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Narrator: OCEANS COVER 75%OF
THE EARTH'S SURFACE
AND IMPACT LIFE ON OUR PLANET
IN PROFOUND WAYS.
THE TROPICAL PACIFIC
SPANNING ALMOST HALF THE
EARTH'S CIRCUMFERENCE
TRIGGERS EL NIÑO EVENTS
AFFECTING STORM TRACKS
RAINFALL
AND TEMPERATURES ACROSS
THE GLOBE.

ON A QUIETERBUT NO LESS
IMPORTANT SCALE
THE TROPICAL OCEANS ARE
TEEMING WITH WHAT MAY BE THE
SMALLEST
AND MOST ABUNDANT
ORGANISMS ON EARTH.
MICROSCOPIC PHYTOPLANKTON
ARE THE BASE OF THE FOOD
CHAIN
ON WHICH MUCH OCEAN LIFE
DEPENDS.
BOTH PROCESSES ARE ONLY
PARTIALLY UNDERSTOOD
YET THEY EACH HAVE

FAR-REACHING EFFECTS ON
OCEAN SYSTEMS
AND ULTIMATELY ON THE
HABITABILITY OF OUR PLANET
FOR HUMAN LIFE.

FERTILIZED BY THE UPWELLING
OF A COLD, NUTRIENT-RICH
CURRENT
THE COASTAL WATERS OF PERU
AND ECUADOR
BRING AN ABUNDANTAND
DEPENDABLE HARVEST
TO THE FISHERMEN OF SOUTH
AMERICA.
BUT, MYSTERIOUSLY, EVERY FEW
YEARS
THIS COLD CURRENTIS REPLACED
BY WARM WATERS
SEVERELY DEPLETING THE FISH
POPULATION.

THIS WARMER CURRENT
APPEARING USUALLY AROUND
CHRISTMAS TIME
BECAME KNOWN AS EL NIÑO, OR
THE CHRIST CHILD.
BUT WHAT THE FISHERMEN DIDN'T
KNOW
WAS THAT THE LOCAL
PHENOMENON THEY CALLED EL
NIÑO

WAS, IN FACT, AN IMMENSE INTERACTION
BETWEEN THE VAST PACIFIC OCEAN AND THE ATMOSPHERE
CAUSING TORRENTIAL RAINS, DROUGHT
AND FAMINE ACROSS THE GLOBE.

MARK CANE, A SCIENTIST AT COLUMBIA'S
LAMONT-DOHERTY EARTH OBSERVATORY
HAS BEEN STUDYING EL NIÑO FOR OVER 30 YEARS.
Cane: WHEN YOU HAVE AN EL NIÑO EVENT
THERE ARE THINGS THAT HAPPEN AROUND THE WORLD.
THEY DON'T ALWAYS HAPPEN,
BUT THEY USUALLY HAPPEN
AND THEY HAVE SOME --
SOME BAD CONSEQUENCES FOR PEOPLE.
THERE IS TYPICALLYA POOR MONSOON IN INDIA.
THERE ARE DROUGHTS IN SOUTHERN AFRICA
DROUGHTS IN ETHIOPIA,
DROUGHTS IN NORTHEAST BRAZIL
WHICH IS THE POOREST PART OF BRAZIL.
IN PERU AND ECUADOR,YOU HAVE

CATASTROPHIC FLOODING
IN MANY PLACES THAT WASHES
OUT INFRASTRUCTURE.
Narrator: BECAUSE OF ITS
DEVASTATING EFFECTS AROUND
THE GLOBE
SCIENTISTS TRIED TO
ACCURATELY PREDICT EL NIÑO IN
ADVANCE
TO HELP PEOPLE PREPARE.
THESE ATTEMPTS WERE
UNSUCCESSFUL UNTIL THE
MID-1980s
WHEN CANE AND HIS COLLEAGUE
STEVE ZEBIAK
SET OUT TO CREATE A
PHYSICALLY BASED COMPUTER
MODEL
TO PREDICT THESE PHENOMENA.
Cane: HERE IS THIS EL NIÑO
PHENOMENON WHICH I KNEW
ABOUT
BECAUSE IT HAD CAUSED THESE
ANOMALIES
IN WINTERTIME CIRCULATION
OVER NORTH AMERICA IN '77, '78.
AND I WAS LIVING IN BOSTON AT
THE TIME
AND IT DUMPED THIS INCREDIBLE
AMOUNT OF SNOW ON US.
WE KEPT GETTING HIT BY
SNOWSTORMS.

AND THEN WE FINALLY GOT HIT BY THE BIG ONE.
SO, THESE EL NIÑO EVENTS
IF WE COULD FORECAST THEM
AND GET THIS INFORMATION OUT THERE
THERE'S THE POSSIBILITY OF TAKING ACTIONS
THAT WILL MITIGATE THESE IMPACTS.

