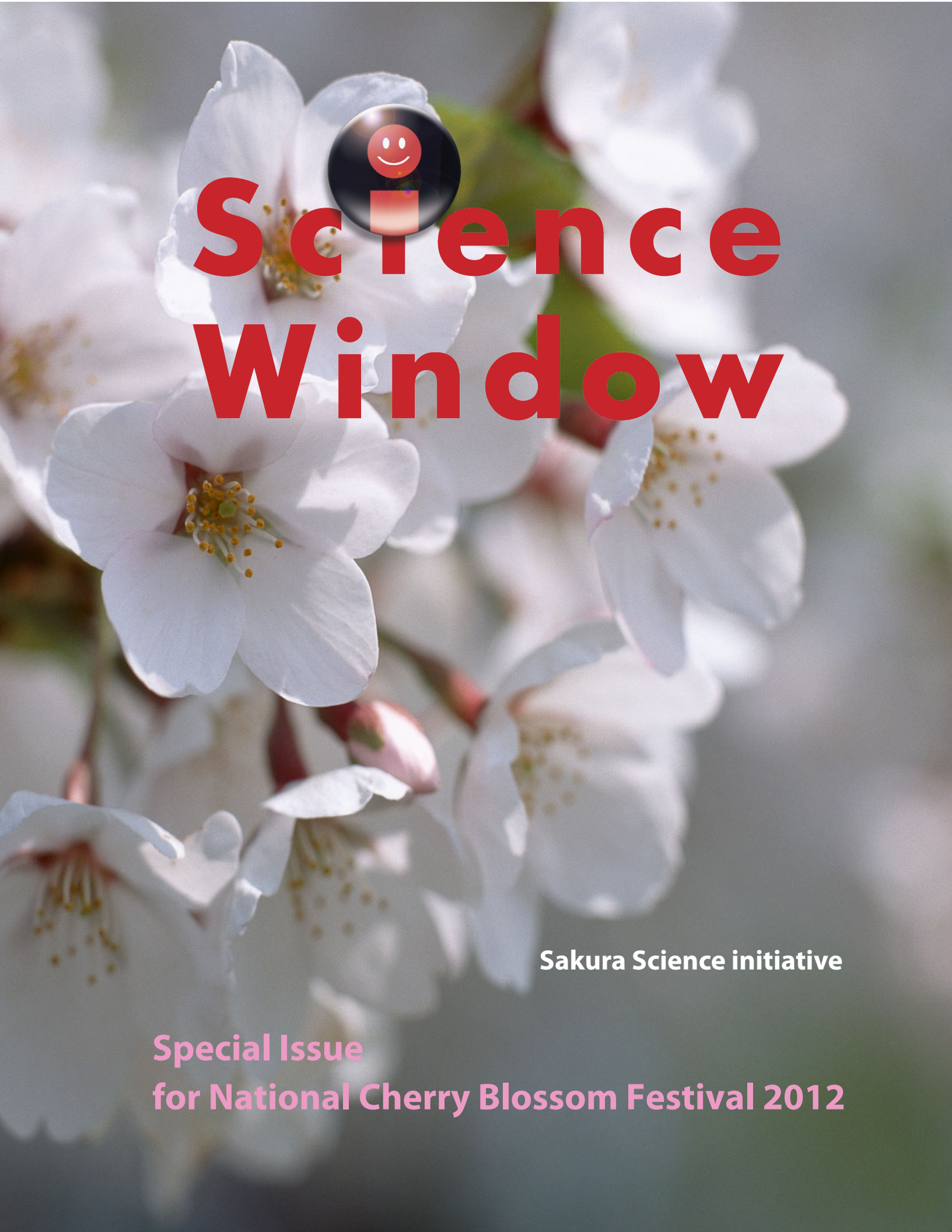


Science Window

Sakura Science initiative

Special Issue
for National Cherry Blossom Festival 2012

SAKURA SCIENCE

Carbon Fiber

"Carbon Fiber" is a hot topic right now, said to be even stronger than metal.

Industry has been paying a lot of attention to "carbon fiber" in recent years. Japan is now leading the world in the technologies needed to develop it. Because of its remarkable features, demand continues to climb for carbon fiber in a variety of fields.

