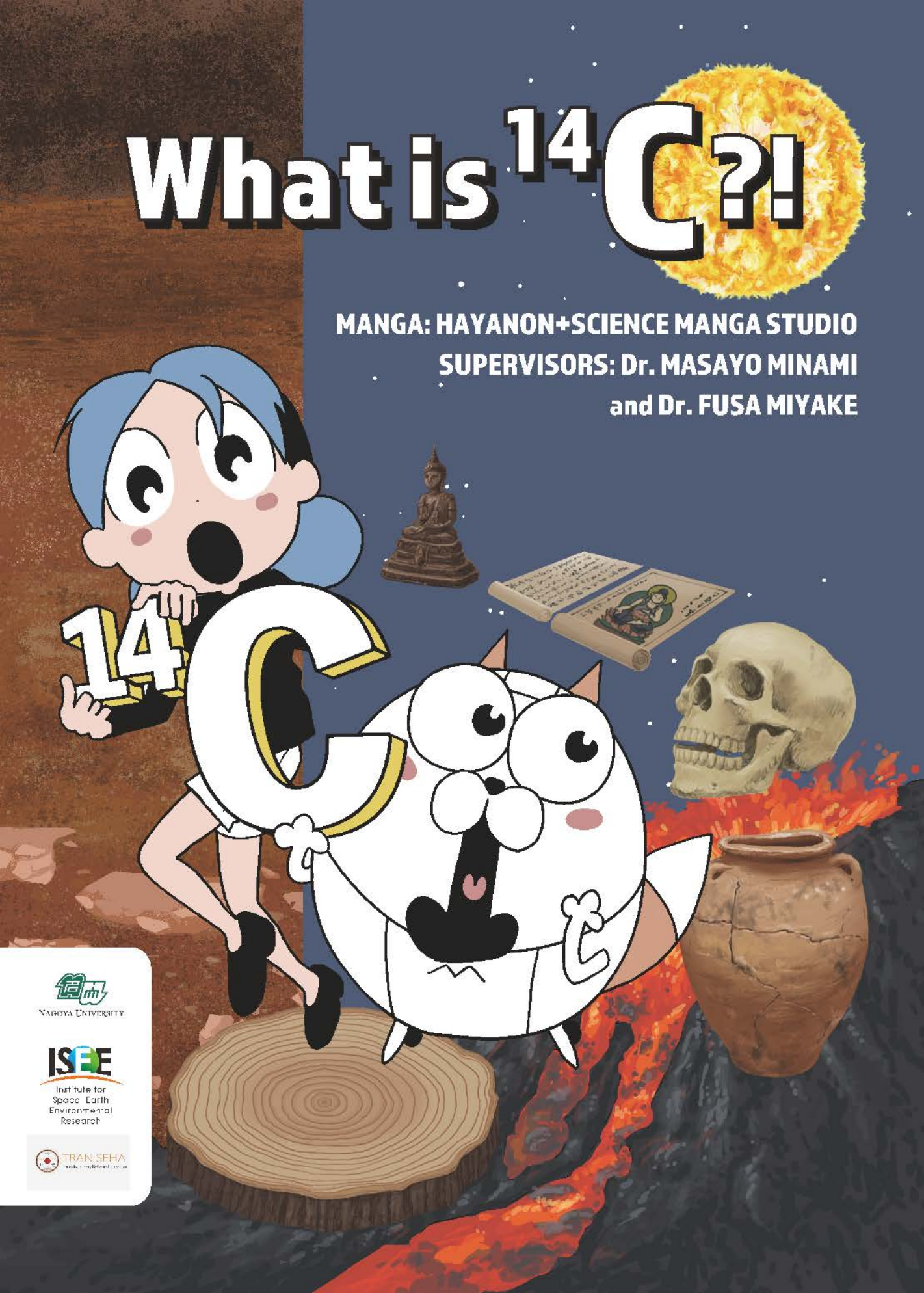
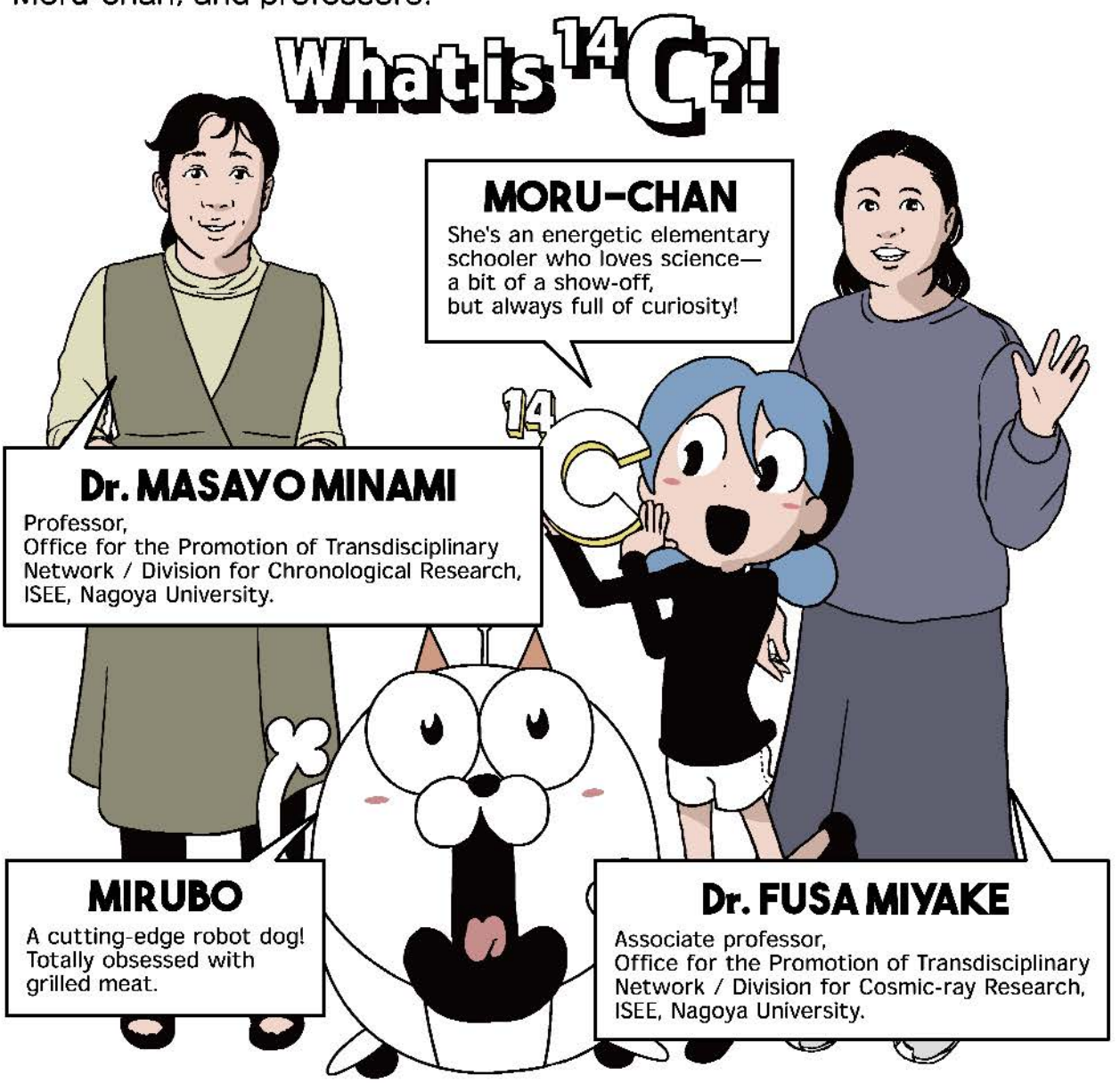
What is ^{14}C?!