Narrator: TO UNDERSTAND EL NIÑO
IT IS FIRST IMPORTANT
TO UNDERSTAND THE DYNAMICS
OF THE PACIFIC OCEAN.

IN THE 1960s
UCLA METEOROLOGIST JACOB BJERKNES PROPOSED
THAT OCEAN-SURFACE TEMPERATURES
WERE LINKED TO ATMOSPHERIC WINDS.
THE EVIDENCE HE FOUND
CAME FROM THE VARIATION IN OCEAN TEMPERATURES
ON EITHER SIDEOF THE TROPICAL PACIFIC.
Cane: HE NOTICED
THAT THE STATE THAT WE CONSIDER NORMAL IS VERY ODD
BECAUSE THE WESTERN PACIFIC

IS WARM.
LIKE 30 DEGREES CELSIUS -- HIGH
TO MID-80s FAHRENHEIT --
THE KIND OF WATER EVEN MY
WIFE WOULD SWIM IN, IT'S SO
WARM.
BATHTUB TEMPERATURE.
THE OTHER END, THE EASTERN
END OF THE PACIFIC
HAS TEMPERATURES LIKE 20,22
DEGREES CELSIUS --
AROUND 70 FAHRENHEIT.
WHY THIS ENORMOUS
TEMPERATURE CONTRAST?
BOTH ENDS OF THE OCEAN GET
ABOUT THE SAME AMOUNT OF
SUNLIGHT --
YOU KNOW, WE'RE TALKING ON
THE EQUATOR HERE.
AND THE REASON FOR IT
IS THE WAY THE OCEAN
RESPONDS TO THE WINDS.

Narrator: WHEN EL NIÑO IS NOT
PRESENT
THE AIR OVER THE WARM
WATERS OF THE WESTERN
PACIFIC
IS HEATED AND RISES.
AS THIS WARM AIR MOVES
UPWARD
IT'S REPLACED BY AIR

CONVERGING
FROM THE INDIAN OCEAN TO THE WEST
AND THE PACIFIC TO THE EAST.
THESE PACIFIC TRADE WINDS
ALSO PUSH THE WARM SURFACE WATERS ALONG WITH THEM.
THE WARM WATERS COLLECT IN THE WESTERN PACIFIC NEAR ASIA
DEEPENING THE BOUNDARY
BETWEEN THE WARM SURFACE LAYER
AND THE COLD OCEAN DEPTHS.
BACK EAST, OFF THE COAST OF SOUTH AMERICA
THE WARM SURFACE WATERS
FLOWING TOWARD THE WEST
ARE REPLACED BY COLDER
WATERS UPWELLING FROM THE DEEP OCEAN.
THIS COOLS THE AIR ABOVE
CREATING AN EVEN GREATER
TEMPERATURE VARIATION
WHICH IN TURN MAKES THE
TRADEWINDS BLOW EVEN STRONGER.
Cane: IN OTHER WORDS
THIS TEMPERATURE CONTRAST
BETWEEN EAST AND WEST
WHICH WAS GENERATED BY THE WINDS
WAS ALSO HELPING TO

GENERATE THE WINDS.
A POSITIVE FEEDBACK BETWEEN
THE OCEAN AND THE
ATMOSPHERE.

Narrator: BJERKNES ALSO
REALIZED
THAT THE FEEDBACK COULD
OPERATE IN REVERSE.

ROUGHLY EVERY FOUR TO SEVEN
YEARS
THE EASTERLY WINDS SLOW
AND THE WARM WATER THAT WAS
PILING UP IN THE WESTERN
PACIFIC
SLOSHES BACK TOWARD THE
EAST.
THIS CREATES A WARM CURRENT
OF WATER
THAT MOVES FROM WEST TO
EAST.
AS THE TROPICAL-OCEAN
TEMPERATURE GRADIENT
DISAPPEARS
THE TRADE WINDS SLOW OR EVEN
REVERSE
ALLOWING WARM WATER TO
ACCUMULATE
OFF THE COAST OF SOUTH
AMERICA.
THIS IS EL NIÑO

AND ITS EFFECTS ARE
FAR-REACHING.
Cane: BJERKNES NOTICED THAT
EL NIÑO
WHICH HAD BEEN KNOWN TO
PEOPLE ON THE COASTS
AS A COASTAL WARMING
ACTUALLY EXTENDED OUT INTO
THE CENTRAL PACIFIC
ALL THE WAY FROM THE
COASTLINE TO THE DATELINE.
THE PACIFIC IS BIG.
THAT'S A QUARTER OF THE
CIRCUMFERENCE OF THE EARTH.
THAT'S A LOT OF AREA TO
CHANGE THE WATER IN.
THAT'S A BIG DISRUPTION IN THE
TEMPERATURE --
THE THERMAL-BOUNDARY
CONDITION THAT THE
ATMOSPHERE SEES.

