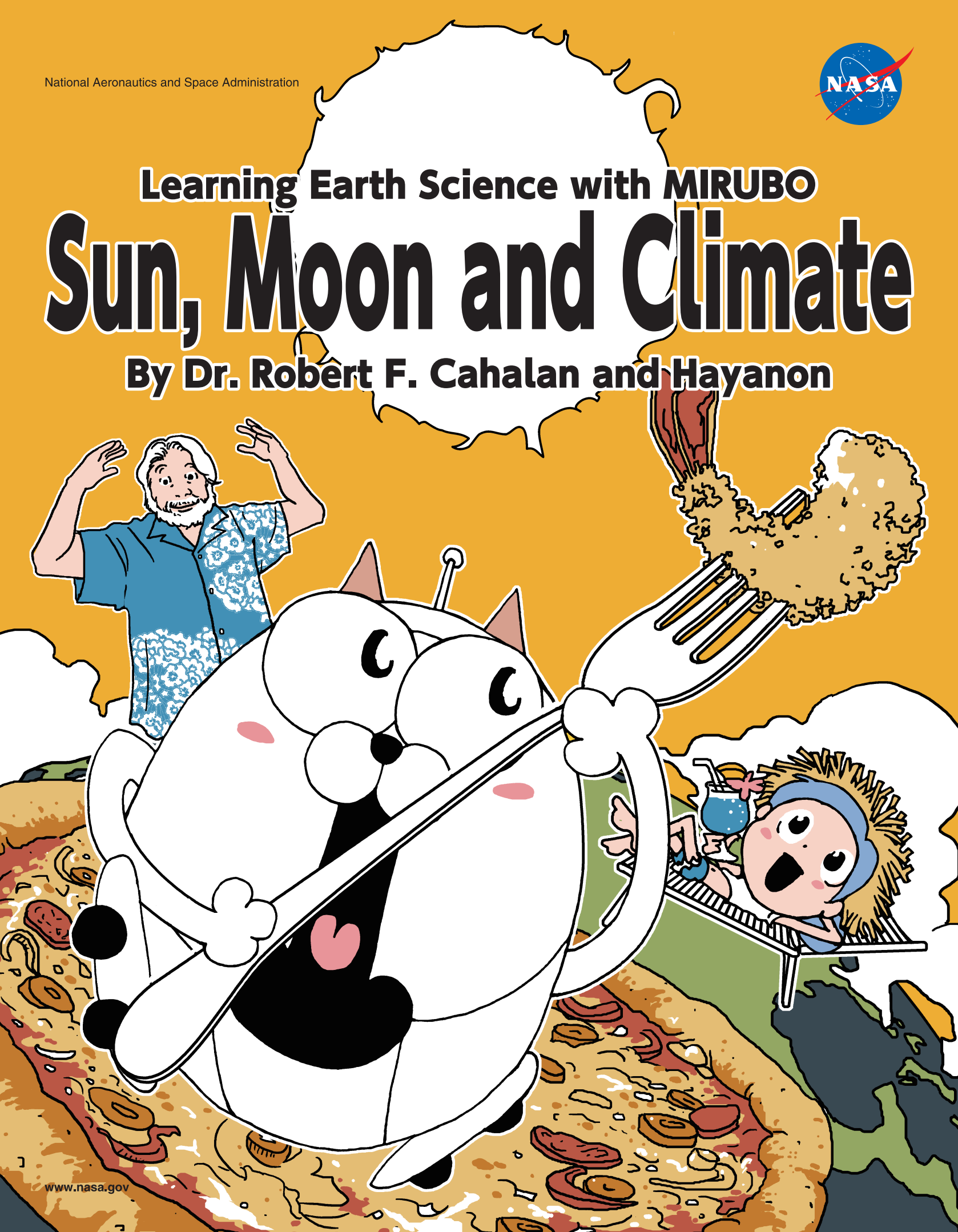




Learning Earth Science with **MIRUBO**

# Sun, Moon and Climate

By **Dr. Robert F. Cahalan and Hayanon**



# Learning Earth Science with MIRUBO

# Sun, Moon and Climate

MIRUBO THE ROBOTIC DOG SUDDENLY FELL DOWN DURING HIS MEAL. AN ELEMENTARY SCHOOL GIRL "MOL" BEGINS TO STUDY UNDER BOB, AN EARTH SCIENTIST TO REPAIR MIRUBO'S MALFUNCTION. BOB SAYS THAT STUDYING EARTH SCIENCE COULD HELP MIRUBO, BECAUSE MIRUBO'S PROBLEM IS CAUSED BY "ENERGY IMBALANCE" JUST THE SAME AS PROBLEMS ON EARTH.

*"WHAT'S THAT?" "WHY DOES IT HAPPEN?" "HOW CAN WE SOLVE THIS?"*

YOU WILL LEARN ABOUT EARTH SCIENCE THROUGH THIS EDUCATIONAL COMIC BOOK.

## BOB (Dr. Robert F. Cahalan)

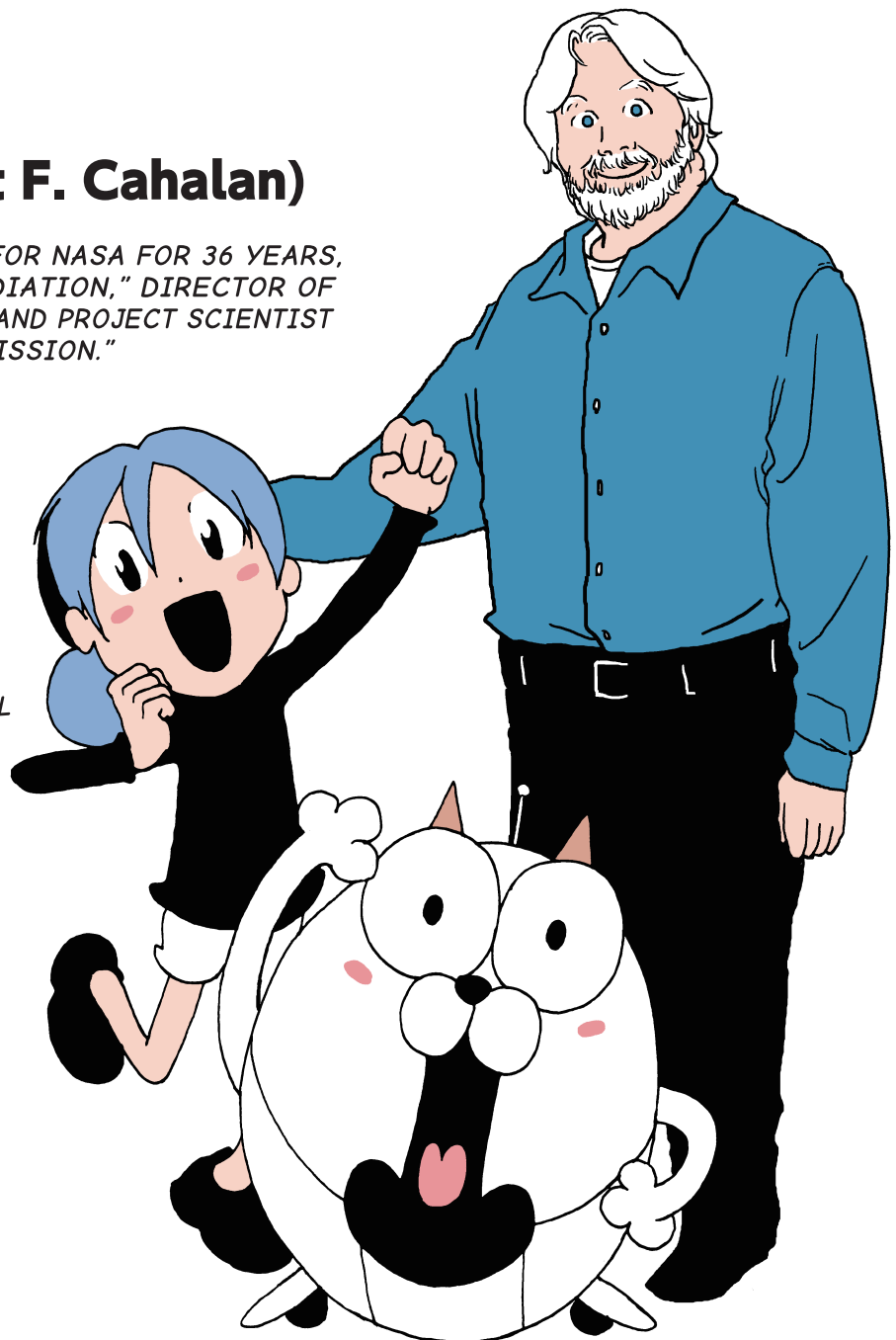
EARTH SCIENTIST WORKING FOR NASA FOR 36 YEARS, CHIEF OF "CLIMATE AND RADIATION," DIRECTOR OF THE "SUN-CLIMATE CENTER," AND PROJECT SCIENTIST OF THE "SORCE SATELLITE MISSION."