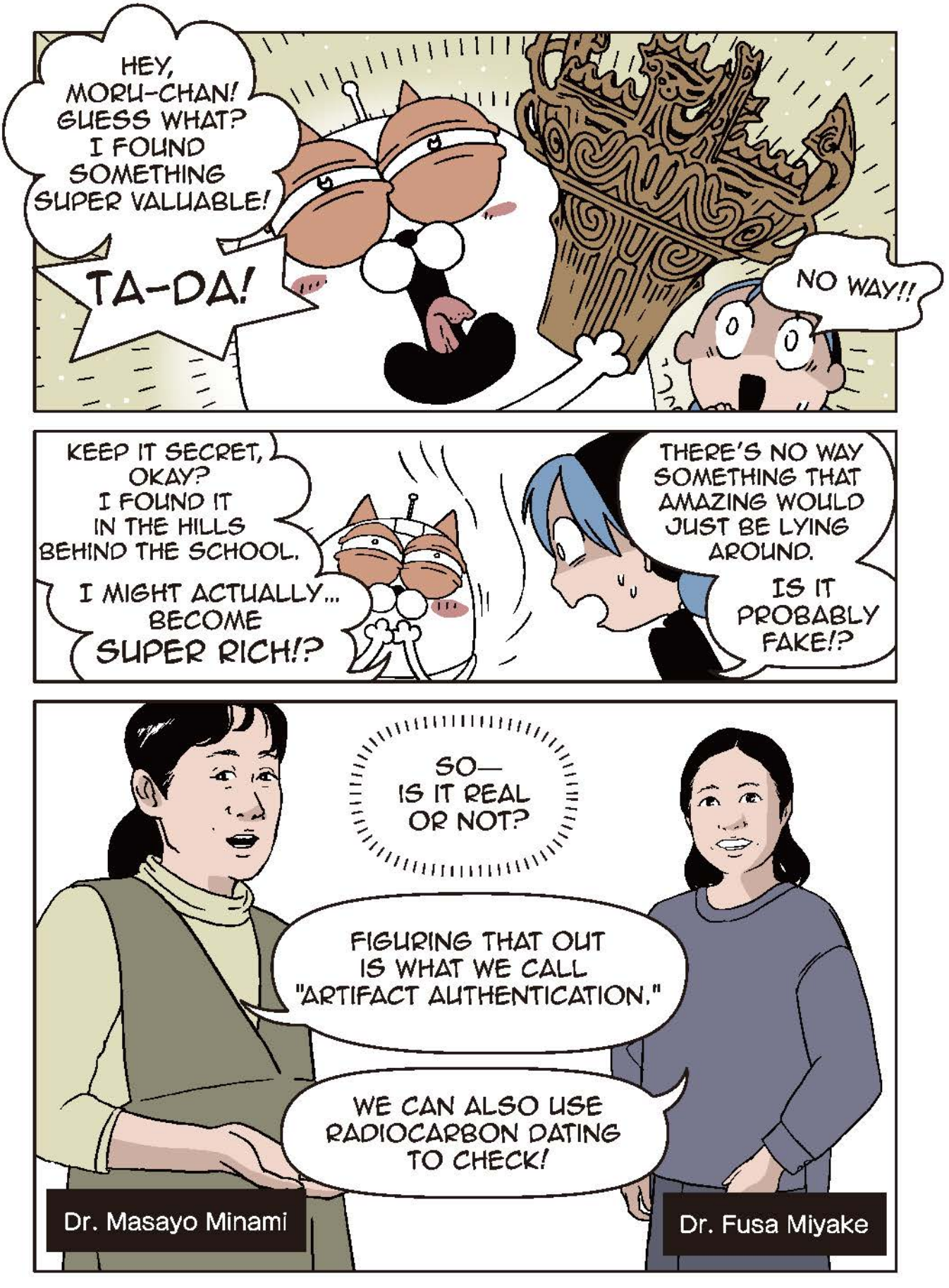
MANGA: HAYANON+SCIENCE MANGA STUDIO
SUPERVISORS: Dr. MASAYO MINAMI
and Dr. FUSA MIYAKE

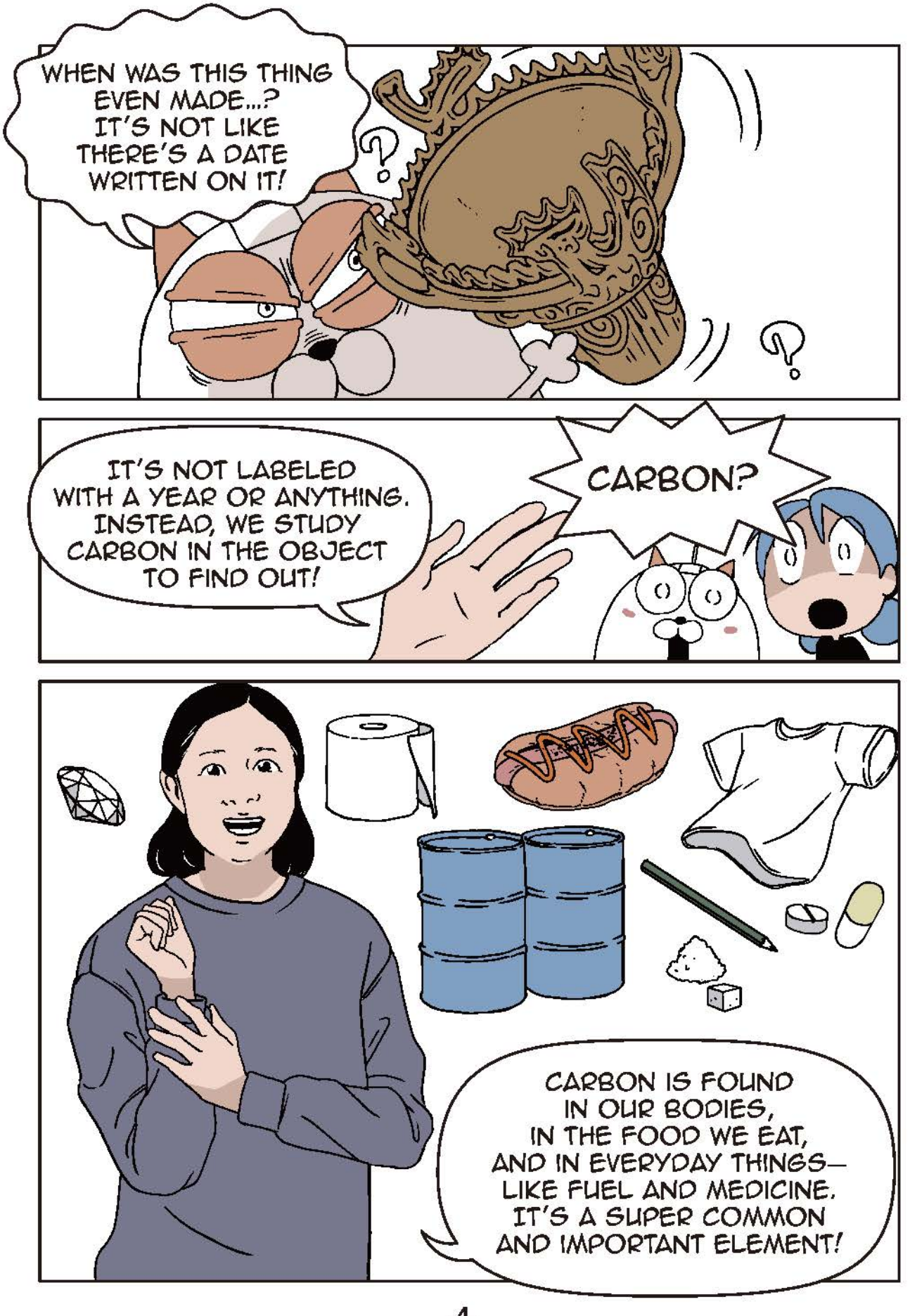


NAGOYA UNIVERSITY
ISEE
Institute for Space-Earth Environmental Research
TRANSCHA

Can we really learn about the past just by studying "carbon"?
Carbon is all around us—in our bodies, in the food we eat, and in everyday objects. A special type of carbon called ^{14}C (Carbon-14) is produced in atmosphere by cosmic rays from space. It is known to decay over time, with half of it disappearing every 5,730 years. This unique property enables scientists to determine the age of various things, and it is useful in fields such as Earth science, space science, archaeology, and anthropology. Researchers have even used it to study past changes in the Earth's environment and Sun's activity for parallelism. In this comic, let's learn all about ^{14}C with Mirubo, Moru-chan, and professors!