Narrator: IN 1982, CONDITIONS
WERE BUILDING
TOWARD AN EL NIÑO OF
UNPRECEDENTED PROPORTIONS.
BUT THE WARNING SIGNS WENT
UNHEEDED.
THECONRAD, A RESEARCH
VESSEL
FROM COLUMBIA'S
LAMONT-DOHERTY EARTH

OBSERVATORY
NOTICED DRAMATIC INCREASES
IN SEA-SURFACE TEMPERATURE
AS IT STEAMED EAST ALONG THE
EQUATOR.
THE TEMPERATURES WERE SO
HIGH
THAT COMPUTERS IN
WASHINGTON, D.C., REJECTED
THE DATA
BECAUSE IT WAS TOO MUCH OF
AN ANOMALY.
Cane: I WAS IN A MEETING IN THE
FALL IN 1982
AND THE PREVAILING SENSE OF
THINGS
WAS, "THERE'S NO EL NIÑO GOING
ON.
THERE WON'T BE AN EL NIÑO,"
AND SO ON.
NOW, THIS WAS, SAY, SOMETHING
LIKE SEPTEMBER
IF I REMEMBER RIGHT
AND WE WERE ALREADY WELL
INTO
WHAT WOULD BE THE LARGEST EL
NIÑO IN 100 YEARS, OKAY?
AND I THOUGHT, "WHAT A GREAT
PREDICTION PROBLEM TO GO
AFTER.
"IF I UNDERSTAND SOMETHING
"THEN I SHOULD BE ABLE TO TURN

IT INTO A SET OF EQUATIONS
"THAT I COULD PUT ON A
COMPUTER
"AND THEY'LL SIMULATE THE
THING I UNDERSTAND.
SO, I'LL BE ABLE TO, IN THAT
SENSE, MAKE A MODEL OF IT."
Narrator: CANE AND ZEBIAK BEGAN
WORK ON THEIR COMPUTER
MODEL
BY SIMPLIFYING THE EL NIÑO
CYCLE TO ITS ESSENTIAL
FEATURES.

FIRST, SEA-SURFACE
TEMPERATURES WERE ENTERED
INTO THE MODEL
TO CALCULATE WIND SPEED AND
DIRECTION.
AS THE COMPUTER STEPPED
THROUGH EACH CYCLE OF THE
SIMULATION
THE CALCULATED WINDS WERE
COUPLED TO A MODEL OF THE
OCEAN
AND CAUSED THE BORDER
BETWEEN THE WARM SURFACE
WATERS
AND COOLER UNDERLYING
WATER TO MOVE UP AND DOWN.

Cane: IF WE STARTED WITH A

STATE
THAT GAVE A GOOD DESCRIPTION
OF WHERE THIS LAYER OF WARM
WATER WAS --
WHERE IT WAS HIGHER THAN
NORMAL
AND WHERE IT WAS LOWER THAN
NORMAL --
THEN IF WE COULD JUST
INITIALIZE A MODEL
WITH THOSE CONDITIONS
START IT OFF IN THAT STATE AND
LET IT GO FORWARD
SIMULATING THE WORLD, THEN IT
MIGHT WELL WORK
TO SIMULATE WHAT WAS GOING
TO HAPPEN NEXT IN THE REAL
WORLD.
AND THAT, IN ESSENCE, IS A
PREDICTION.
Narrator: TO TEST THEIR MODEL
CANE AND ZEBIAK USED
ARCHIVAL RECORDS GOING BACK
TO 1970
AND ENTERED THIS DATA INTO
THEIR MODEL
TO SEE IF IT COULD RECREATE
THE CONDITIONS
THAT LED TO THE 1982 EL NIÑO.

BY PROGRAMMING DATA A FEW
MONTHS AT A TIME

AND THEN COMPARING THE
COMPUTER'S RESULTS
WITH WHAT HAD REALLY
HAPPENED --
A PROCESS CALLED
RETROSPECTIVE FORECASTING --
THE TWO RESEARCHERS
WERE ABLE TO VERIFY THE
ACCURACY OF THEIR PROGRAM.
Cane: WE STARTED FROM JUNE,
AND WE WENT AHEAD, AND IT
WORKED.
AND THEN WE WENT BACK AND
WE TRIED IT FROM APRIL
AND IT WORKED AGAIN.
AND WE KEPT GOING BACK LIKE
THREE, FOUR MONTHS IN TIME.
AND ALL OF THOSE FORECASTS
ACTUALLY GAVE SOMETHING LIKE
A VERY LARGE EL NIÑO EVENT.
Narrator: CONFIDENT THAT THEIR
MODEL WAS ACCURATE
CANE AND ZEBIAK WERE
READYTO FORECAST INTO THE
FUTURE
AND PREDICTED AN EL NIÑO FOR
THE END OF 1986.
Cane: NOW WHAT DO WE DO?
DO WE SIT ON THE INFORMATION
ON THE GROUNDS
THAT, WELL,YOU DON'T WANT TO
SCARE PEOPLE?