## MOL

AN ELEMENTARY SCHOOL GIRL WHO IS ENTHUSIASTIC ABOUT SCIENCE!

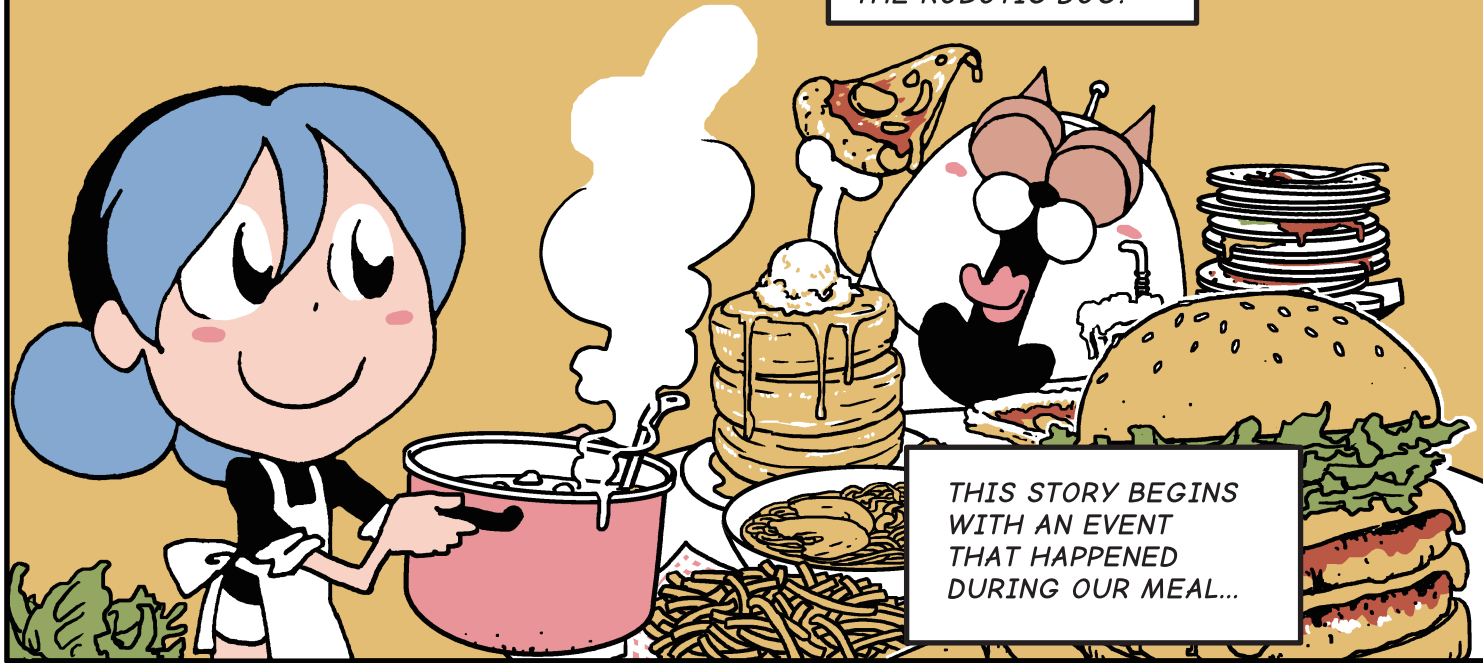
## MIRUBO

THE ROBOTIC DOG WITH HIGH SPEED CALCULATOR, ROCKET BOOSTERS, AND A STRONG STOMACH!

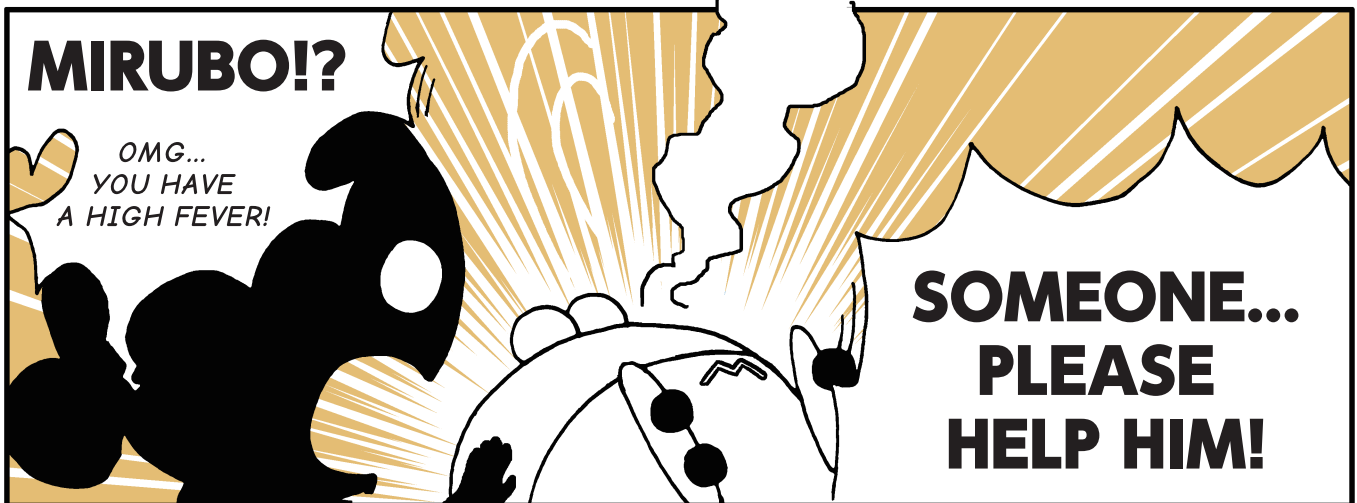
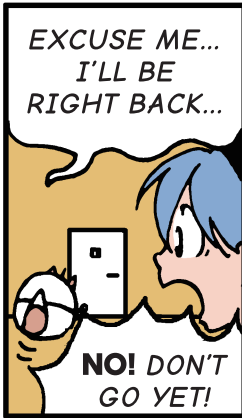
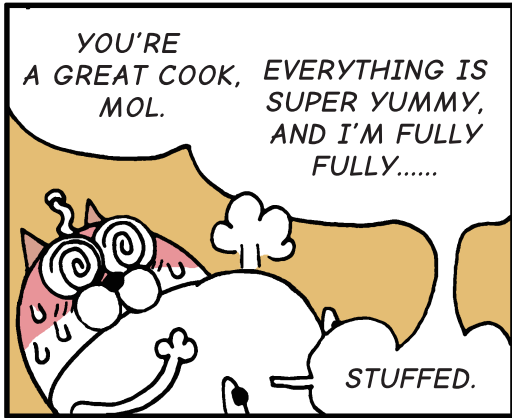


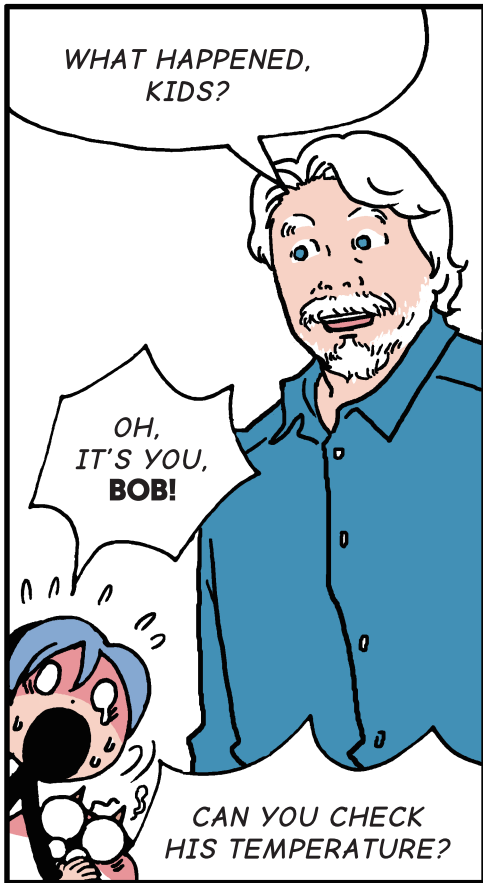
HI EVERYONE, I'M **MOL**!  
I'M AN ELEMENTARY SCHOOL GIRL  
WHO IS ENTHUSIASTIC  
ABOUT SCIENCE!

AND THIS IS **MIRUBO**,  
THE ROBOTIC DOG.



THIS STORY BEGINS  
WITH AN EVENT  
THAT HAPPENED  
DURING OUR MEAL...