Carbon fiber is lighter and stronger than metal, and is often used as a material in the construction of aircraft and automobile cockpits, computer bodies, boat decks, bridge support beams, large building roofs, etc.

Thinner than Human Hair

The Boeing 787 is a cutting-edge, mid-size passenger jet that started being used regularly in November 2011. Roughly half of the material used to make its wings and fuselage is a composite of carbon fibers and resin, making it a topic worthy of TV news coverage.

The diameter of a single carbon fiber strand is one tenth that of a human hair, making it extremely thin. Using such a thin fiber to construct the body of an aircraft might sound a bit worrisome at first, but when processed, this thin fiber becomes a very durable substance ideal for aircraft construction.

To start with, carbon fibers can be classified into two material types, PAN-based and pitch-based. PAN-based fibers are scientifically created out of "acrylic fiber" thread, a material often used in blankets, sweaters, and other such clothing items. Since this type of carbon fiber is durable and difficult to alter, it is used in the construction of various products, from the bodies of aircraft and spacecraft to tennis rackets. On the other hand, pitch-based fibers are made of materials, such as oil and coal. Since they are good at conducting heat and electricity, they are often used as electrodes for lithium batteries, fuel cells, etc. This section will cover about 90% of the PAN-based carbon fibers used on the market today.

* PAN: An abbreviation for "polyacrylonitrile," which is the ingredient used in acrylic fibers

Reasons for Strong, Lightweight Structure

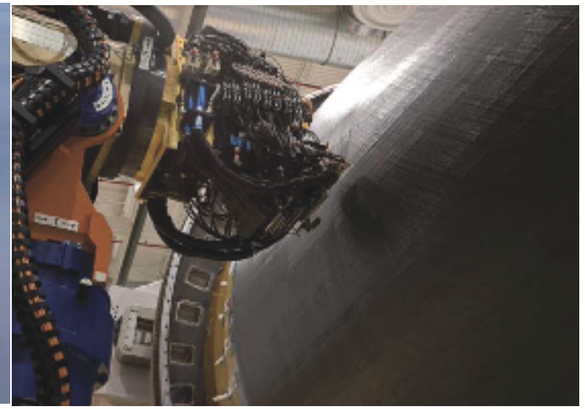
Just as the name implies, "carbon fibers" are fibers created out of carbon. Perhaps, you have an image of carbon being scientifically combined to create these fibers, but in reality they are created just as charcoal is, except out of acrylic fiber. Other than carbon, nitrogen and hydrogen are included as well. However, in order to prevent it from burning, the areas in which no oxygen is present are gradually heated, ultimately separating the nitrogen and hydrogen, so that only carbon remains. At the same time, carbon atoms are bonded together to form a crystalline structure covered by hexagonal shapes.

These hexagonal shapes are what make carbon fibers so strong and lightweight. A structure made up of hexagonal shapes with no spaces in between is called a "honeycomb structure," known for its remarkably stable and durable properties. As you might have noticed, beehives and turtle shells also have this structure. In addition, carbon filters have the same crystalline structure that is found in pencil graphite. This is what makes it lighter and more durable than metal.

The resulting threadlike carbon is also very flexible. By grouping these fibers together into a bundle, they become remarkably strong, and cannot be torn by hand. The bundle of carbon fibers is then spread into sheet form and soaked with resin to harden it.

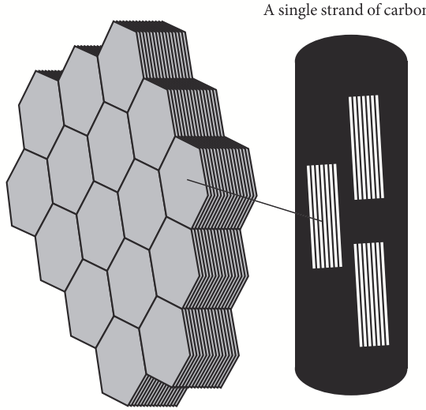
After that, several of these hardened sheets are stacked together into the required shape, and baked in a kiln to make them into extremely hard parts. These are the actual shapes carbon fibers are made into for building aircraft bodies.