HEY, MORU-CHAN! GUESS WHAT? I FOUND SOMETHING SUPER VALUABLE!
TA-DA!
NO WAY!!
KEEP IT SECRET, OKAY? I FOUND IT IN THE HILLS BEHIND THE SCHOOL.
I MIGHT ACTUALLY... BECOME SUPER RICH!?
THERE'S NO WAY SOMETHING THAT AMAZING WOULD JUST BE LYING AROUND.
IS IT PROBABLY FAKE!?
SO— IS IT REAL OR NOT?
FIGURING THAT OUT IS WHAT WE CALL "ARTIFACT AUTHENTICATION."
WE CAN ALSO USE RADIOCARBON DATING TO CHECK!
Dr. Masayo Minami
Dr. Fusa Miyake

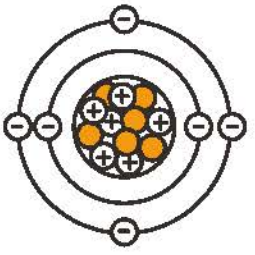

WHEN WAS THIS THING EVEN MADE...? IT'S NOT LIKE THERE'S A DATE WRITTEN ON IT!
IT'S NOT LABELED WITH A YEAR OR ANYTHING. INSTEAD, WE STUDY CARBON IN THE OBJECT TO FIND OUT!
CARBON?
CARBON IS FOUND IN OUR BODIES, IN THE FOOD WE EAT, AND IN EVERYDAY THINGS— LIKE FUEL AND MEDICINE. IT'S A SUPER COMMON AND IMPORTANT ELEMENT!

CARBON ATOMS HAVE A NUCLEUS WITH 6 PROTONS AT THE CENTER.

NORMALLY, THEY ALSO HAVE 6 NEUTRONS, BUT SOME HAVE 7 OR EVEN 8.

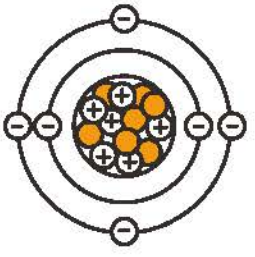
ATOMS WITH THE SAME NUMBER OF PROTONS BUT DIFFERENT NUMBERS OF NEUTRONS ARE CALLED ISOTOPES.

6 Protons ⊕
6 Neutrons ●



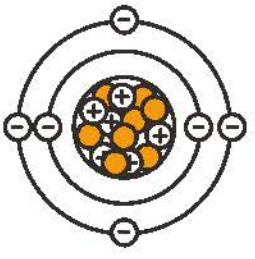
^{12}C

6 Protons ⊕
7 Neutrons ●



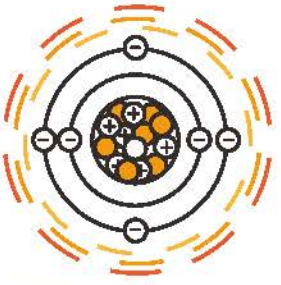
^{13}C

6 Protons ⊕
8 Neutrons ●



^{14}C

ONE OF THESE ISOTOPES, ^{14}C, OR CARBON-14, HAS EXTRA NEUTRONS, MAKING IT UNSTABLE.



^{14}C UNDERGOES RADIOACTIVE DECAY...

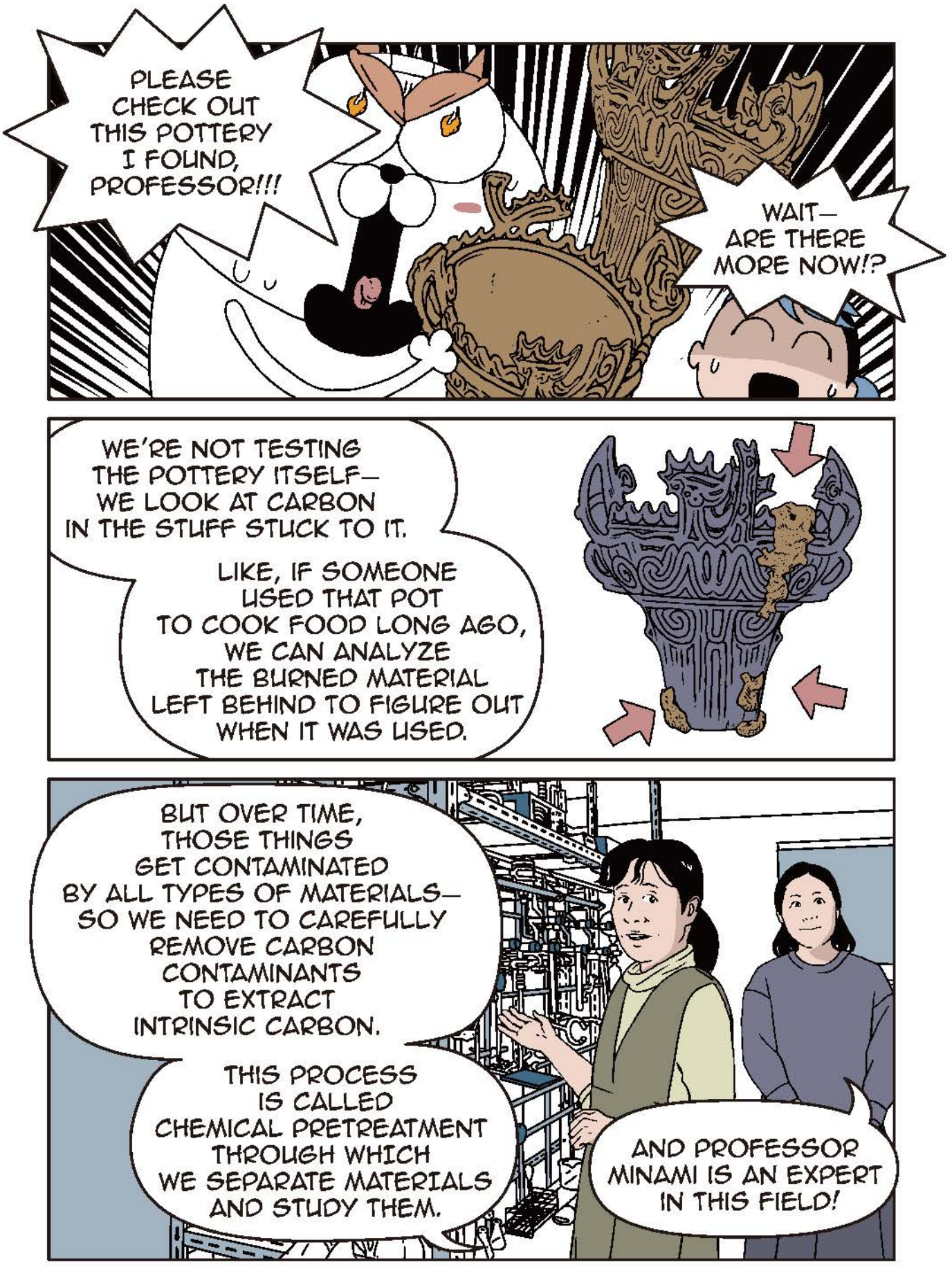
IT DECAYS...