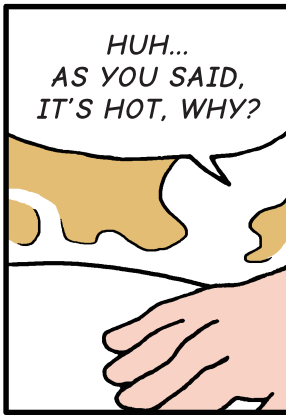




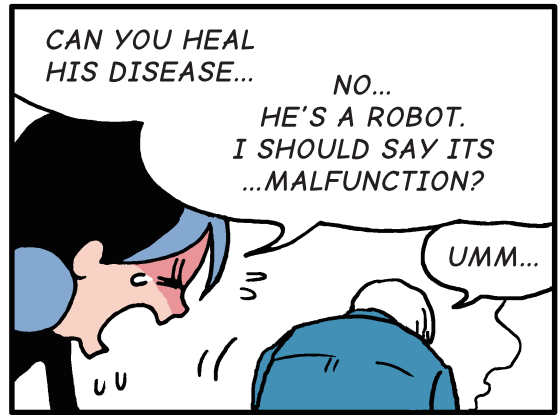
WHAT HAPPENED, KIDS?

OH, IT'S YOU, BOB!

CAN YOU CHECK HIS TEMPERATURE?



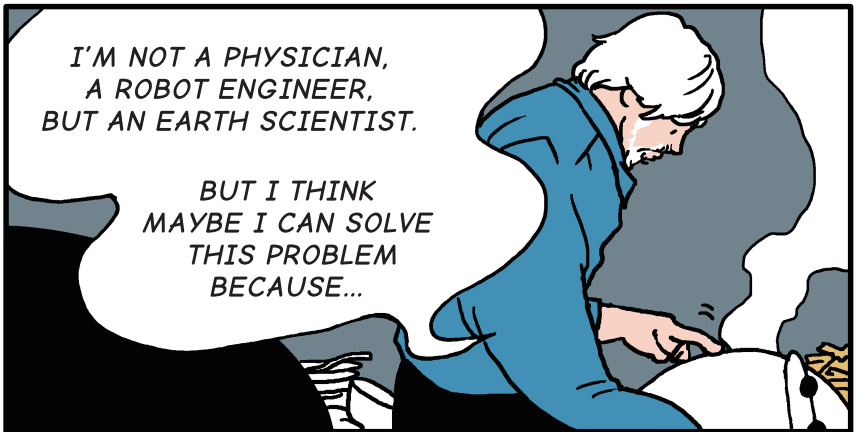
HUH... AS YOU SAID, IT'S HOT, WHY?



CAN YOU HEAL HIS DISEASE...

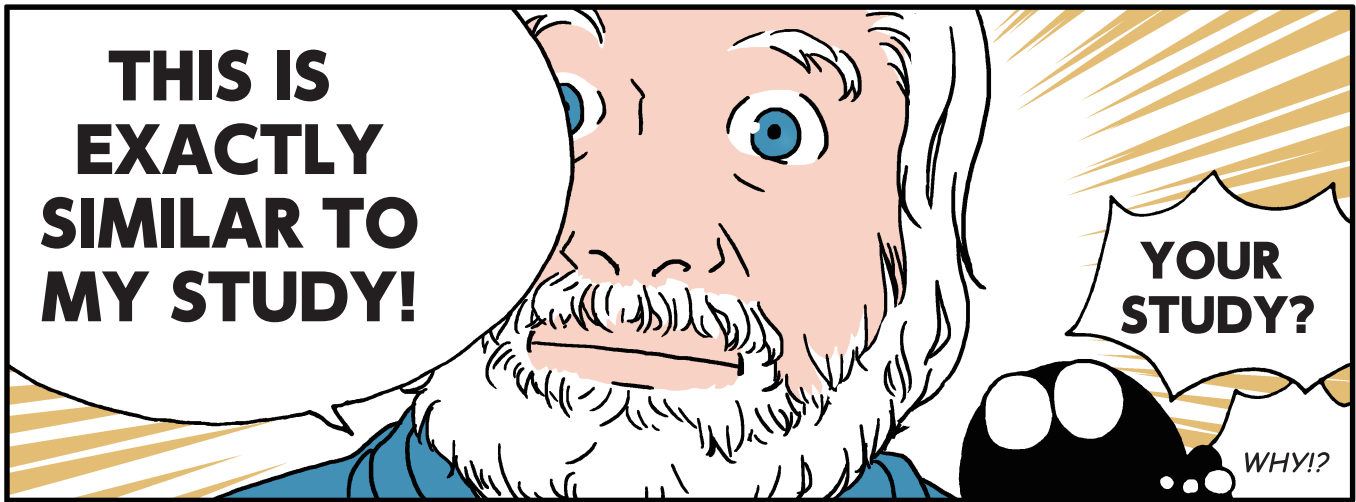
NO... HE'S A ROBOT. I SHOULD SAY ITS ...MALFUNCTION?

UMM...



I'M NOT A PHYSICIAN, A ROBOT ENGINEER, BUT AN EARTH SCIENTIST.

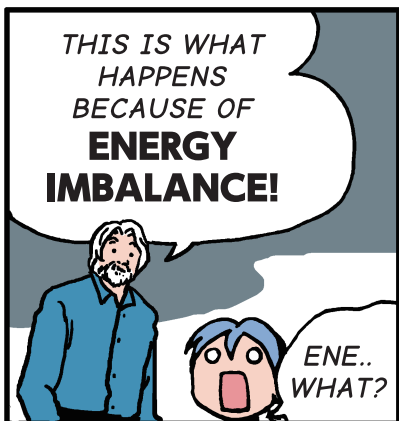
BUT I THINK MAYBE I CAN SOLVE THIS PROBLEM BECAUSE...



**THIS IS EXACTLY SIMILAR TO MY STUDY!**

YOUR STUDY?

WHY!?



THIS IS WHAT HAPPENS BECAUSE OF **ENERGY IMBALANCE!**

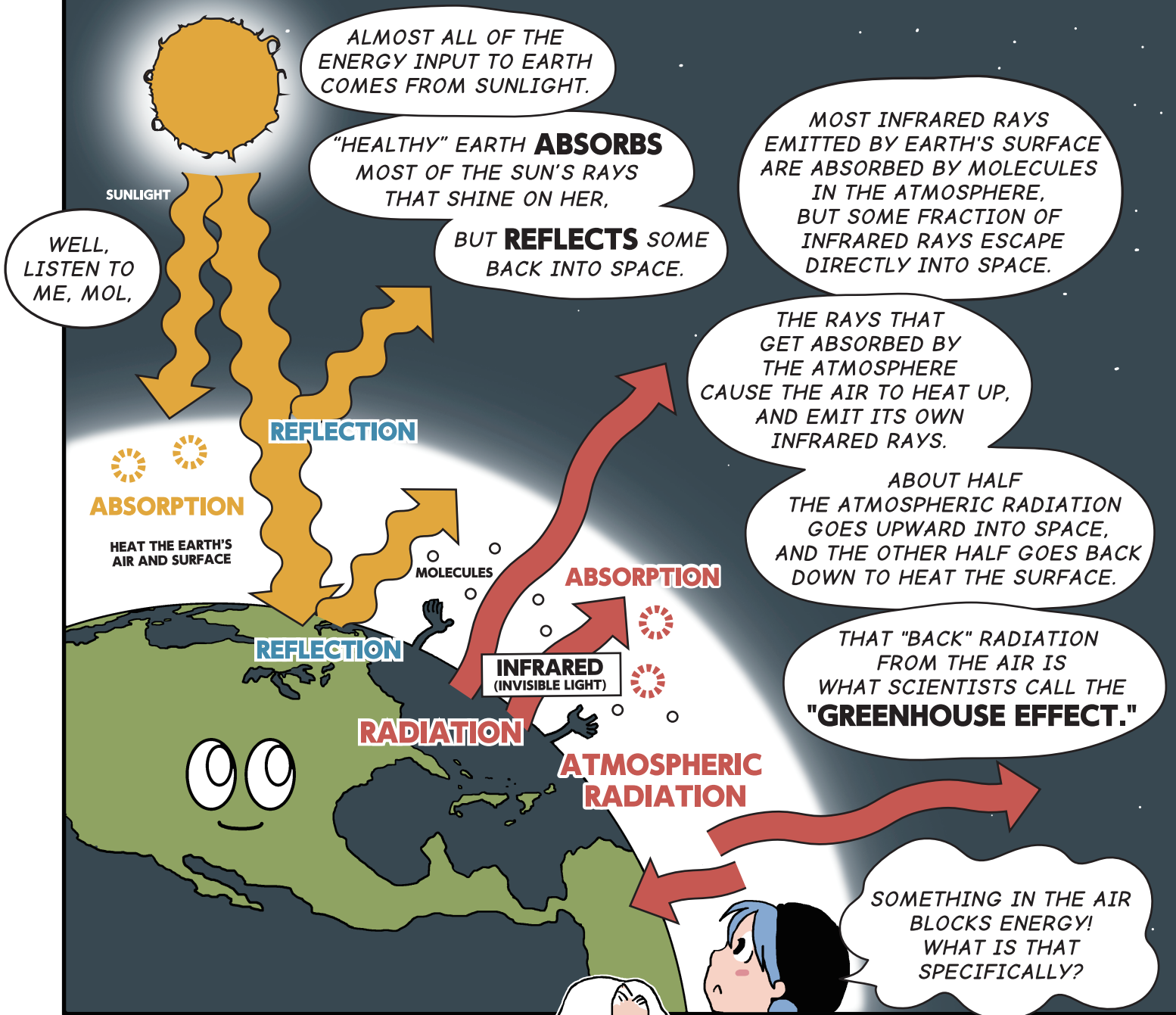
ENE.. WHAT?