REMEMBER, THIS IS FOUR YEARS
AFTER THE 1982 EL NIÑO
HAD REARRANGED THE
SHORELINE IN CALIFORNIA
HAD WASHED OUT A LOT
OF THE TRANSPORTATION
INFRASTRUCTURE
IN PERU AND ECUADOR.
THERE WAS A HUGE FOREST FIRE
IN BORNEO
AND THAT FIRE HAS NEVER
STOPPED BURNING.
YOU COULDN'T TALK ABOUT EL
NIÑO IN SOME PARTS OF THE
WORLD
WITHOUT GETTING PEOPLE
REALLY FRIGHTENED.
ON THE OTHER HAND
THERE ARE THINGS YOU CAN DO
TO PREPARE FOR IT
IF YOU KNOW IT'S COMING.
THE CONCLUSION WAS,"WELL,
THIS IS GOOD SCIENCE
SO...LET'S DO IT."

Narrator: CANE AND ZEBIAK
ANNOUNCED THEIR PREDICTION
IN MARCH
AND, AS FORECASTED, AN EL
NIÑO EVENT DID DEVELOP
AT THE END OF 1986.
THIS SUCCESS OF THE

CANE/ZEBIAK MODEL
WAS THE FIRST TIME EL NIÑO HAD
BEEN PREDICTED IN ADVANCE.
IT LED TO POLICY CHANGES IN
ETHIOPIA
THAT HELPED AVOID FAMINE THE
FOLLOWING YEAR.
TODAY, ALTHOUGH MANY NEW
CLIMATE MODELS
HAVE BECOME AVAILABLE SINCE
1986
A NEW GENERATION OF
RESEARCHERS CONTINUES TO
RELY
ON THE SIMPLICITY OF THE
ORIGINAL CANE/ZEBIAK MODEL.
AND SCIENTISTS HOPE TO BE
ABLE TO USE THEIR PREDICTIONS
TO LESSEN THE EFFECTS OF EL
NIÑO.
Cane: SO, ONE ISSUE WAS HOW
DO YOU GET PEOPLE TO USE
THIS?
WHAT ARE THE IMPLICATIONS
FOR AGRICULTURE, FOR WATER
MANAGEMENT
FOR TOURISM, FOR
ECOSYSTEMS?
AND IF YOU KNOW THOSE
IMPLICATIONS
WHAT SHOULD SOMEBODY DO
ABOUT IT?

Narrator: THE WARM CURRENTS OF EL NIÑO
ARE NOW UNDERSTOOD TO BE PART OF A GLOBAL, DYNAMIC SYSTEM
THAT AFFECTS THE LIVES AND WELL-BEING
OF MILLIONS OF PEOPLE AROUND THE EARTH.

SURPRISINGLY, TINY ORGANISMS IN OUR OCEANS
ALSO HAVE A HUGE IMPACT ON THE HABITABILITY OF OUR PLANET.

THE TOP LAYERS OF THE OCEANS
ARE TEEMING WITH A HUGE VARIETY
OF SINGLE-CELLED MICROSCOPIC ORGANISMS
CALLED PHYTOPLANKTON.
THESE TINY ORGANISMS PLAY A KEY ROLE
IN REGULATING ATMOSPHERIC CARBON DIOXIDE.
AND AS THE BOTTOM RUNG IN THE FOOD CHAIN
THEY ARE ESSENTIAL TO OCEAN ECOSYSTEMS.

UNDERSTANDING THE ECOLOGY
OF PHYTOPLANKTON
IS THE GOAL OF PENNY CHISHOLM
AT THE MASSACHUSETTS
INSTITUTEOF TECHNOLOGY.
Chisholm: WHAT MOST PEOPLE
DON'T REALIZE
IS THAT THE OCEANS ARE
RESPONSIBLE
FOR HALF OF THE
PHOTOSYNTHESIS ON EARTH
AND THAT IS THAT THEY
PRODUCE HALF OF THE OXYGEN
THAT IS PRODUCED THROUGH
THE PHOTOSYNTHETIC
MECHANISM.
THE ORGANISMS THAT DO THIS
ARE THE MICROBES
THE PHYTOPLANKTON IN THE
OCEANS.

WE CALL THEM THE INVISIBLE
FOREST.
THEY ARE THE PLANTS OF THE
OCEANS
AND THEY ARE THE BASE OF THE
FOOD WEB.
IF THEY WEREN'T THERE
THERE WOULD BE NOTHING ELSE
LIVING IN THE OCEANS.