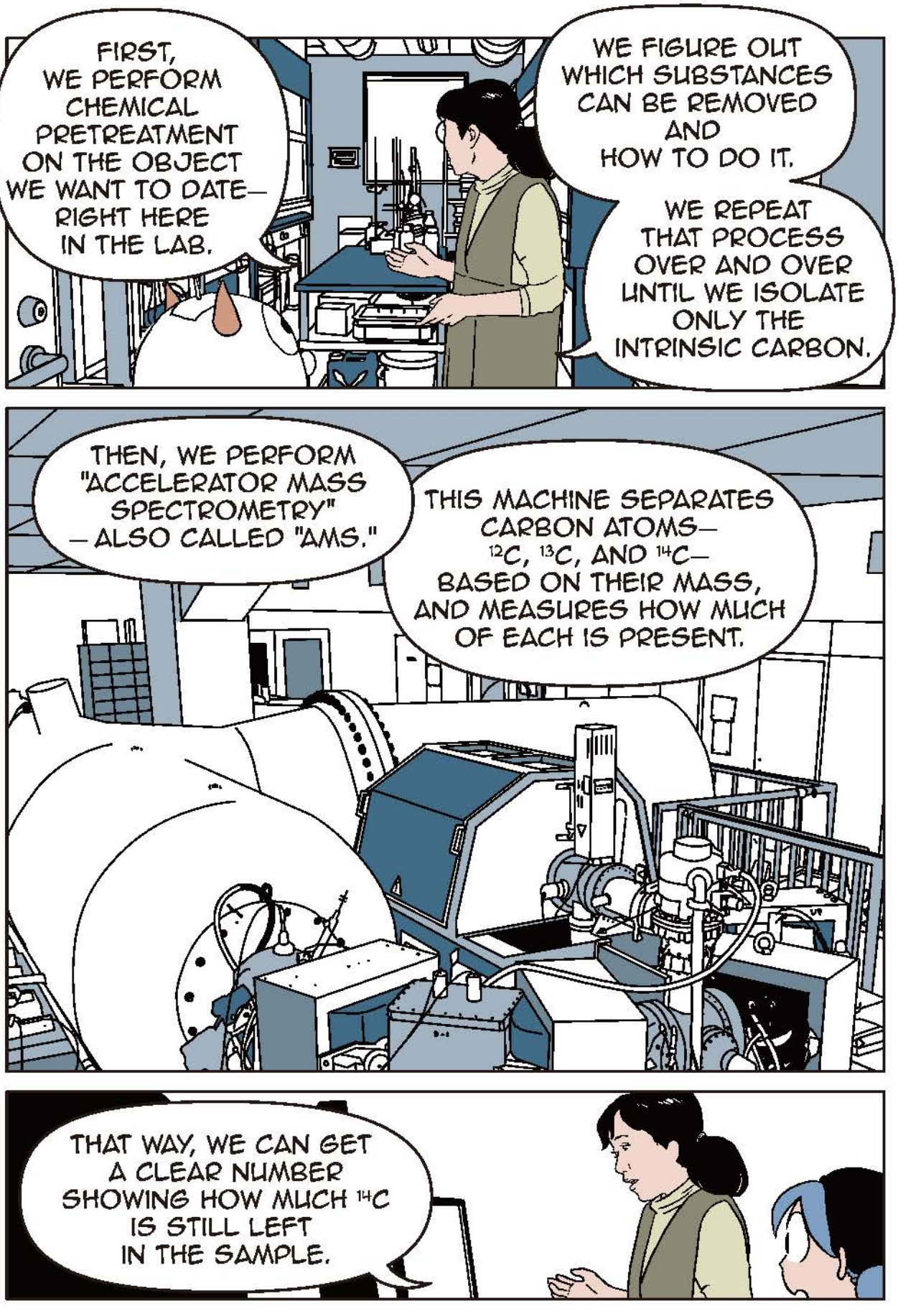
AND DECAYS...

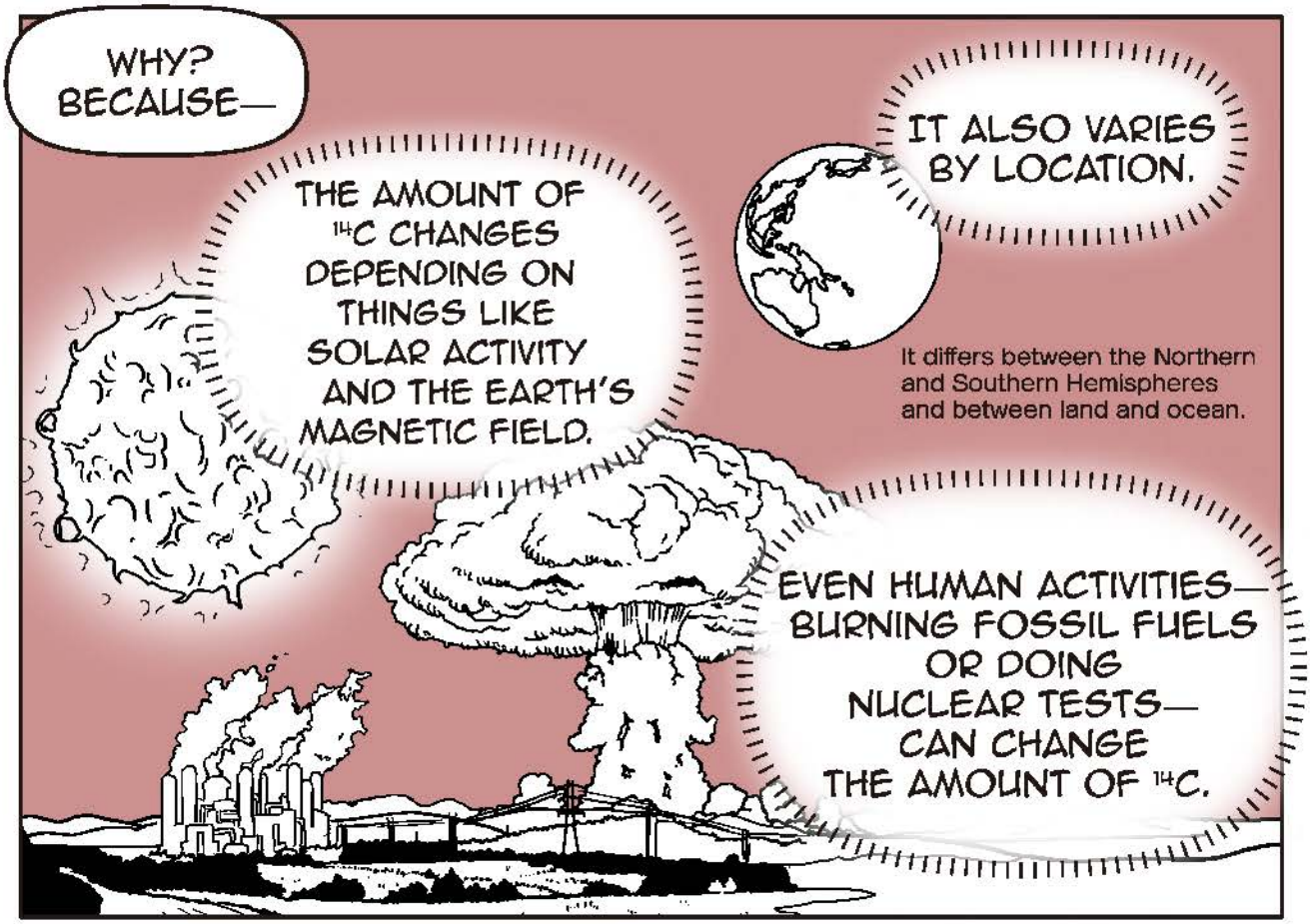
UNTIL HALF OF IT IS GONE— AFTER 5,730 YEARS!