YOU WILL BE ABLE TO SAVE HIM BY LEARNING "IMPORTANT THINGS" FROM MY STUDY!

**YES!!! I'LL DO IT! COME ON EARTH SCIENCE!!**

CAN I DO THAT ...?



HUMAN ACTIVITIES, ESPECIALLY BURNING FOSSIL FUELS, DIRECTLY INCREASE MOLECULES IN OUR ATMOSPHERE.

**CARBON DIOXIDE (CO<sub>2</sub>)**  
**METHANE (CH<sub>4</sub>)**  
**NITROUS OXIDE (N<sub>2</sub>O)**  
**OZONE (O<sub>3</sub>)**

THOSE "EXTRA" MOLECULES THEN BLOCK EARTH'S RADIATION, SO CAUSING THE AIR TO WARM.

**FIVE MOLECULES!**

WARMER AIR ALLOWS MORE EVAPORATION OF WATER, WHICH INCREASES WATER VAPOR IN THE AIR, INCREASING THE BLOCKAGE, AND MAKING AIR EVEN WARMER.

**WATER VAPOR (H<sub>2</sub>O)**

THESE FIVE MOLECULES ARE CALLED COLLECTIVELY "**GREENHOUSE GASES.**"

NEXT,

IMAGINE WHAT HAPPENS  
WHEN THE ENERGY IS  
BLOCKED FROM  
RETURNING FROM EARTH  
TO SPACE.

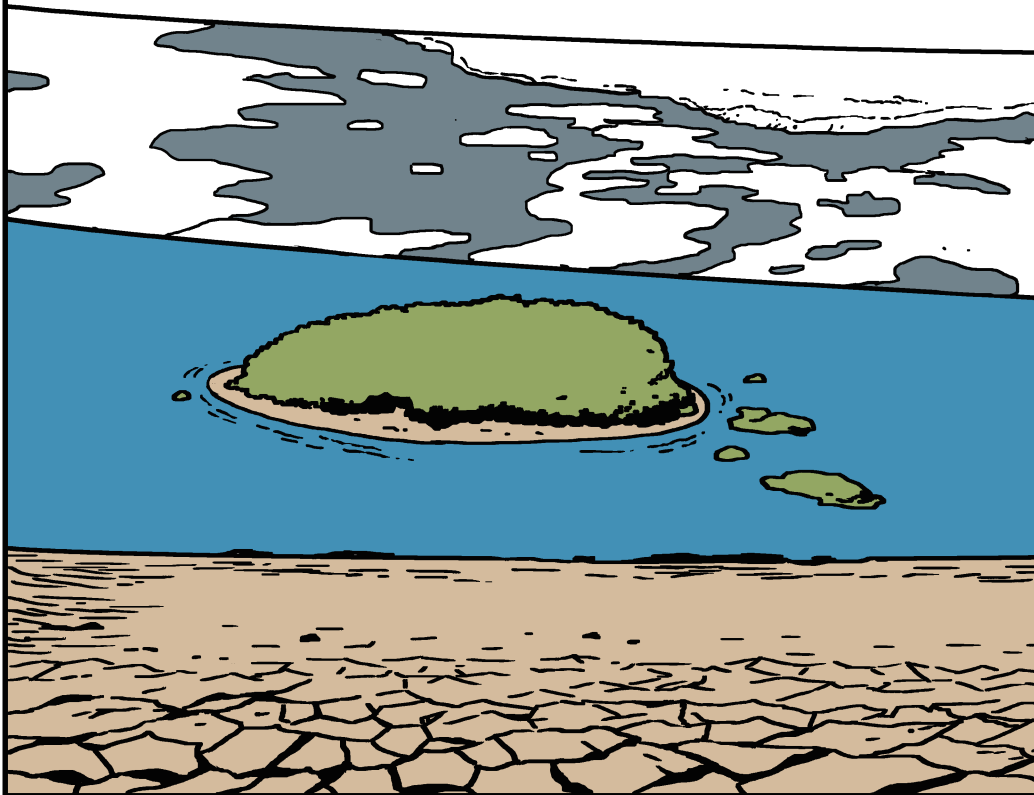
WHAT'S WRONG?  
IS THAT A BAD THING?



EARTH SCIENTISTS  
GIVE WARNING  
ABOUT FUTURE CRISES:

## 1. INCREASING TEMPERATURE

## 2. CLIMATE CHANGE

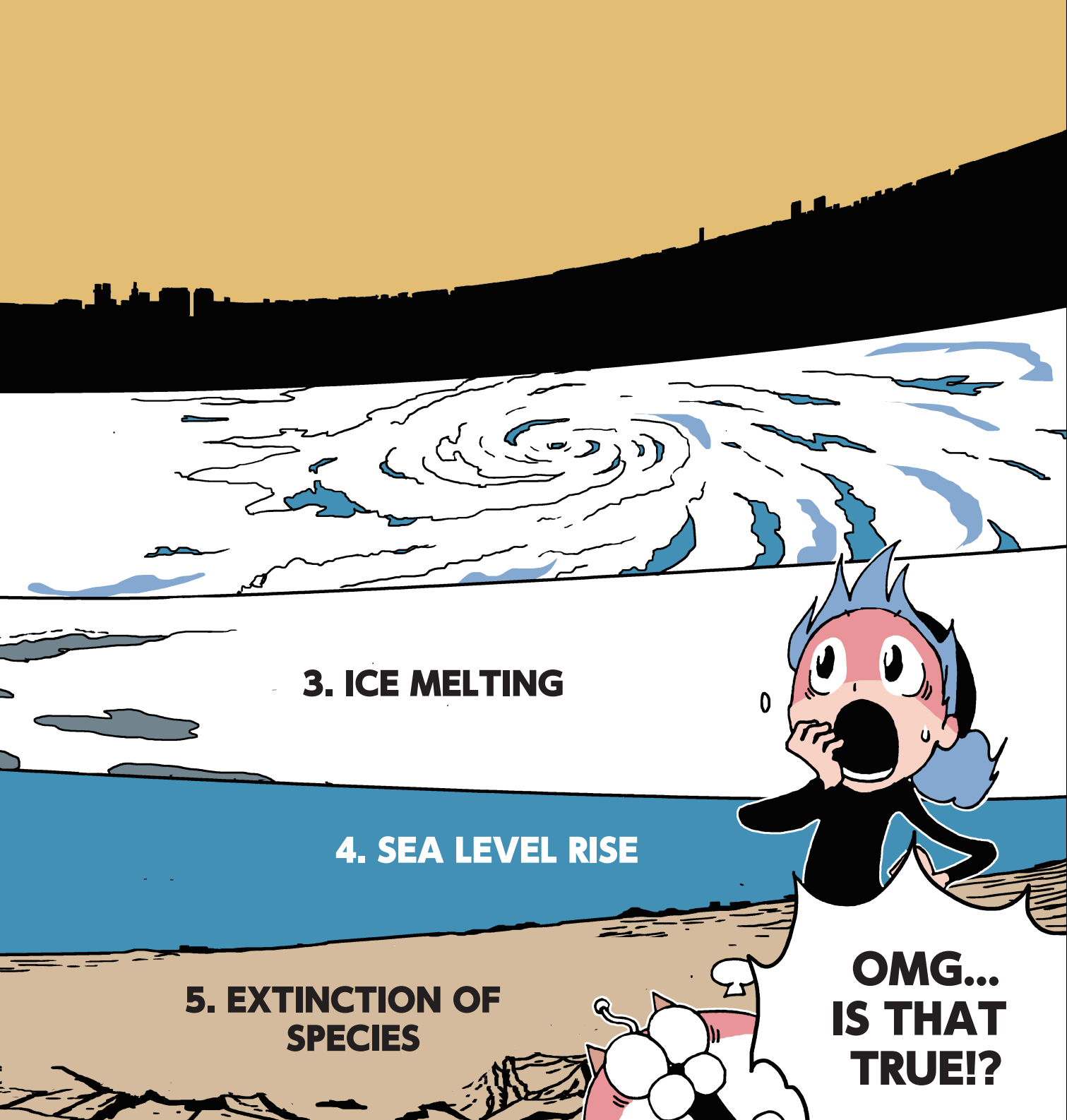


ACCORDING TO FACTS  
GAINED FROM STUDIES,  
WE CAN SAY

**“GLOBAL WARMING  
IS PROGRESSING”**



IN A FEW DECADES,  
HALF A CENTURY,  
A CENTURY,  
AND OVER THE YEARS...  
EARTH'S AVERAGE SURFACE  
AIR TEMPERATURE IS  
INCREASING GRADUALLY.



