGES
HAVE TO DO WITH
WATER...

...SO THAT'S
OUR NEXT
TOPIC.

BAH! DON'T BE SO RISK AVERSE!

IT'LL BE SOMETHING FUN ABOUT WATER, OR THE LACK OF IT, OR SOMETHING.