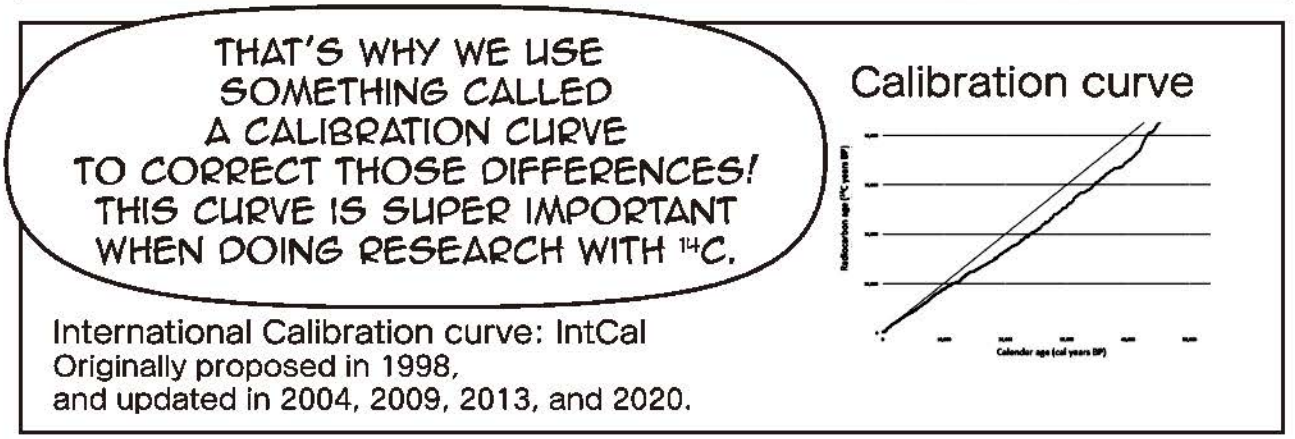
THIS IS CALLED THE "HALF-LIFE."


^{14}C IS PRODUCED IN THE EARTH'S ATMOSPHERE BY COSMIC RAYS— RADIATION THAT COMES FROM OUTER SPACE.
PLANTS AND ANIMALS TAKE IN THIS ^{14}C.
WAIT, WE DO TOO!
EVEN ME?
ONCE A LIVING THING DIES, IT STOPS TAKING IN ANY NEW ^{14}C.
BY MEASURING THE AMOUNT OF ^{14}C LEFT IN THE BODY—
WE CAN FIGURE OUT THE AGE OF AN OBJECT!
THIS METHOD IS CALLED "RADIOCARBON DATING," AND IT'S WIDELY USED IN ARCHAEOLOGY, GEOLOGY, AND MANY OTHER FIELDS.

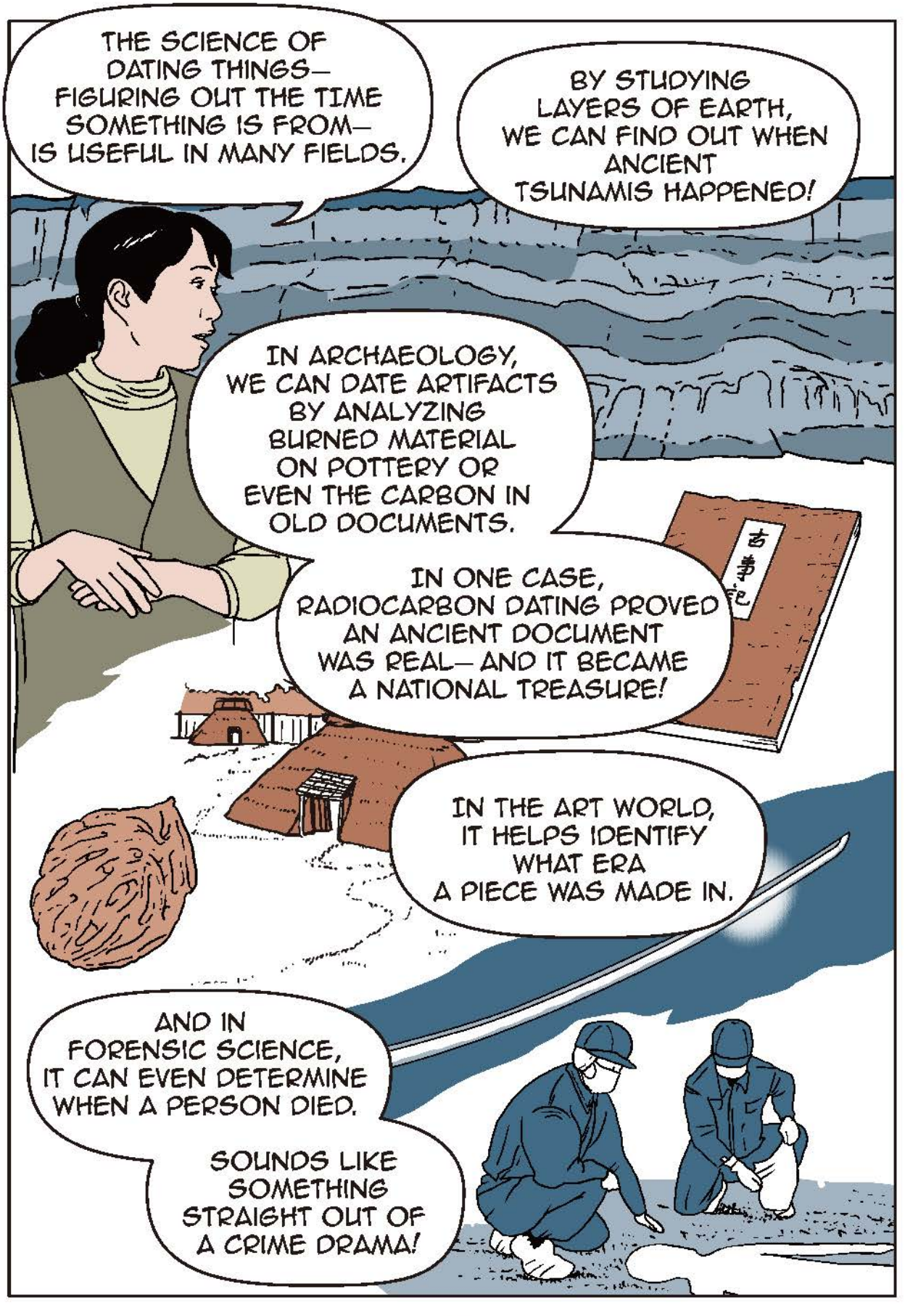

PLEASE CHECK OUT THIS POTTERY I FOUND, PROFESSOR!!!
WAIT— ARE THERE MORE NOW!?
WE'RE NOT TESTING THE POTTERY ITSELF— WE LOOK AT CARBON IN THE STUFF STUCK TO IT.
LIKE, IF SOMEONE USED THAT POT TO COOK FOOD LONG AGO, WE CAN ANALYZE THE BURNED MATERIAL LEFT BEHIND TO FIGURE OUT WHEN IT WAS USED.
BUT OVER TIME, THOSE THINGS GET CONTAMINATED BY ALL TYPES OF MATERIALS— SO WE NEED TO CAREFULLY REMOVE CARBON CONTAMINANTS TO EXTRACT INTRINSIC CARBON.
THIS PROCESS IS CALLED CHEMICAL PRETREATMENT THROUGH WHICH WE SEPARATE MATERIALS AND STUDY THEM.
AND PROFESSOR MINAMI IS AN EXPERT IN THIS FIELD!