For many years now, straw has been mixed with clay, or resin has been mixed with glass fibers to increase material strength. In the same way, carbon fibers within resin are pulled together equally to make the material more durable. A clump of carbon fibers is actually stronger than steel but lighter than aluminum, and will not rust, offering remarkable heat resistance and near complete transparency to X-rays (radiolucency). And, depending on which direction the sheets are facing, the strength's directional properties can be controlled. For example, the wings of an aircraft cannot be twisted by strong wind. So by adjusting the sheet direction, potential twisting can be eliminated, further strengthening the wings.



The Boeing 787 “Dreamliner”
A composite of carbon fibers and resin that is lighter and more durable than metal was used to create about half of this aircraft’s wings and fuselage. According to Boeing, using carbon fibers makes it possible to create structures with larger aircraft parts, with the additional merit of reducing waste products and harmful substances during manufacturing. The bottom photo shows a durable plastic (CFRP) that uses carbon fibers, which is being wrapped around the back of an aircraft by a machine.

A single strand of carbon fiber

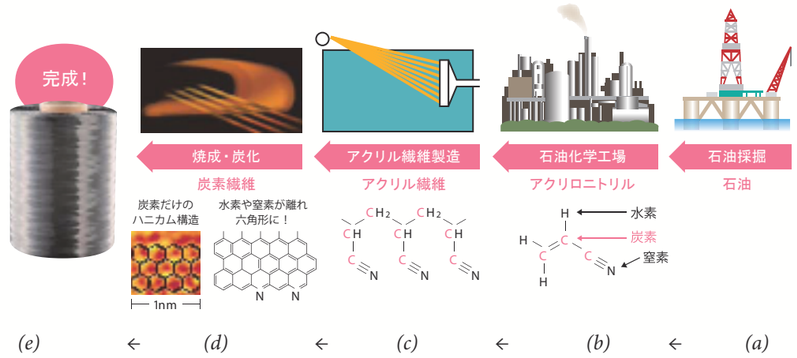


Carbon fiber and honeycomb structure

Within a single strand of carbon fiber, a great deal of carbon atoms line up vertically in a hexagonal shape. This “honeycomb” structure is remarkably strong, and by combining this type of thread with resin, a material lighter and more durable than metal is created.

Environmental Benefits

Carbon fibers have been used since the 1970s in fishing poles, golf club shafts, tennis rackets, and other sports-related items. Since then, usage has expanded to aircraft bodies, automobile and satellite parts, computer bodies, windmill parts used for wind-generated electricity, and X-ray devices for medical purposes. Since they are widely accepted as a safe material for passenger jets, industrial usage will most likely increase more and more. In recent years, “eco-friendly” has become a commonly heard phrase, especially in terms of automobile manufacturing. There are also ecological concerns when creating aircraft, and by using carbon fibers to create automobiles and aircraft, their bodies will ultimately become lighter in weight. Lighter vehicles mean less fuel consumption, and less fuel consumption means a decrease in greenhouse gases can be achieved. Unfortunately, manufacturing costs are quite costly at this time, so use of carbon fibers is limited to Formula One race cars or other top-class, expensive vehicles. The most significant topic of the next few years involves the challenge of establishing a mass production system for carbon fibers that will ultimately reduce costs.



How to make carbon fiber
A material called “acrylonitrile” is created from crude oil containing lots of carbon at a petrochemical plant. Acrylic fiber (called polyacrylonitrile) is created by linking together this acrylonitrile. Using a special method to heat up the acrylic fiber causes only carbon to remain, forming a strong type of thread with a hexagonal “honeycomb” structure. The orange photo in the upper left corner *(d)* shows a magnified example of carbon fiber (the black lines are computer images).

(a) Oil drilling - Oil

(b) Petrochemical plant - Acrylonitrile

(c) Acrylic fiber manufacturing - Acrylic fiber

(d) Heat treatment/carbonization
• Carbon fiber
• Hydrogen and nitrogen are separated to form a hexagonal shape.
• A honeycomb structure containing only carbon

(e) Complete!