Narrator: ANOTHER CRUCIAL ROLE

OF PHYTOPLANKTON
IS TO REGULATE CARBON DIOXIDE
IN THE ATMOSPHERE.
Chisholm: WE THINK OF THE
OCEAN ECOSYSTEM
AS A PHOTOSYNTHETIC MACHINE,
IN A SENSE.
AND A CRITICAL FUNCTION OF
THIS MACHINE
IS TO STEADILY PUMP CARBON
DIOXIDE
FROM THE ATMOSPHERE INTO
THE SURFACE OCEANS
AND THEN EXPORT IT TO THE
DEEP OCEAN.

Narrator: PHYTOPLANKTON ARE AT
THE BASE OF THIS OCEAN PUMP
CAPTURING CO2 AND
CONVERTING IT TO SUGARS AND
PROTEINS
WHICH ARE TRANSFERRED
THROUGH THE MARINE FOOD
WEB.
EACH STEP ALONG THE WAY
SOME CO2 IS RELEASED BACK
INTO THE ATMOSPHERE.
BUT SOME OF THE ORGANIC
CARBON FALLS FROM THE UPPER
OCEAN
MAKING A SLOW RAIN OF DEAD
ORGANISMS

AND ORGANIC WASTE PRODUCTS
THAT GRADUALLY ACCUMULATE
IN THE COLD DEPTHS.
HERE, BECAUSE OF THE SLOW
CIRCULATION OF THE DEEP
OCEAN
THE CARBON REMAINS OUT OF
CONTACT WITH THE ATMOSPHERE
FOR A THOUSAND OR MORE
YEARS.
Chisholm: IF THERE WERE NO
PHYTOPLANKTON
AND IF THE PUMP DIDN'T EXIST
AND THE OCEANS ALL MIXED, TOP
TO BOTTOM
AND ALL OF THAT CO2 IN THE
DEEP OCEAN
EQUILIBRATED WITH THE
ATMOSPHERE
THE CONCENTRATION OF CO2 IN
THE ATMOSPHERE
WOULD MORE THAN DOUBLE.
SO THAT JUST GIVES YOU AN IDEA
OF HOW MUCH THE DEEP OCEAN
PLAYS A ROLE
IN THE GLOBAL-CARBON
INVENTORY
AND HOW IMPORTANT THE
PHYTOPLANKTON ARE
IN KEEPING THAT PUMPED --
PUMPING DOWNWARD TO KEEP
THAT CO2

IN THE DEEP PART OF THE OCEAN.

Narrator: BY REGULATING CARBON DIOXIDE AND PRODUCING OXYGEN
PHYTOPLANKTON PLAY AN ESSENTIAL ROLE
IN MAINTAINING A HABITABLE PLANET.
ALTHOUGH THE ROLE OF PHYTOPLANKTON
IN THE WORLD'S OCEANS HAVE BEEN STUDIED INTENSIVELY
SURPRISINGLY, THE MOST ABUNDANT VARIETY OF PHYTOPLANKTON
WAS ONLY RECENTLY DISCOVERED.
PROCHLOROCOCCUS.
Chisholm: IT'S INCREDIBLY HUMBLING
TO REALIZE THAT WE DIDN'T KNOW THIS CELL EXISTED
UNTIL 15 YEARS AGO
AND WE HAD MODELS OF THE OCEAN PROCESSES
AND MODELS OF THE EARTH.
WE THOUGHT WE UNDERSTOOD THIS PRETTY WELL.
WE ALWAYS THINK WE UNDERSTAND IT PRETTY WELL
AND THEN ALONG COMES

SOMETHING
THAT JUST COMPLETELY
CHANGES THE WAY WE THINK
ABOUT THESE SYSTEMS.

Narrator: PROCHLOROCOCCUS
WAS FINALLY DISCOVERED
WHEN AN INSTRUMENT USED FOR
BIOMEDICAL RESEARCH
A FLOW CYTOMETER
WAS BROUGHT ON BOARD AN
OCEANOGRAPHIC-RESEARCH
VESSEL
TO TEST ITS USEFULNESS IN THE
STUDY OF PHYTOPLANKTON.

THE FLOW CYTOMETER BREAKS
AN EXTREMELY NARROW STREAM
OF WATER
INTO INDIVIDUAL DROPS -- EACH
ONE ONLY SLIGHTLY LARGER
THAN THE CELLS UNDER
INVESTIGATION.
THE DROPS ARE ILLUMINATED BY
A LASER
AND IF A DESIRED CELL IS
PRESENT IN ONE OF THE DROPS
IT WILL GIVE OFF A PARTICULAR
WAVELENGTH OF LIGHT.
A TINY FORCE CAN THEN BE
APPLIED
TO SORT THAT DROPLET FROM