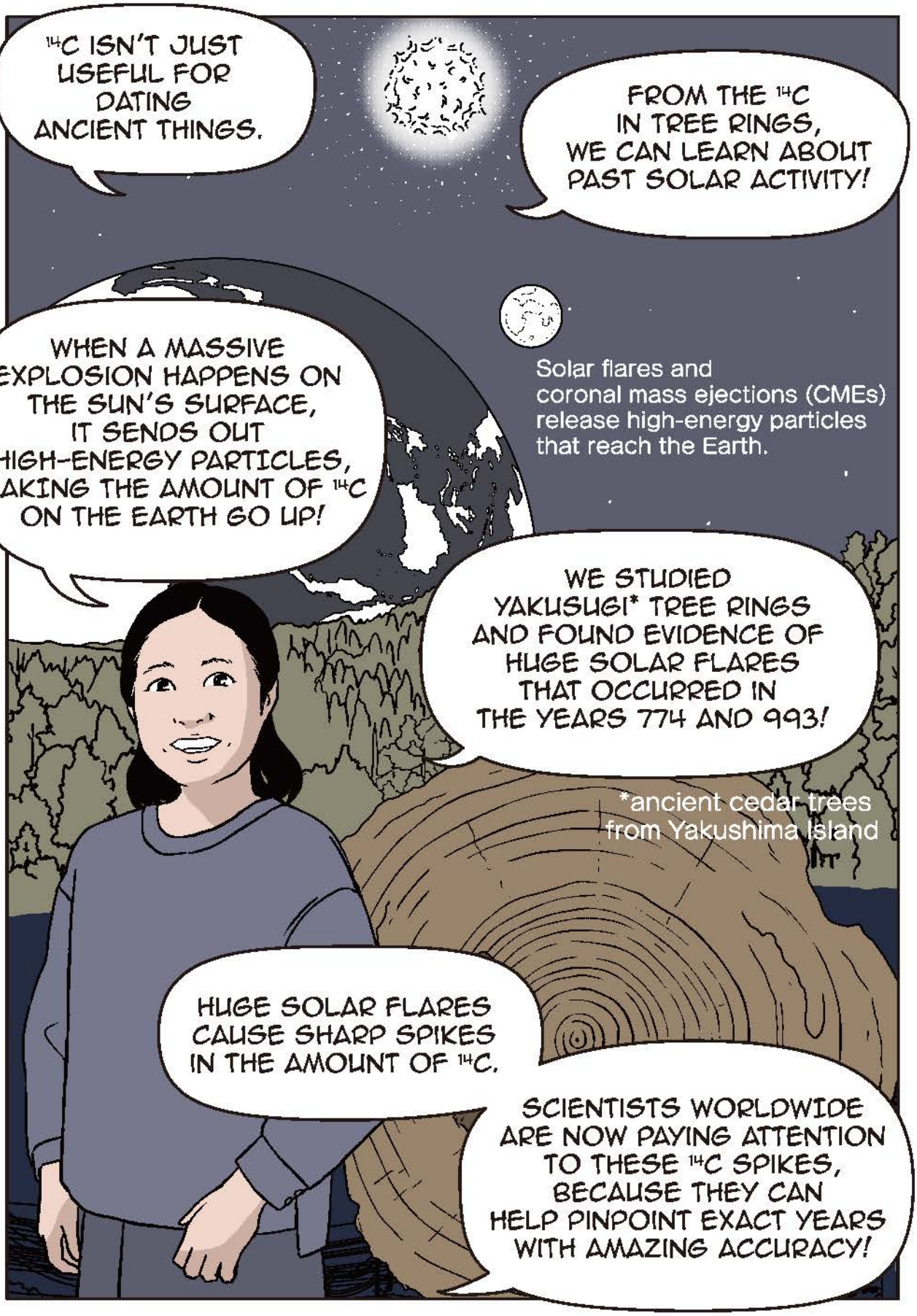

FIRST, WE PERFORM CHEMICAL PRETREATMENT ON THE OBJECT WE WANT TO DATE— RIGHT HERE IN THE LAB.
WE FIGURE OUT WHICH SUBSTANCES CAN BE REMOVED AND HOW TO DO IT.
WE REPEAT THAT PROCESS OVER AND OVER UNTIL WE ISOLATE ONLY THE INTRINSIC CARBON.
THEN, WE PERFORM "ACCELERATOR MASS SPECTROMETRY" —ALSO CALLED "AMS."
THIS MACHINE SEPARATES CARBON ATOMS— ^{12}C, ^{13}C, AND ^{14}C— BASED ON THEIR MASS, AND MEASURES HOW MUCH OF EACH IS PRESENT.
THAT WAY, WE CAN GET A CLEAR NUMBER SHOWING HOW MUCH ^{14}C IS STILL LEFT IN THE SAMPLE.

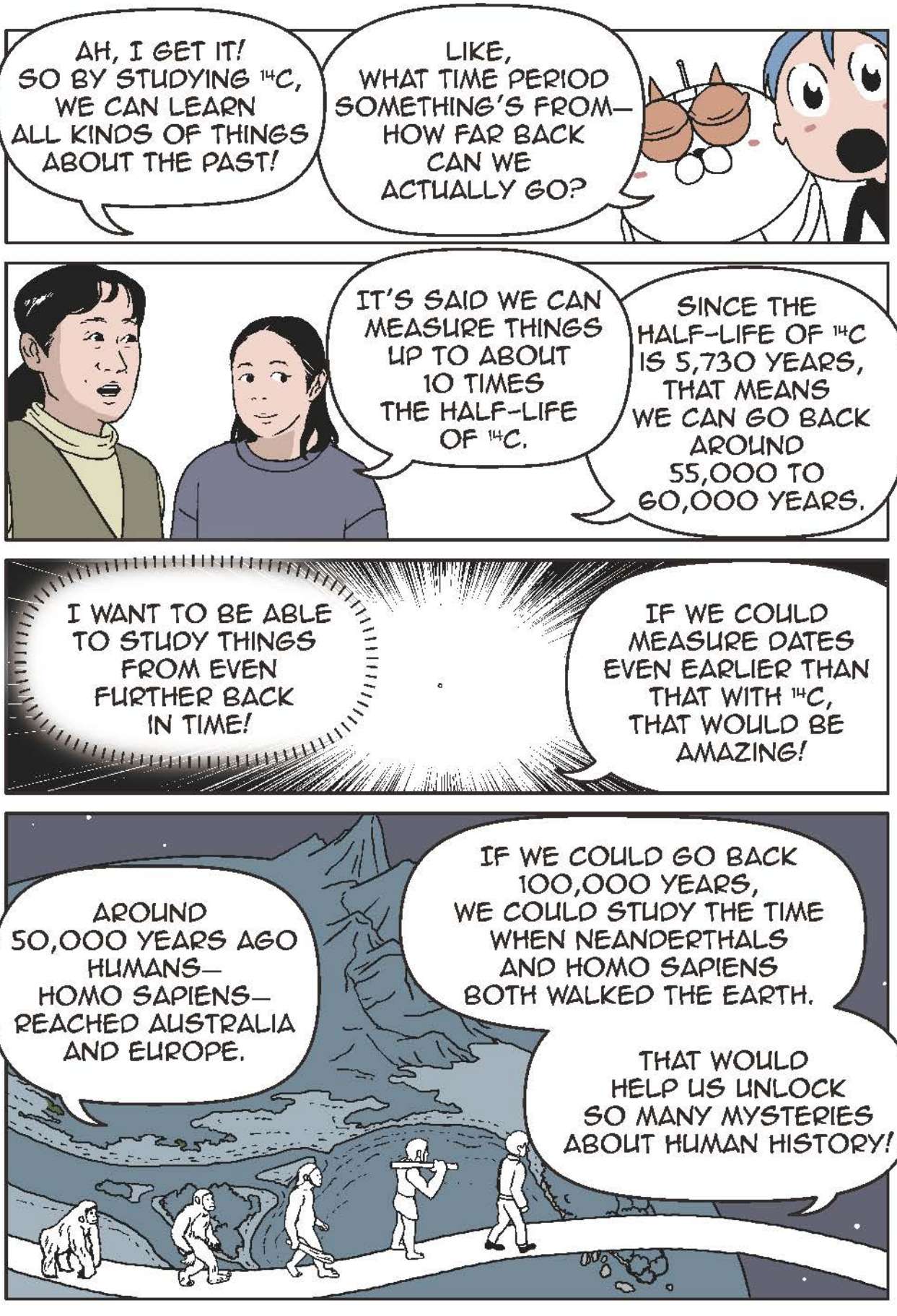




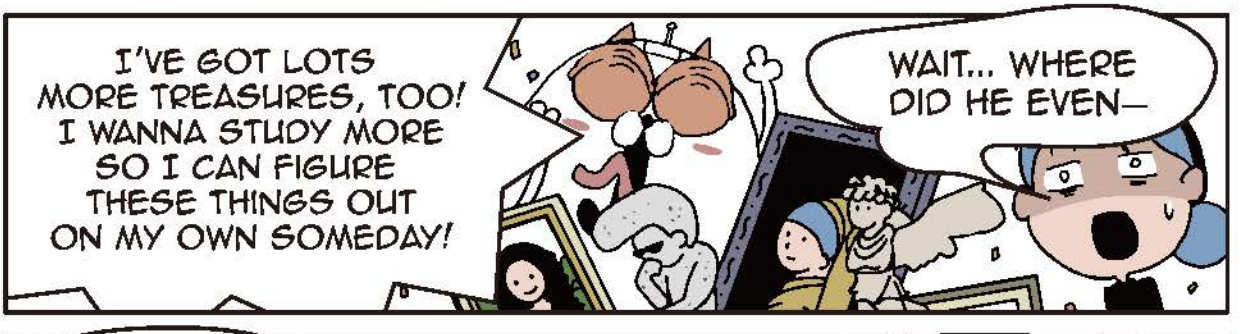
International Calibration curve: IntCal
Originally proposed in 1998,
and updated in 2004, 2009, 2013, and 2020.