Japan’s Manufacturing Muscle

In 1959, PAN-based carbon fibers were invented by Dr. Akio Shindo at the Agency of Industrial Science and Technology (AIST). From that moment on, Japan’s fiber manufacturers carried out research and development for carbon fibers, and today roughly 70% of all carbon fibers on the world market are manufactured by three Japanese companies.
A lot of time was needed to hone the material for a wide range of practical uses. A Japanese company called Toray is responsible for manufacturing the carbon fibers used in the Boeing 787. For nearly 40 years, Toray has been in cooperation with Boeing to develop carbon fibers for use in aircraft construction. According to Toray’s public relations director Toshinori Matsumura, “There is no other material out there with the properties that carbon fibers provide, and we believe they offer a great deal of potential for future use, which is a major reason we are spending so much time and effort developing them today. I think that development continues persistently here because of our culture in Japan, which emphasizes serious effort in manufacturing. It’s very important for Japanese manufacturers to hone our technologies so that we are capable of creating products that cannot and will not be imitated.”
These words reinforce the feeling that Japan’s manufacturing culture is truly world-class.

* PAN: An abbreviation for “polyacrylonitrile,” which is the ingredient used in acrylic fibers.
* PITCH: A by-product resulting from the refinement of crude oil.

Story/text: Chisato Hata
Illustrations: Mineko Kobayashi
Cooperation: Toray Industries, Inc. / The Boeing Company
This is what changes when carbon fibers are used:
http://www.carbonfiber.com.gr.jp/
The Japan Carbon Fiber Manufacturers Association’s website uses photos and illustrations on the “Main Fields of Use” page to provide carbon fiber usage examples and results.

Science Window 2011-12 Winter Edition

Animal Secrets

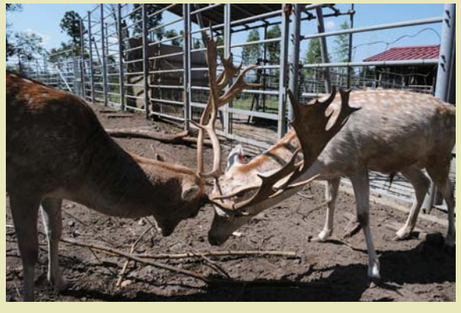
Fallow Deer (Dama dama)

Their antlers change shape every year.

Seen from the front, their large antlers spread out to the sides.

The sound of antlers clashing fills the air as two fallow deer interlock in battle. "Annmitsu", the strongest among them, was eating leaves from a tree when "Kashimia" got a little too close for comfort, and was attacked for it, causing him to flee the scene.

Fallow Deer were once bred in Europe, not far from their natural habitat, as a means to enhance the scenery. Three of them live in Toyama City Family Park Zoo, where they are fed breakfast and dinner, as well as a diet of leafy branches from keyaki and mulberry trees daily at 2:30 in the afternoon. Mami Hirokawa takes care of them here, and says, "They especially enjoy soft leaves in the early spring. When they see their favorite leaves, sometimes they'll stand up on their hind legs to eat them." Since leaves harden in the fall, they won't stand up on two legs to eat those, but at times they will interlock antlers in a scuffle for food.



Antlers locked in combat: "Kashimia" (left) vs. "Annmitsu" (right)

Ranking has already been clearly determined among the three of them, with Number 2 "Kashimia" and Number 3 "Spirit" waiting for Number 1 "Annmitsu" to finish eating his meal before they can dig in. Even though "Spirit" has to wait until the others are done, sometimes he can sneak a bite while "Kashimia" and "Annmitsu" are fighting.

As Fallow Deer have no claws or fangs to use as weapons, antlers are very important tools for fighting. But when spring comes they fall out at the roots, where a new set of antlers begin to sprout in their place, and continue to grow into August. The new antlers are usually larger than those of the previous year. According to Hitoshi Murai, head of the breeding display section, "The shape of their antlers may be determined by genetics to some extent, but the amount of nutrition they took in during the previous year also plays a role, so we are really determined to keep them healthy so they can grow a beautiful set of antlers." Although feeding them nutritious foods will enable them to grow a beautiful set of antlers, feeding them too much will make them fat. Therefore moderation is key.

As they grow, the antlers are broad and shovel-shapped (palmate).

They "ruminate" their previously swallowed food. Ruminate means to chew the cud.

Fallow Deer | Japanese Sika Deer | Père David's Deer

Comparing antlers
Antlers come in a variety of shapes depending on the type of deer.

The skin peeling off of these antlers occurs only two days out of the year. These antlers begin sprouting up in the spring, and are covered in a thin layer of skin. This skin falls off in the summer, and white antlers are revealed from inside.

The Satoyama Ecological Park has Japanese macaques (Snow Monkeys).