THE OTHERS.
Chisholm: WE STARTED WORKING WITH THIS INSTRUMENT
AND WE REALIZED THAT IT WOULD BE REALLY USEFUL
FOR STUDYING PLANKTON.
ROB OLSON WAS A POST DOC IN MY LAB AT THAT TIME.
HE'S A SCIENTISTAT WOODS HOLE NOW.
AND WE STARTED STUDYING A GROUP OF PLANKTON CALLED SYNECOCOCCUS
WHICH ARE INTERESTING IN THAT THEY FLUORESCE ORANGE.
MOST PLANKTON, IF YOU SHINE BLUE LIGHT, FLUORESCE RED.
AS TIME WENT ON
WE STARTED SEEING SOME VERY, VERY TINY SIGNALS
THAT WERE FLUORESCING RED
BUT SCATTERING MUCH LESS LIGHT THAN, UM...
THAN ANY KNOWN PHYTOPLANKTON CELL WOULD SCATTER --
WHICH SAID THAT THEY WERE EXTREMELY SMALL.
AND WE THOUGH TTHAT WAS ELECTRONIC NOISE.
BUT ROB PERSISTED IN LOOKING AT THIS

AND, ULTIMATELY
IT STARTED TAKING ON
CHARACTERISTICS THAT WERE
ALIVE
AND THAT IT CHANGED WITH
DEPTH IN THE OCEANS AND, UM...
SO, WE STARTED FOCUSING ON
THESE LITTLE SIGNALS
WITH THE FLOW CYTOMETER
AND ULTIMATELY WERE ABLE TO
ISOLATE THE
PROCHLOROCOCCUS.
AND THAT TURNED OUT TO BE A
VERY IMPORTANT COMPONENT
OF THE OCEAN ECOSYSTEM.

Narrator: PROCHLOROCOCCUS IS
THE SMALLEST
AND MOST ABUNDANT
PHOTOSYNTHETIC ORGANISM ON
EARTH.
ALTHOUGH ONLY ONE-HALF
MICRON IN DIAMETER
SO SMALL THAT ABOUT 200
COULD FIT ACROSS A HUMAN
HAIR
THE
SINGLE-CELLEDPROCHLOROCOCC
US
IS THE MOST EFFICIENT LIGHT
ABSORBER
OF ALL KNOWN PHOTOSYNTHETIC

CELLS.
Chisholm: IF THE OCEANS ARE RESPONSIBLE
FOR HALF OF THE PHOTOSYNTHESISON EARTH
AND PROCHLOROCOCCUS AREA SIGNIFICANT FRACTION OF THAT
THAT MAKES THIS ONE PARTICULAR GROUP OF ORGANISMS
AN IMPORTANT PHOTOSYNTHESIZER ON A GLOBAL SCALE.

Narrator: IN ADDITION TO BEING THE SMALLEST IN SIZE
PROCHLOROCOCCUS ALSO HAS THE FEWEST GENES
OF ANY PHOTOSYNTHETIC ORGANISM.
Chisholm: OVER TIME WE'VE COME TO LEARN
THAT PROCHLOROCOCCUSIS A VERY SPECIAL PHYTOPLANKTON.
WITH THE SMALLEST NUMBER OF GENES
IT CAN CONVERT SOLAR ENERGY, CO2
AND INORGANIC COMPOUNDS INTO ORGANIC CARBON.
SO, I THINK OF IT AS THE MINIMAL LIFE FORM.

Coleman: WITH THESE VERY FEW GENES
THEY'RE ABLE TO DO PHOTOSYNTHESIS
IN PARTS OF THE OCEANS THAT ARE REALLY, REALLY LOW IN NUTRIENTS.
AND THESE TINY CELLS WITH VERY FEW GENES
ARE REALLY ABLE TO CAPITALIZE ON THAT.

Narrator: TO LEARN MORE ABOUT THE ROLE PROCHLOROCOCCUS PLAYS
IN THE OCEAN ECOSYSTEM
RESEARCHERS FROM THE CHISHOLM LAB
ROUTINELY TAKE SAMPLES OF OCEAN WATER
FROM A RANGE OF DEPTHS AROUND THE WORLD.
THE BIG QUESTION THEY ARE TRYING TO ANSWER
IS WHY THE POPULATION OF PROCHLOROCOCCUS
REMAINS FAIRLY CONSTANT OVER TIME.
WHAT FACTORS REGULATE ITS BIRTH AND DEATH?
Chisholm: THE INTERESTING THING ABOUT PROCHLOROCOCCUS

IS HOW STABLE IT IS IN THE
DEEP-BLUE OCEAN.
THAT IS, IN THE WARMER WATERS
OF THE OPEN OCEAN
YOU FIND ON AVERAGE, AND
FAIRLY STABLY
ABOUT 10 MILLION CELLS PER
LITER OF SEAWATER.
AND THERE ARE SOME
FLUCTUATIONS IN THEIR
NUMBERS
BUT NOT DRAMATIC.
AND THEY DOUBLE ABOUT ONCE
EVERY ONE OR TWO DAYS
SO THAT MEANS THEY'RE EATEN
AS FAST AS THEY'RE GROWING
AND THEY'RE GROWING
RELATIVELY FAST
FOR OCEAN PHYTOPLANKTON IN
THE MIDDLE OF THE OCEAN.