**3. ICE MELTING**

**4. SEA LEVEL RISE**

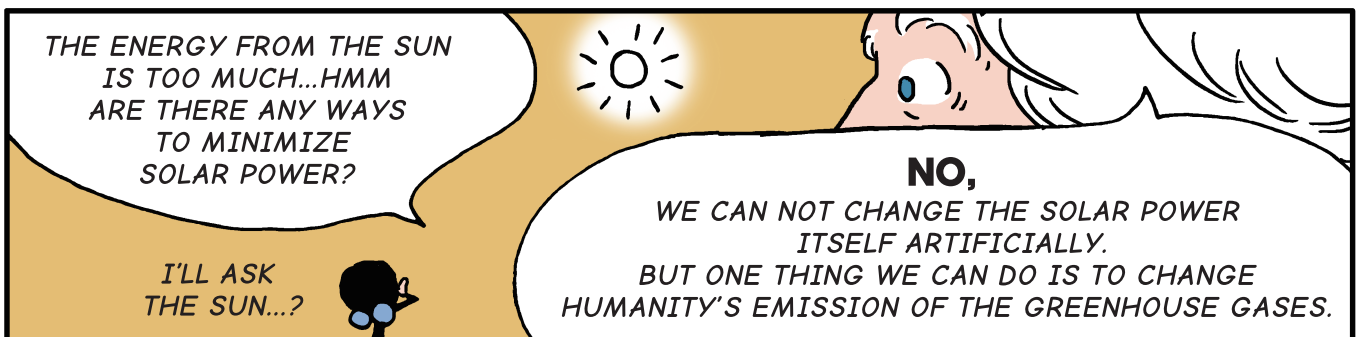
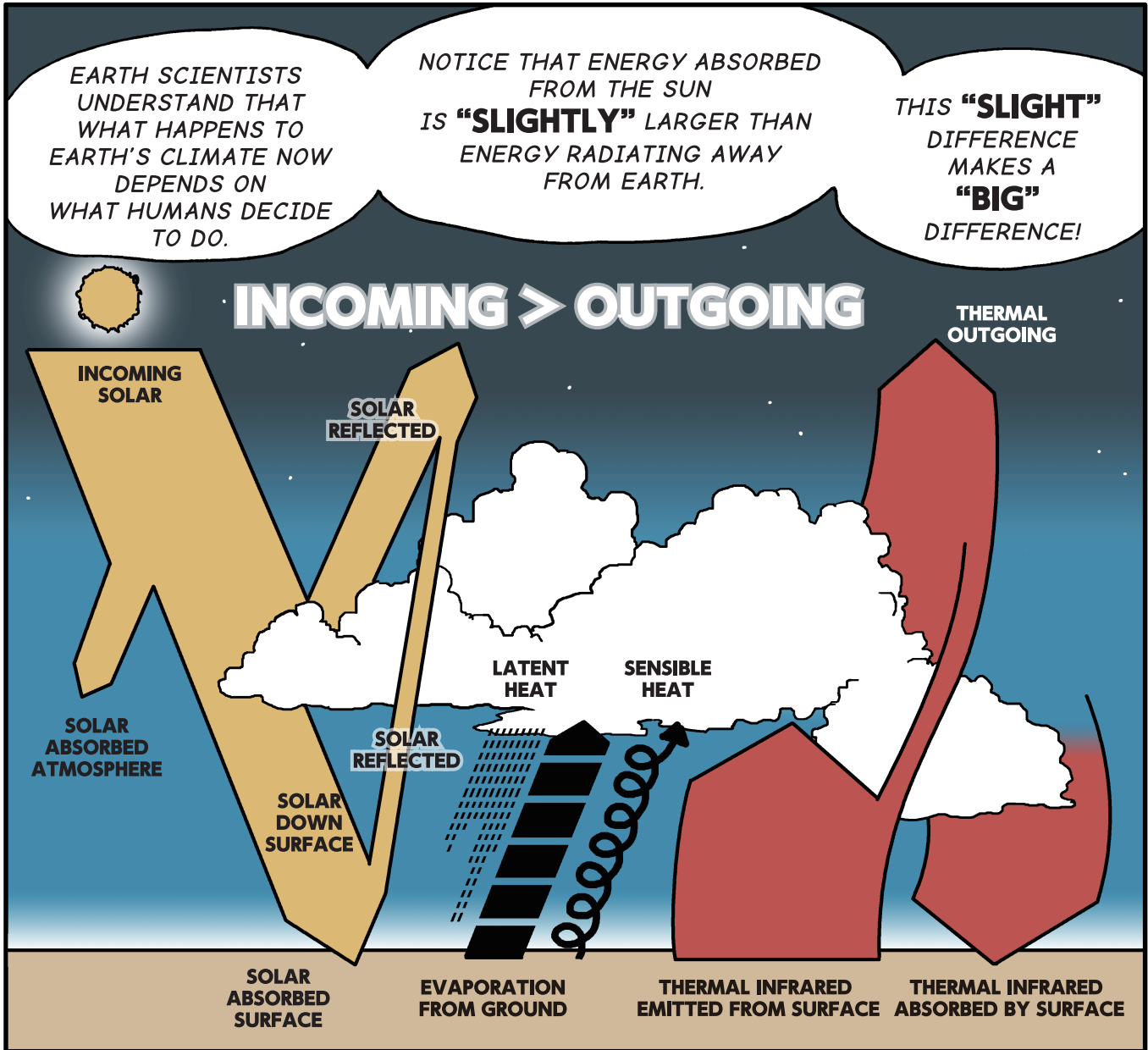
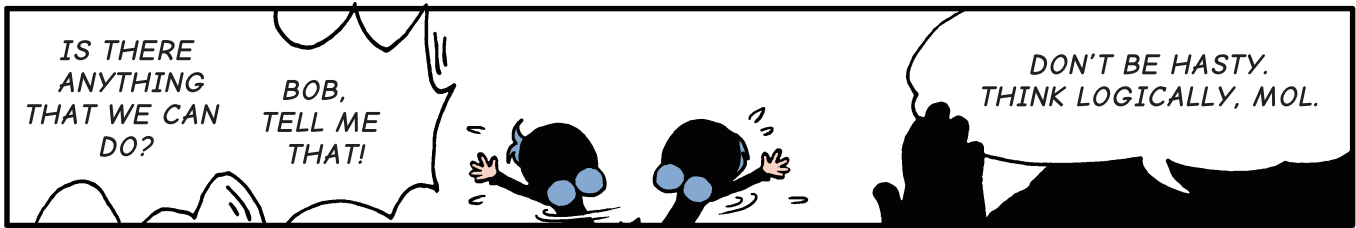
**5. EXTINCTION OF SPECIES**

**OMG...  
IS THAT  
TRUE!?**

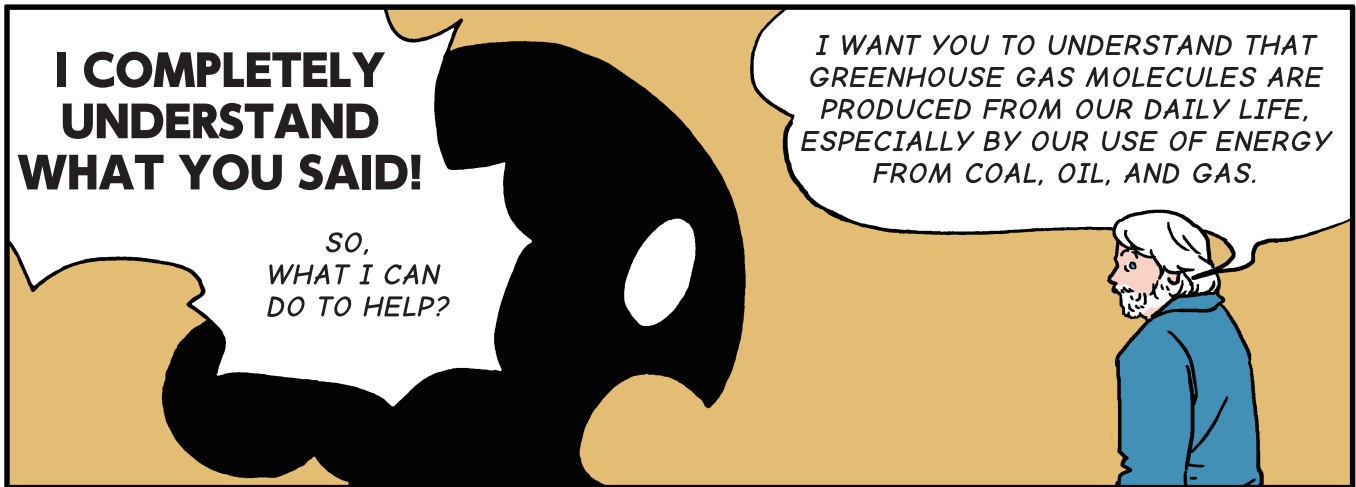
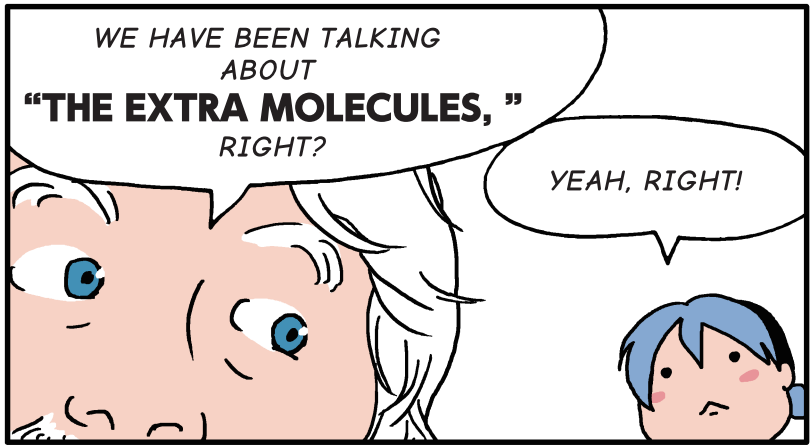
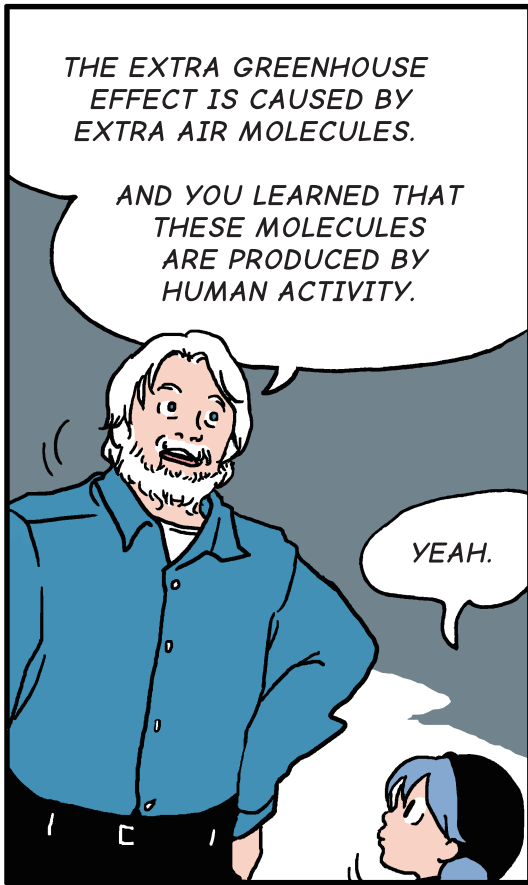