Fallow Deer live in the forests and bush of Western Eurasia. Even males (buck) are no more than 1 meter (3'3") shoulder heights. Males (buck) and females (doe) live separate from each other through most of the year. Adult males only stay with males, while females form groups with other females and young deer (fawm). For breeding purposes, males and females will form a herd from the fall into early winter. Although the tips of Japanese deer (Sika deer) antlers are sharp, fallow deer antlers are broad and shovel-shaped (palmate). During the day, they will hide in forest underbrush, and at nightfall they will come to an open area near the forest for food.

They occasionally rub their antlers on fences.

This particular zoo feels it is important to show off the animals of Japan. The fallow deer are most closely related to "*Sinomegaceros yabei" which once lived in Japan but have gone extinct. This deer had shovel-shaped (palmate) antlers just as the fallow deer, and the fallow deer are being raised at this zoo to let people observe the shape of their antlers. Seeing the fallow deer here is a great opportunity to imagine how deer of the past must have looked.

*Ancient Giant Deer: They lived from 10 thousand to 100 thousand years ago. They were nearly 2 meter (6'6") shoulder height with palmate antlers.

Toyama City Family Park Zoo is located near Toyama City. At the "Satoyama Ecological Park" newly built this year, a good deal of focus has been put into raising Japanese animals. The park takes advantage of the area's natural landscape of mountain slopes, where energetic Japanese Snow Monkeys can be spotted. Japanese "Sika" deer and "Tanuki" (raccoon dogs) are also being raised in the same area, as part of a goal to re-create scenes from the natural Japanese woodlands. In addition, the Japanese live stock animals such as horses and chickens are being raised at this zoo. The relatives of animals thought to have once lived in Japan but have gone extinct, such as the Eurasian otter and Eastern Timber Wolf, are also being raised here to promote an awareness of the relationship between humans, animals, and nature.

Address: 254 Furusawa, Toyama City
Phone: 076-434-1234
Transportation: Get on Chitetsu Bus 16 "For Toyama University Hospital" from JR Toyama Station, and ride it for about 25 minutes, then get off at "Family Park Front". http://www.toyama-familypark.jp/
Photos: Akira Sato

Science Window 2011-12 Winter Edition

Fossils

For elementary school teachers

Split a rock, and you will find a fossilized leaf!

Have you ever wondered if there's an interesting experiment related to landscape evolution and changes?
If so, I recommend fossil digging. You can do it in the science lab.

Experience fossil digging!

Ms. Nanako (Nana below): My 6th graders are learning about "landscape evolution and changes" now, and I'd like to try some experiments that would get them interested in this topic. Do you have any good ideas?
Professor Ringoro (Ri below): I've got an experiment that's easy to do, and fun for the kids.
Nana: Great! What is it exactly?
Ri:**Fossil digging!**
Nana: That sounds like a lot of work...
Ri: Well, it can all be done in the science lab.

Obtaining raw stone for fossils

Nana: Usually when we want to find fossils, we have to research an area where they might be, and then go there to excavate them, right?

Ri: Actually, there are museums that will send you raw fossil stones through the mail.

Nana: Fossil stones?

Ri: Basically, fossil stones are stones that contain fossils.

Nana: How much would something like that cost?

Ri: If it's for educational purposes, Tochigi Prefecture's Konoha Fossils Museum (see page 8) offers 5 stones, each about the size of a bar of soap, for 500 yen ($6.25). If you buy in bulk, they will also send them to you by mail, so I recommend giving them a call for details.

Nana: And, are there actual fossils in these stones?

Ri: If you're lucky, you will find one. Sometimes you won't find a fossil, but I think it makes things more exciting while you're chipping away at it that you may or may not find one.

りんごろう先生の

Professor Ringoro's experimental method starts from the basics


A


B

More like "splitting" than "digging"

Nana: What sort of tools and things do we need?

Ri: Other than the fossil rocks themselves, you'll need a flathead screwdriver, nails, a hammer, a microscope, microscope slides, a mortar, and ceramics adhesive (A). A stereoscopic microscope is the best for this experiment, but a regular one can also be used. If you have them, magnifying glasses would also be useful.

Nana: So this is a fossil rock!(B) Looks like a layered cake. How do you dig into it?