Narrator: PROCHLOROCOCCUS
REPRODUCES BY CELL DIVISION.
DIVIDING ONCE A DAY
THE POPULATION WILL DOUBLE
EVERY 24 HOURS
UNLESS THE CELLS ARE KILLED
OFF AS FAST AS THEY ARE BORN.
THIS DELICATE BALANCE
IS MAINTAINED WEEK AFTER
WEEK, YEAR AFTER YEAR.
SO, IT'S A VERY STABLE SYSTEM

AND YET VERY DYNAMIC
IN HOW FAST THE CELLS ARE GROWING.
SO, WE THINK THAT THIS SYSTEM IS PLAYING AN IMPORTANT ROLE IN REGULATING THE STABILITY OF THE OCEAN ECOSYSTEM.

Narrator: TO HELP UNDERSTAND HOW THE POPULATION OF PROCHLOROCOCCUS IS MAINTAINED
THE RESEARCH TEAM HAS BEEN INVESTIGATING VIRUSES
THAT INFECT THE ORGANISM.
Chisholm: IT TURNS OUT THE OCEANS ARE TEEMING WITH VIRUSES
THAT INFECT MICROBIAL CELLS IN THE SYSTEM
AND SO IT'S NOT A SURPRISE THAT THERE ARE VIRUSES
THAT INFECT PROCHLOROCOCCUS.

Narrator: MATT SULLIVAN, A RESEARCHER IN CHISHOLM'S LAB HAS BEEN WORKINGON ISOLATING THESE VIRUSES.
SO FAR, THE TEAM HAS IDENTIFIED THREE DIFFERENT VIRUSES

AFFECTING THE POPULATION.
USING DNA SEQUENCING
THE TEAM THEN DETERMINES
WHICH GENES ARE IN THESE
VIRUSES
AND HOW THEY AFFECT THE
PROCHLOROCOCCUS HOST CELL.
SURPRISINGLY, THEY ARE
FINDING
THAT VIRUSES MAY NOT ONLY BE
HELPING TO KILL OFF THESE
CELLS
BUT ALSO TO HELP THEIR HOSTS
ADAPT TO DIFFERENT
CONDITIONS.
Sullivan: SO, MY GOAL'S ALL IN
UNDERSTANDING RIGHT NOW
THE KINDS OF VIRUSES THAT ARE
THERE
AND HOW THE INTERACTION
BETWEEN THE VIRUSAND THE
HOST CELL HAPPENS.
AND WHAT'S INTERESTING ABOUT
THAT
IS THAT WE CAN INTERPRET FROM
THE GENES THAT ARE THERE
WHAT PROCESSES THEY'RE
INTERACTING WITH THE HOST
WITH.
SO, IN ONE INSTANCE
SOME OF THESE VIRUSES
CONTAIN CORE PHOTOSYNTHESIS

GENES.
THEY'RE ACTUALLY ABLE TO
BOOST PHOTOSYNTHESIS
DURING INFECTION IN THESE
PARTICULAR HOSTS.
Narrator: A VIRUS INFECTS ITS
HOST
BY INJECTING ITS GENETIC
MATERIAL INTO THE CELL
CAUSING THE CELL'S
BIOCHEMISTRY TO SWITCH OVER
TO MAKING MORE VIRUS
PARTICLES.
SOMETIMES DNA FROM THE TWO
SOURCES GETS MIXED UP
AND THE HOST TAKES AWAY
SOME OF THE GENETIC MAKEUP
FROM THE VIRUS.
Sullivan: SO, IS THE VIRUS JUST
LYSING AND KILLING THOSE HOST
CELLS
OR ARE THEY ALSO PERHAPS
TAKING GENES FROM THE HOST
AND MOVING THOSE GENES BACK
INTO THE HOST
AFTER THEY'VE CHANGED A
LITTLE BIT IN THE VIRAL
POPULATION?

Narrator: MAUREEN COLEMAN HAS
BEEN STUDYING THE GENETIC
COMPOSITION

OF SEVERAL
PROCHLOROCOCCUS STRAINS.
SHE WAS ABLE TO IDENTIFY
SIGNATURES IN THEIR GENOMES
TO SUGGEST THAT VIRUSES ARE
ACTUALLY IMPORTANT
IN MOVING GENETIC
INFORMATION BETWEEN HOST
CELLS.
AND THIS TRANSFER OF GENETIC
INFORMATION
LEADS TO DIVERSIFICATION
WITHIN THE POPULATION.