*EARTH SCIENTISTS PREDICT THAT MANY PLANTS AND ANIMALS WILL NO LONGER SURVIVE AFTER EARTH'S GREENHOUSE WARMING.*

*DOES THAT MEAN... WE WON'T BE ABLE TO LIVE ON THE EARTH? NO WAY...*

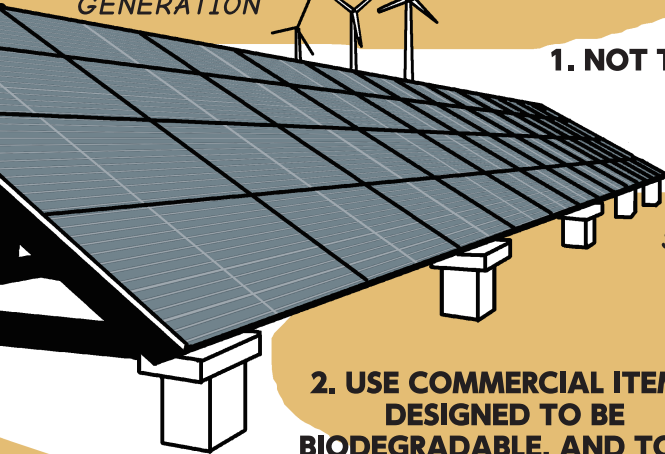






YOU NEED TO FIGURE OUT WHAT PRODUCES THESE MOLECULES. AND THEN HOW TO REDUCE THEIR USE.

WIND POWER GENERATION



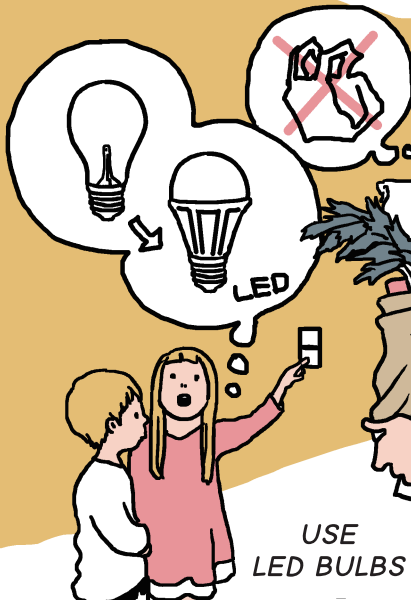
SOLAR ENERGY GENERATION

1. NOT TO DEPEND ON FOSSIL FUELS, AND SWITCH TO ALTERNATIVE FUELS.



2. USE COMMERCIAL ITEMS DESIGNED TO BE BIODEGRADABLE, AND TO BE INFINITELY RECYCLED

LOOK BACK ON YOUR DAILY LIFE AND ASK YOURSELF; "DO I NEED THIS TRULY?" "WOULD IT BE AN UNNECESSARY THING?" "DO I HAVE ALTERNATIVES?"

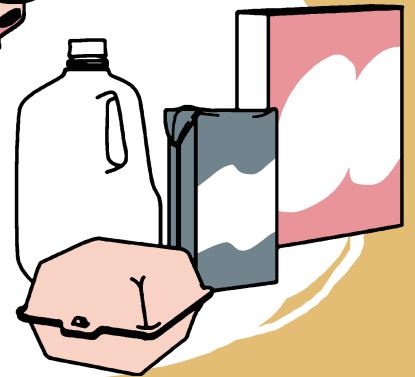


BRING YOUR OWN BAG

CHOOSE REUSABLE CONTAINER

REDUCE PACKAGING AND REFUSE OVER PACKAGING

USE LED BULBS



THERE ARE LARGE-SCALE ENVIRONMENTAL ISSUES THAT NEED TO BE DEALT WITH AT THE NATIONAL AND INTERNATIONAL LEVELS,

SOME PROBLEMS FOR EXPERTS LIKE ENGINEERS AND OTHER SPECIALISTS,

AND ALSO YOU CAN PARTICIPATE IN THE EFFORTS AS AN INDIVIDUAL.

LIMIT  
HOW MUCH  
YOU BUY

EVEN **A SMALL CHANGE** BY THE PEOPLE  
IN YOUR NEIGHBORHOOD,  
CITY, STATE, OR WHOLE COUNTRY,  
OR WHOLE WORLD,  
COULD CREATE **A BIG DIFFERENCE**  
IN ENERGY SAVINGS.



YOU MIGHT THINK  
YOU HAVE NO POWER  
TO OVERCOME YOUR HABIT,  
BUT IN FACT, YOU CAN DO IT.  
JUST CHANGE YOUR MINDSET!

**3. REDUCE CONSUMPTION,  
ESPECIALLY OF MEAT AND FISH.  
USE PLANT BASED FOODS.**

ANIMAL AGRICULTURE IS A MAJOR SOURCE OF  
CO<sub>2</sub>(FROM TRACTORS, etc.) METHANE (EMITTED BY CATTLE,) AND NITROUS OXIDE (FROM FERTILIZER, etc.)  
ANIMAL AGRICULTURE ALSO USES LARGE AMOUNTS OF WATER.



OVERFISHING OF GLOBAL OCEANS HAS  
LED TO COLLAPSES IN OCEAN ECOSYSTEMS.

**4. PLANT TREES  
WHERE POSSIBLE**



SCIENTISTS AND ENGINEERS ALSO  
IMPROVE SCIENCE AND TECHNOLOGY  
WHICH CAN HELP PEOPLE TO GET  
A NEW LIFESTYLE.

HAVE YOU HEARD THIS  
MEANINGFUL POEM?

Little drops of water,  
little grains of sand,  
Make the mighty ocean  
and the pleasant land.  
So the little minutes,  
humble though they be,  
Make the mighty ages  
of eternity.

Julia A. Fletcher Carney (1824-1908)

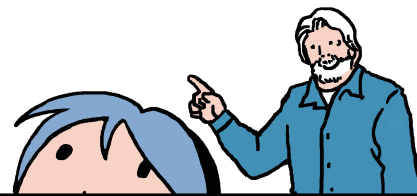
A LITTLE IS LITERALLY A SMALL THING,  
THOUGH, IT MAKES A BIG DIFFERENCE.  
EACH AND EVERY ONE OF US HAVE  
AN IMPORTANT PART  
TO PLAY IN THIS ISSUE.