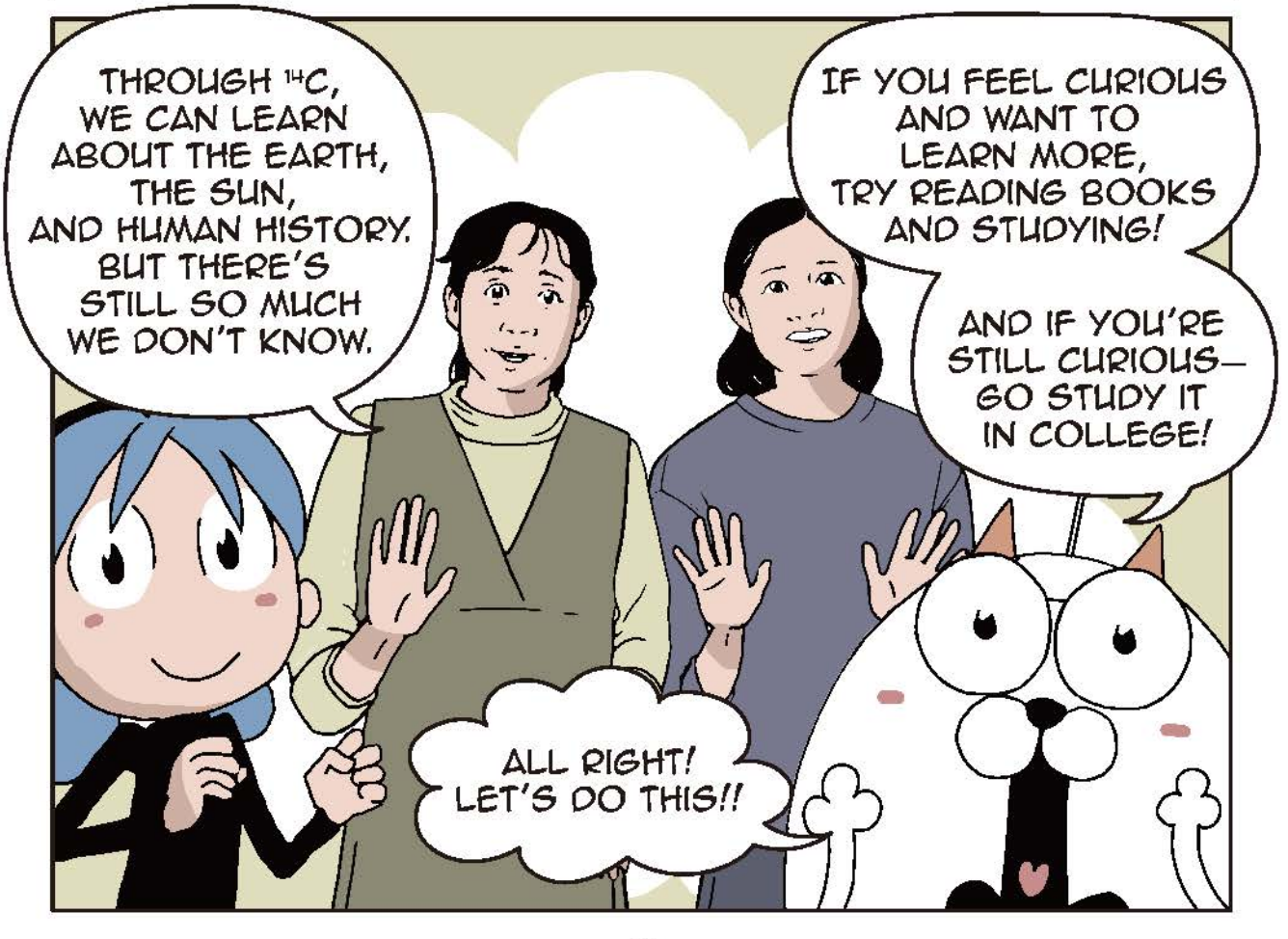

THE SCIENCE OF DATING THINGS— FIGURING OUT THE TIME SOMETHING IS FROM— IS USEFUL IN MANY FIELDS.
BY STUDYING LAYERS OF EARTH, WE CAN FIND OUT WHEN ANCIENT TSUNAMIS HAPPENED!
IN ARCHAEOLOGY, WE CAN DATE ARTIFACTS BY ANALYZING BURNED MATERIAL ON POTTERY OR EVEN THE CARBON IN OLD DOCUMENTS.
IN ONE CASE, RADIOCARBON DATING PROVED AN ANCIENT DOCUMENT WAS REAL— AND IT BECAME A NATIONAL TREASURE!
IN THE ART WORLD, IT HELPS IDENTIFY WHAT ERA A PIECE WAS MADE IN.
AND IN FORENSIC SCIENCE, IT CAN EVEN DETERMINE WHEN A PERSON DIED.
SOUNDS LIKE SOMETHING STRAIGHT OUT OF A CRIME DRAMA!


^{14}C ISN'T JUST USEFUL FOR DATING ANCIENT THINGS.
FROM THE ^{14}C IN TREE RINGS, WE CAN LEARN ABOUT PAST SOLAR ACTIVITY!
WHEN A MASSIVE EXPLOSION HAPPENS ON THE SUN'S SURFACE, IT SENDS OUT HIGH-ENERGY PARTICLES, MAKING THE AMOUNT OF ^{14}C ON THE EARTH GO UP!
Solar flares and coronal mass ejections (CMEs) release high-energy particles that reach the Earth.
WE STUDIED YAKUSUGI* TREE RINGS AND FOUND EVIDENCE OF HUGE SOLAR FLARES THAT OCCURRED IN THE YEARS 774 AND 993!
*ancient cedar trees from Yakushima Island
HUGE SOLAR FLARES CAUSE SHARP SPIKES IN THE AMOUNT OF ^{14}C.
SCIENTISTS WORLDWIDE ARE NOW PAYING ATTENTION TO THESE ^{14}C SPIKES, BECAUSE THEY CAN HELP PINPOINT EXACT YEARS WITH AMAZING ACCURACY!


AH, I GET IT! SO BY STUDYING ^{14}C, WE CAN LEARN ALL KINDS OF THINGS ABOUT THE PAST!
LIKE, WHAT TIME PERIOD SOMETHING'S FROM— HOW FAR BACK CAN WE ACTUALLY GO?
IT'S SAID WE CAN MEASURE THINGS UP TO ABOUT 10 TIMES THE HALF-LIFE OF ^{14}C.
SINCE THE HALF-LIFE OF ^{14}C IS 5,730 YEARS, THAT MEANS WE CAN GO BACK AROUND 55,000 TO 60,000 YEARS.
I WANT TO BE ABLE TO STUDY THINGS FROM EVEN FURTHER BACK IN TIME!
IF WE COULD MEASURE DATES EVEN EARLIER THAN THAT WITH ^{14}C, THAT WOULD BE AMAZING!
AROUND 50,000 YEARS AGO HUMANS— HOMO SAPIENS— REACHED AUSTRALIA AND EUROPE.
IF WE COULD GO BACK 100,000 YEARS, WE COULD STUDY THE TIME WHEN NEANDERTHALS AND HOMO SAPIENS BOTH WALKED THE EARTH.
THAT WOULD HELP US UNLOCK SO MANY MYSTERIES ABOUT HUMAN HISTORY!