EVEN THOUGH EVERYTHING
LOOKS SIMILAR IF YOU LOOK AT IT
UNDER A MICROSCOPE OR IN A
CULTURE TUBE --
THEY ALL LOOK LIKE SMALL
GREEN CELLS --
IT TURNS OUT THAT ALL OF THESE
PROCHLOROCOCCUS
ARE ACTUALLY QUITE DIFFERENT
FROM EACH OTHER.
THIS IS MED-4, AND THE "MED"
STANDS FOR "MEDITERRANEAN."
SO, THIS ONE HAS ADAPTED
TO REALLY HIGH-LIGHT
CONDITIONS IN THE OCEANS.
AND SO, IF YOU WERE TO GO OUT
TO THE OCEAN
YOU WOULD FIND A STRAIN LIKE

MED-4 AT THE SURFACE --
SO, RIGHT ON THE TOP LAYERS
OF THE WATER.
AND THEN, THESE OTHER
STRAINS...
UM...
THESE ONES GROW DEEPER, AND
THESE ARE LOW-LIGHT ADAPTED.
SO, YOU WOULDN'T FIND THE
SEAT 5 METERS DEPTH
BECAUSE THEY CAN'T COPE WITH
THE HIGH LIGHT.
BUT YOU MIGHT FIND THESE AT
150 METERS DEPTH
BECAUSE THEY'RE MUCH BETTER
AT HARVESTING THE VERY SMALL
AMOUNT OF LIGHT
THAT IS AVAILABLE DOWN THERE
AND DOING PHOTOSYNTHESIS
WITH IT.
SO, NOW THAT WE HAVE A
GENOME SEQUENCE
YOU CAN ACTUALLY SEE THAT
THERE ARE GENES SPECIFIC
FOR THIS LOW-LIGHT
ENVIRONMENT.
THEY HAVE A LOT MORE GENES
THAT ARE INVOLVED IN
HARVESTING LIGHT, FOR
INSTANCE
THAN THE HIGH-LIGHT-ADAPTED
STRAINS DO.

THE HIGH-LIGHT-ADAPTED
STRAINS, ON THE OTHER HAND
HAVE GENES FOR DEALING WITH
U.V. RADIATION
AND SO THESE GUYS THAT LIVE
DEEP
DON'T EVER SEE THAT MUCH U.V.
RADIATION
SO THEY DON'T NEED THOSE
GENES.

Chisholm: IT'S A VERY COMPLEX
STORY
AND HAS SORT OF CHANGED OUR
VIEW
OF THE ROLE OF VIRUSES IN THE
OCEANS
THAT MAYBE IT ISN'T JUST THAT
THEY'RE THERE
TO KILL PROCHLOROCOCCUS
BUT MORE THAT, YES,THEY DO
CAUSE CELL DEATH
BUT THEY ARE ALSO MOVING
GENES AROUND
BETWEEN DIFFERENT STRAINS.
AND WE THINK THAT THAT'S VERY
IMPORTANT
IN MAINTAINING THE GLOBAL
PROCHLOROCOCCUS
POPULATION
BECAUSE IT MAINTAINS GENETIC
DIVERSITY

IN THIS GROUP OF CELLS.
SO, I'VE STARTED TO THINK OF IT
AS SOME KIND OF A SYMBIOSIS
MORE THAN A PREDATOR/PREY
RELATIONSHIP
WHICH IS REALLY HERESY AND
MAYBE COMPLETELY WRONG
BUT THEY'VE BEEN WORKING ON
THAT STORY
AND FIGURING IT OUT.
Narrator: SINCE
PROCHLOROCOCCUS
IS AN INTEGRAL PART OF THE
OCEAN'S FOOD CHAIN
KNOWING HOW IT FUNCTIONS IS
KEY
TO A BETTER UNDERSTANDING OF
THE CARBON CYCLE.
WITHOUT PROCHLOROCOCCUS
AND THE THINGS LIKE IT
THAT DO PHOTOSYNTHESIS AND
PRODUCE OXYGEN
THEN WE WOULDN'T BE ABLE TO
SURVIVE.
I'M TRYING TO DO MY PART TO
UNDERSTAND THINGS
AT THE MOST BASIC LEVEL.
AND THEN EVENTUALLY SOMEDAY
WE MIGHT BE ABLE TO PREDICT
HOW THESE SYSTEMS WILL
RESPOND
TO ENVIRONMENTAL PROBLEMS.

BUT RIGHT NOW WE KNOW SO LITTLE ABOUT THE BASIC SCIENCE THAT THAT'S REALLY WHERE WE NEED TO START.
Chisholm: MY HOPE FOR PROCHLOROCOCCUS
IS THAT WE WILL HAVE A LOT OF PEOPLE FOCUSING
ON UNDERSTANDING THIS ONE ORGANISM
AND THAT IT WILL SERVE AS A MODEL SYSTEM
FOR WHAT I CALL SYSTEMS BIOLOGY
AND THAT IS THE STUDY OF ONE ORGANISM
FROM THE MOLECULAR LEVEL
TO THE ENTIRE ECOSYSTEM THAT IT'S EMBEDDED IN.

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