ALL RIGHT,  
NOW WE CAN SUM UP  
TODAY'S FINDINGS:

1. NORMALLY, EARTH GAINS ENERGY FROM THE SUN, AND RADIATES INFRARED ENERGY BACK INTO SPACE. HOWEVER EARTH SCIENTISTS DETECT AN **ENERGY IMBALANCE** FROM THEIR STUDIES.
2. OUR EARTH IS IN A STATE OF **"GLOBAL WARMING"**.
3. GLOBAL WARMING IS THE INCREASE OF EARTH'S AVERAGE SURFACE AIR TEMPERATURE, CAUSED BY **"GREENHOUSE GASES"** IN THE AIR, WHICH ABSORB SOME OF EARTH'S INFRARED RADIATION.
4. ONE THING WE CAN DO IS TO CHANGE HUMANS' EMISSION OF THE GREENHOUSE GASES. SPECIFICALLY, WE NEED TO JOIN EFFORTS **TO REDUCE COAL, OIL, AND GAS IN OUR DAILY LIFE.**

**"WHAT WE CAN DO  
FOR THIS IS TO CHANGE  
OUR LIFESTYLE HABITS!"**



IT WAS A LONG  
STORY AND  
YOU ARE FORGETTING ME,  
MOL AND BOB?

**NOOO...  
MIRUBO!**

WE HAD

FORGOTTEN YOU!

I TALKED QUITE A LONG WHILE  
WHAT I JUST WANTED TO SAY WAS;  
YOUR BAD STATE IS CAUSED BY  
**ENERGY IMBALANCE.**

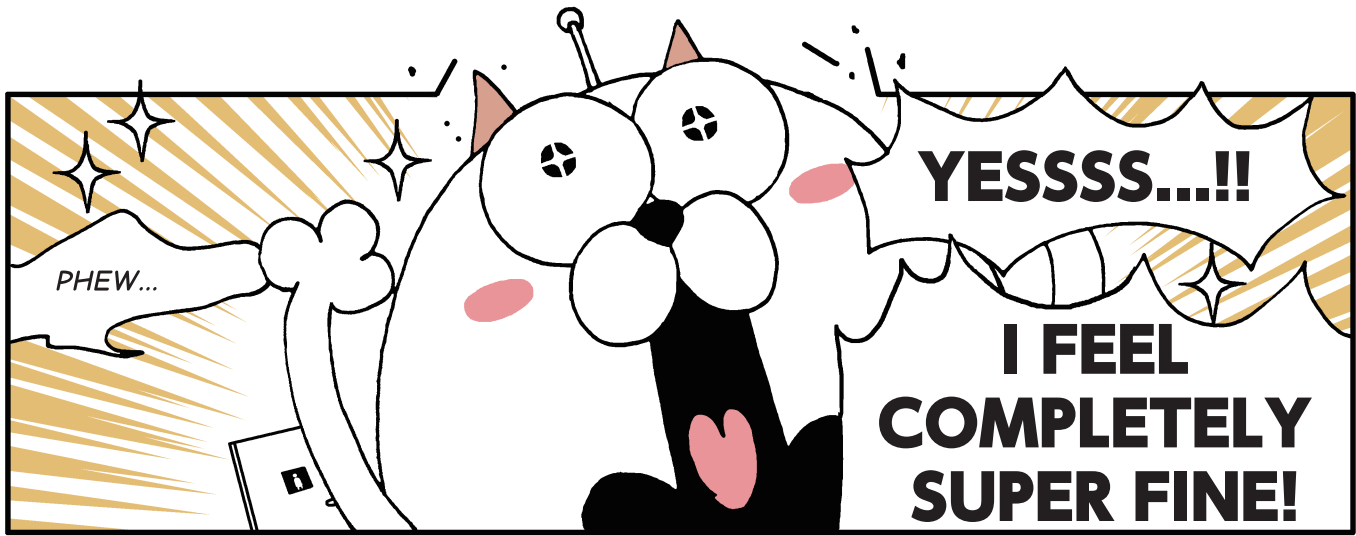
I MEAN, WHEN YOU EAT TOO MUCH,  
THEN YOU NEED TO EXCRETE FROM  
YOUR BODY APPROPRIATELY,  
FOR YOUR WEIGHT TO STAY  
**"BALANCED."**

FIND AND REMOVE  
CAUSATIVE FACTORS,

YOU KNOW,  
YOU SHOULDN'T EAT  
ANY MORE TODAY!

AND...  
GO AHEAD!

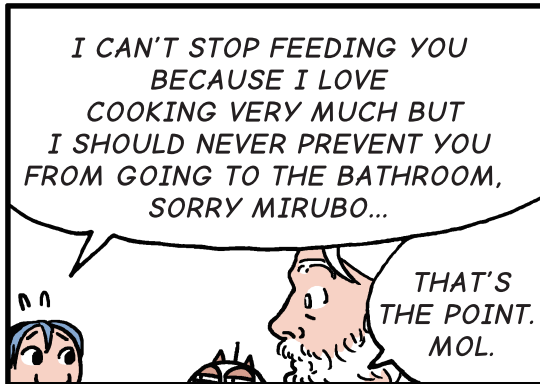
**EXPLO-  
SIOOON!!**



PHEW...

**YESSSS...!!**

**I FEEL  
COMPLETELY  
SUPER FINE!**



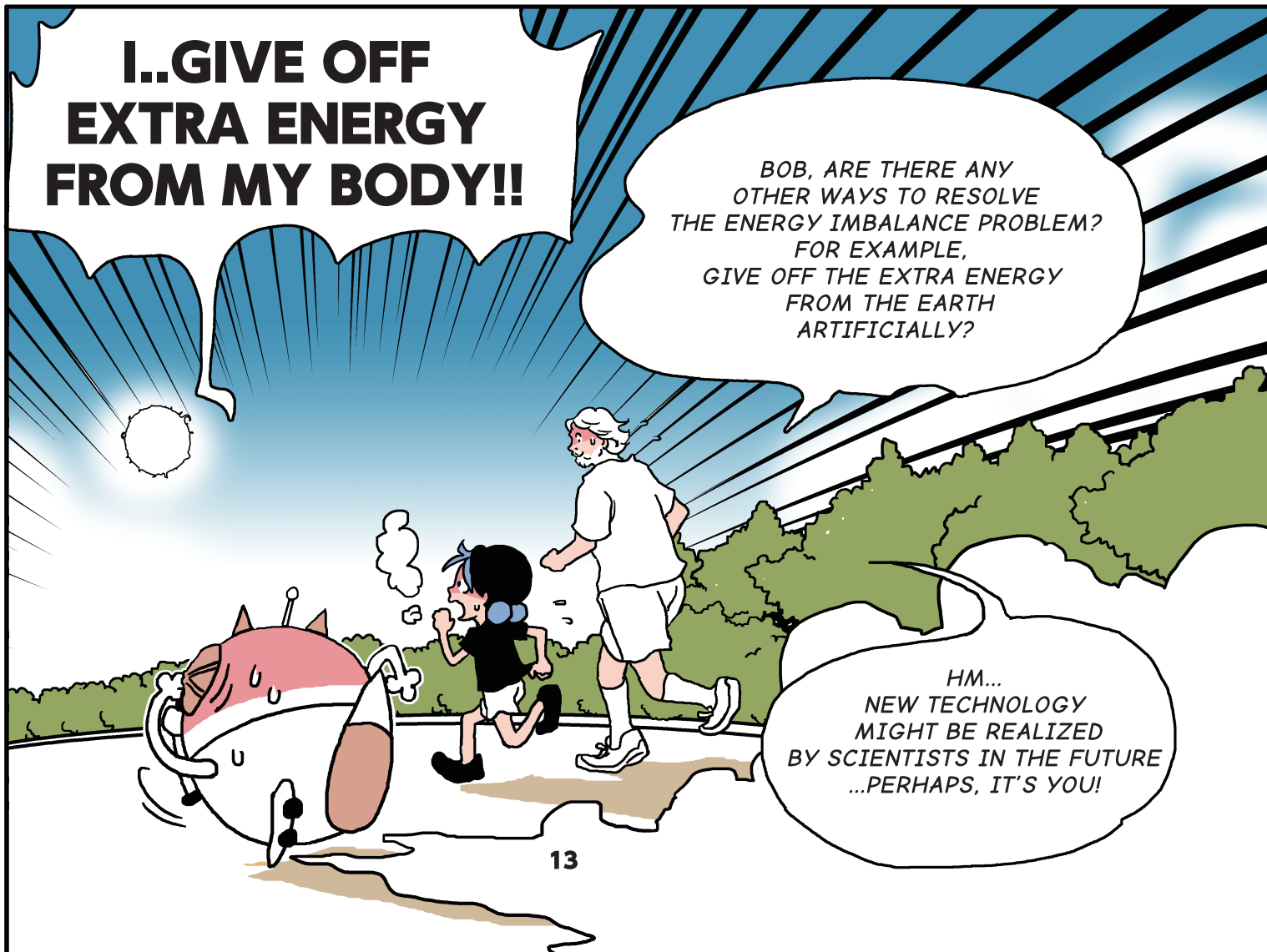
I CAN'T STOP FEEDING YOU  
BECAUSE I LOVE  
COOKING VERY MUCH BUT  
I SHOULD NEVER PREVENT YOU  
FROM GOING TO THE BATHROOM,  
SORRY MIRUBO...