*5,000-year-old Japanese pottery with flame-like shapes.





What is ^{14}C ?!

Mirubo : ^{14}C is so useful! What should I try dating next?

Moru-chan : Professor! Can we use ^{14}C to date dinosaur fossils?

Dr. Minami : Great question! Radiocarbon dating works for things that are up to about 50,000 years old. However, dinosaurs lived over 65 million years ago, so this method doesn't work for them.

Dr. Miyake : When we date dinosaur fossils, we usually look at rock layers or minerals around fossils— not fossils themselves. We often use methods like uranium-lead technique.

Mirubo : So, it sounds like there are lots of dating methods besides ^{14}C!

Moru-chan : I remember learning that you can date things with an age of about 10 times the half-life of an isotope using that isotope. So, if we use elements with a longer half-life, can we date stuff from way earlier?

Mirubo : (Hmm, sharp question!) I was just about to ask the same thing!

Dr. Minami : Exactly. For example, beryllium-10 (^{10}Be) has a half-life of about 1.4 million years. So, we can use it to date samples that are 5 million years old. It's actually used to study the age of soils, sediments, and ice sheets.

Mirubo : Whoa—awesome! All right, let's try using that method right now!

Dr. Miyake : Well, we can only use it on things that actually contain beryllium.

Dr. Minami : Meanwhile, carbon is found in almost all living things and artifacts. That's why ^{14}C is so widely used across many different fields.

Mirubo : ^{14}C is the best! It makes me wanna analyze everything!

Dr. Minami : ^{14}C dating often pops up on TV shows like dramas and variety shows — so lots of people have heard of it.

Dr. Miyake : But, isn't ^{14}C just for dating objects? Because ^{14}C is produced by cosmic rays, variations in cosmic-ray intensity also affect the amount of ^{14}C.

Moru-chan : How do you get carbon from tree rings specifically?

Dr. Minami : Great question! The thing we're testing is called a sample. It's super important to treat the sample properly— to remove any contaminants through chemical processing.

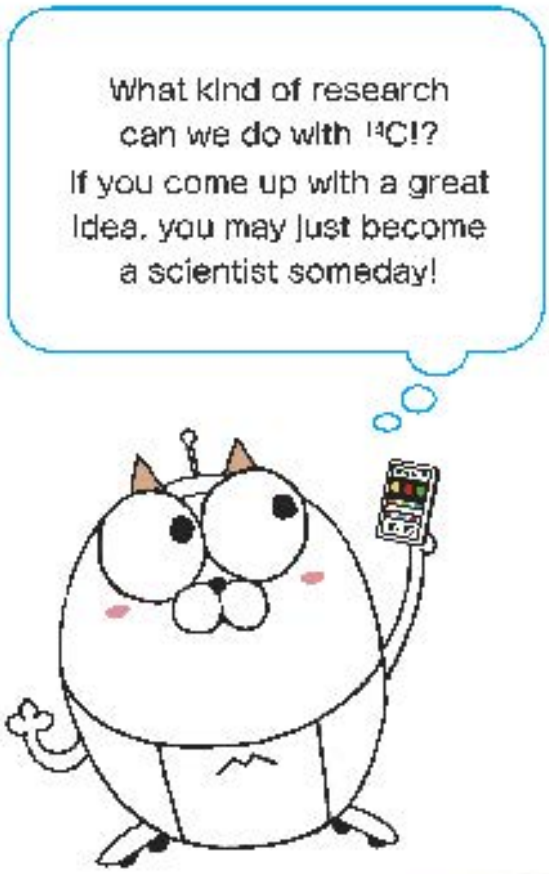
Mirubo : So, it's like cooking, right? You prep your ingredients carefully to bring out the best flavor!

Dr. Minami : Exactly! For example, with tree rings, we remove any contaminants from the wood and purify just carbon we need— so, we can measure it accurately. How well we prepare the sample makes a huge difference in how precise the results are.

Moru-chan : Who usually does this kind of research?

Dr. Miyake : At ISEE, Nagoya University, we are applying the knowledge and techniques of space and Earth environmental science researchers to studies in the fields of history and archaeology.
We also work with specialists in precision measurement, archaeologists, and data analysts. Everyone contributes their knowledge and skills to make new discoveries together!

Mirubo : I wanna do ^{14}C research myself someday! All right—maybe I'll become a scientist too!



Institute for Space-Earth Environmental Research, Nagoya University

In 2015, three major research centers at Nagoya University —Solar-Terrestrial Environment Laboratory, Hydrospheric -Atmospheric Research Center, and the Center for Chronological Research— were merged to form the Institute for Space-Earth Environmental Research. This integration made it possible to conduct more interdisciplinary research, connecting different scientific fields in new ways. The ISEE is the only institute in Japan that bridges space science and Earth science, working on global environmental challenges and the sustainable use of outer space through international collaborations.
https://www.isee.nagoya-u.ac.jp/

TranSEHA

NEXT Promotion of Development of a Joint Usage/Research System Project: Coalition of Universities for Research Excellence Program (CURE)

In fiscal year 2024, Institute for Space-Earth Environmental Research (ISEE) was selected for a major new research program. As a part of this initiative, ISEE is partnering with five institutions: the National Museum of Japanese History, Yamagata University's Center for Advanced Accelerator Mass Spectrometry, Kyushu University's Center for Asian Archaeological Research, the Joint Support-Center for Data Science Research, and Nagoya University's Center for Digital Humanities and Social Sciences.
Together, these institutions are building a new transdisciplinary research network that brings together Space-Earth environmental science with history and archaeology in innovative and meaningful ways.

Through this program, researchers will evaluate the potential impacts of extreme solar storms on modern civilization and advance history and archaeology by developing new, highly accurate methods of chronological dating.
The project also aims to contribute to the creation of a sustainable, evolving society that can expand into space, while improving preparedness for space weather disasters, earthquakes, and volcanoes.
At the same time, it seeks to foster the next generation of globally minded researchers who will lead future interdisciplinary science.
The program is planned to run for up to 10 years, beginning in fiscal year 2024.

https://transeha.isee.nagoya-u.ac.jp/en

Hayanon

Science manga artist, born in 1975. Graduated from the Department of Physics, Faculty of Science, University of the Ryukyus, with a B.A. (Science).Completed M.A. (Education) in English Education from the Graduate, Graduate School of Education, Chiba University. Her representative works include "GoGo! MIRUBO" (Kodomo no Kagaku), "Fantastic R&D" (Nikkan Kogyo Shimbun), "Lerning Earth Science with MIRUBO" (NASA), and "International Science Olympiad Manga" (Japan Science and Technology Agency). She is a representative of Science Manga Studio, a PR for research business.

Science Manga Studio, Japan

The studio produces manga introducing research in all fields of science and humanities, cover art for academic journals, and provides illustrations explaining the results of research institutions' presentations. Through these works, the studio fosters young science illustrators. https://www.sciencemanga.com/

Science illustrators in the production

Ms. Shell, Mochizuki Ami, Hakushi Jaco, and Akiba from Science Manga Studio.

What Is…?! Series

This is a research introduction Manga series started in 2002. You can learn about the study of the Sun and Earth with Sensei, Mirubo, and Mol.

https://www.isee.nagoya-u.ac.jp/en/outreach.html ISEE MIRUBO SEARCH

PDFs are distributed free of charge. The original editions were written in Japanese, and translations are available in English and other languages. https://scostep.org/space-science-comic-books/