THAT'S  
THE POINT.  
MOL.



AND HERE IS ONE MORE  
GOOD IDEA  
TO REFRESH YOUR BODY,  
MIRUBO.

YOU HAVE TO  
INCORPORATE PHYSICAL  
ACTIVITY INTO YOUR  
DAILY LIFE!



**I..GIVE OFF  
EXTRA ENERGY  
FROM MY BODY!!**

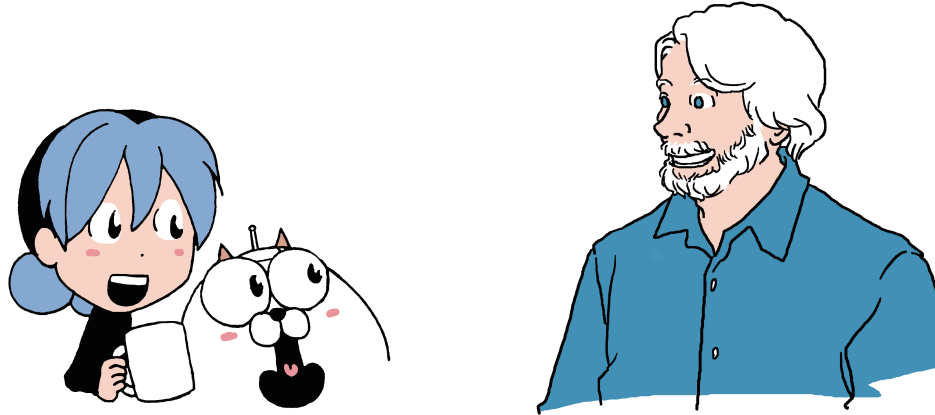
BOB, ARE THERE ANY  
OTHER WAYS TO RESOLVE  
THE ENERGY IMBALANCE PROBLEM?  
FOR EXAMPLE,  
GIVE OFF THE EXTRA ENERGY  
FROM THE EARTH  
ARTIFICIALLY?


HM...  
NEW TECHNOLOGY  
MIGHT BE REALIZED  
BY SCIENTISTS IN THE FUTURE  
...PERHAPS, IT'S YOU!


# Learning Earth Science with MIRUBO

# Sun, Moon and Climate


## Talking with EARTH SCIENTIST




 **MOL:** *Bob, thank you for explaining how the greenhouse gases make it difficult for Earth to cool, which is giving her a fever. Does the Sun ever get a fever?*


 **BOB:** *Good question! Yes, it's true! Approximately every 11 years the Sun has a slight fever of about 1 degree Celsius. That's a very small increase for the Sun, since its "normal" temperature is about 5770 degrees Celsius, much higher than Earth's normal global average temperature of about 14 degrees Celsius. Also, during the past 35 years, while Earth's fever has been increasing, the Sun's fever has come and gone 3 times, but the Sun has not had a steadily increasing fever like Earth's.*


 **MOL:** *What about the Moon? Has it had a fever?*


 **BOB:** *The bright side of the Moon facing the Sun runs a high fever. Also since the Moon has no air flowing around to equalize the temperature, the side away from the Sun is very cold, much colder than anywhere on Earth, even Antarctica. As the Moon orbits around Earth every month, all sides of her get baked by the Sun, and also all sides of her turn freezing cold whenever not in the sunlight.*


 **MOL:** *Wow! Isn't there anyplace on the Moon that has a comfortable temperature?*


 **BOB:** *Yes! On the "terminator" which is the moving boundary between the sunlit side and the dark side. There it is about 14 Celsius, just like Earth's average temperature. Even there, though, you need to wear a spacesuit that supplies air to breath, and also to maintain a comfortable temperature as the terminator moves away from you.*


 **MOL:** *Couldn't I just dig down and bury myself in the Moon dust until the terminator comes back?*

 **BOB:** *That's a great idea! You'd still need the spacesuit for air. You would only need to dig down 1 to 3 feet to reach a comfortable temperature. You would need to be careful that the Moon dust doesn't clog up the operation of your spacesuit.*

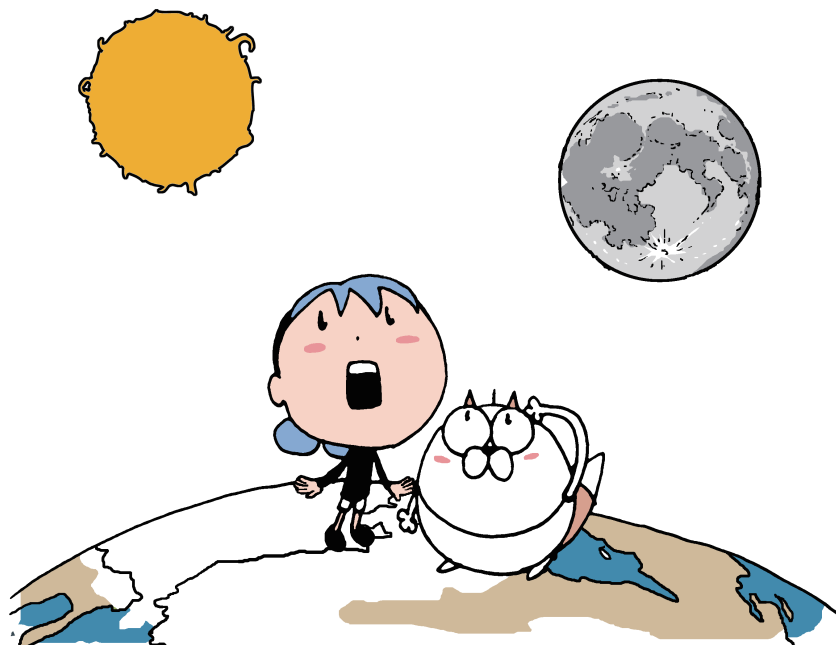
 **MOL:** *Maybe we could outfit Mirubo to dig a tunnel in the Moon. Since Mirubo is a robot, he doesn't need to worry about air supply.*

 **BOB:** *Another great idea! What we'd really like Mirubo to do is dig deeper, down to 30 feet, and measure the temperature very accurately all the way down.*

 **MOL:** *I'm sure he can do that! What might we learn?*

 **BOB:** *In the upper few feet the temperature will vary with the annual and 11-year cycles, so we'd get a good measure of those. As Mirubo goes deeper, only the slower variations in the Sun will matter, and by the time he is 30 feet down, we could discover whether the Sun was brighter or dimmer 400 years ago, when Galileo and others were first beginning to observe sunspots with telescopes. Although we know about the sunspots back then, we don't have any direct measurements of the Sun's brightness or temperature. Mirubo's could be the first!*

 **MOL:** *Great! Mirubo and I will start working on that right away!*



Miyahara H., G. Wen, R.F. Cahalan, and A. Ohmura (2008). Deriving Historical Total Solar Irradiance from Lunar Borehole Temperatures *Geophys. Res. Lett.*, 35, L02716.  
doi:10.1029/2007GL032171

# Sun, Moon and Climate

**Science Educational Content**  
**Dr. Robert F. Cahalan**  
**Character Designs, Artwork, and Story**  
**Hayanon**

## About this project

Book 1 of several about climate change, NASA scientists discuss the issues with two manga style characters, Mirubo the robotic dog, and Mol, an elementary school girl who is enthusiastic about science. These are intended to excite the curiosity of children and their families and friends about changes in Earth's climate, and to encourage them to get involved in their community's action efforts.

## About GSFC

Goddard Space Flight Center is a major NASA center located in Greenbelt, Maryland, and is the largest combined organization of scientists and engineers in the United States dedicated to increasing knowledge of the Earth, the Solar System, and the Universe via observations from space.

## About authors

Hayanon has more than 15 years' experience in educational publishing in Japan as a science manga artist. She holds a Bachelor's degree in physics and a Master's degree in education. The characters Mirubo and Mol, created by Hayanon also appear in several books distributed by Nagoya University. (See references below.)

Dr. Robert F. Cahalan (Bob) has done scientific research for more than 40 years, is a Fellow of the American Meteorological Society, Emeritus President of the International Radiation Commission, Emeritus Chief of Goddard's Climate and Radiation Laboratory, and Project Scientist for NASA's SORCE mission, a satellite that measured the Sun's energy input to Earth during solar cycle 23, and continues during the current solar cycle 24.

## Thanks to

Bob and Hayanon thank Marion August and Cathy Newman of SSAI for their tireless efforts in arranging for the completion of this work.

## References

This booklet may be downloaded as a PDF file at:

<https://science.gsfc.nasa.gov/610/manga.html>

Read about climate change in depth at:

<http://earthobservatory.nasa.gov>

See a summary of five important climate change indicators at:

<http://climate.nasa.gov>

Learn how NASA Earth observations and research are coordinated with several other US federal agencies, and international partners, at:

<http://www.globalchange.gov>

Mol and Mirubo also appear in science manga books at:

<http://www.stelab.nagoya-u.ac.jp/ste-www1/doce/outreach.html>



Produced by NASA's Goddard Space Flight Center  
April 2016