Ri: Set a nail or flathead screwdriver in the groove of this layer, and tap at it with the hammer. I suppose "splitting" would more of an accurate description than "digging." Instead of using a regular nail or screwdriver, a precision screwdriver would be better for making a clean cut due to its sharp edge. You can buy them at the 100 Yen Shop.

Nana: The fossil rock looks pretty irregular, so I imagine it would be better to have someone holding it in place.

Ri: I think it would be best to have the kids work in groups of two, with one holding the rock and the other tapping away at it.

Nana: How about we carefully split this one open?

Ri: You got it! (C)

Nana: Oh look, there's something inside.

Ri: If you're lucky, you'll find a fossilized leaf. (D) If you're even more lucky, you can find insect fossils from time to time. (E)


C


D


E

Nana: I wonder how old this leaf is.

Ri: They say these fossils from Tochigi are about 300 thousand years old. Back then there was a lake in the area. Sediment brought in by rivers and volcanic ash buried leaves and dead animals in the area to form fossils.

Nana: It makes us think about history of the Earth.


F


G


H


I


J


K


L

Ri: Let's clean it up. It's good to scrape off the excess material to make the fossil stand out, then polish it up with a brush or toothbrush. First, set the screwdriver in an area away from the fossil, and start tapping it (F). You have to chip away at it little by little, otherwise the fossil may break.

Nana: Oh no, it split into two halves. Did I ruin it?

Ri: No no. If it's a clean split, you can use a ceramics adhesive to glue it back together (G).

Observing minerals

Nana: This fossil hunting is pretty interesting, but I imagine most kids won't find a fossil in their rocks.

Ri: If that's the case, I encourage you to show them the minerals inside the raw stone through a microscope.

Nana: What do you mean by "minerals"?

Ri: Well, the rocks are made up of granules of many different colors and shapes. Even diamond is a type of mineral.

Nana: What? You mean we ca be diamonds in this thing?

Ri: Not in these rocks, but you can find beautiful pieces of translucent quartz, pretty pieces of black mica, and opaque, candle-like feldspar minerals. For example, if you put your hand to the ground at school, and brush off the dirt, you'll find some tiny black pieces stuck to your hand. That's black mica.

Nana: This is getting more and more interesting. Let's have a look at some.

Ri: All right. First you need to collect some of the fragments that fell off when the fossil was split, then break them up into powder with the hammer (H). Once you have a fine powder, put it into the mortar and add water. Use your finger to mash it around, which will mix it together well. Next, repeatedly drain the water until you eventually have only sediment remaining (I). This will get rid of all the unnecessary material.

Nana: The water is clear now.

Ri: Put a bit of the remaining sediment on a microscope slide, and spread it around with a toothpick so that it's easy to observe (K). You don't need to cover the slide with a glass, but make sure the sediment doesn't touch the microscope lens (L).

Nana: Oh, I can see some clear granules now.

Ri: That would be quartz.

Nana: I'm impressed that such pretty material can be found in the raw stones. I wonder why minerals surface like this.

Ri: It's because the mineral rich rocks are pulverized and hardened in the stratum in which fossils are buried.

Nana: So then, the fossils are actually rocks?

Ri: That's right. There are many ways in which fossils can form, but sometimes biological material from long ago gets combined with sediment carried by rivers or other means, and then sinks to the bottom of the sea or a lake where it is then buried. As that sediment piles up, it creates stratum, which then hardens into rock over a long period of time. As a result, fossils are often included in that rock.

Nana: Wow, fossils can give us a glimpse into the Earth's past.

Ri: Yes, and through this fossil hunting method, I hope you can pass that on to the children in your class.

Konoha Fossils Museum
A museum of natural history in Tochigi Prefecture's Nasushiobara City. There are a lot of leaf fossils for discovery in this area. The museum has more than 200 types of fossils on display of plants, insects, fish, frogs, and more. In addition, exhibitions of rare fossils and crystals from Japan and overseas can be found here. Koshiobara Lake is now dry as well, leaving the bottom exposed for observation (pictured right).

Phone: 0287-32-2052
Website: http://www.konohaisi.jp/

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Mr. Daisuke Orimoto (Chiba Kashiwa City Nadogaya Elementary)
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Photos: Hiroaki Kamei
Special Thanks: Kaijo Junior & Senior High School, Konoha Fossils Museum

Science Window 2012 Early Spring Edition

Translation: HC Language Solutions, inc
Printed in USA

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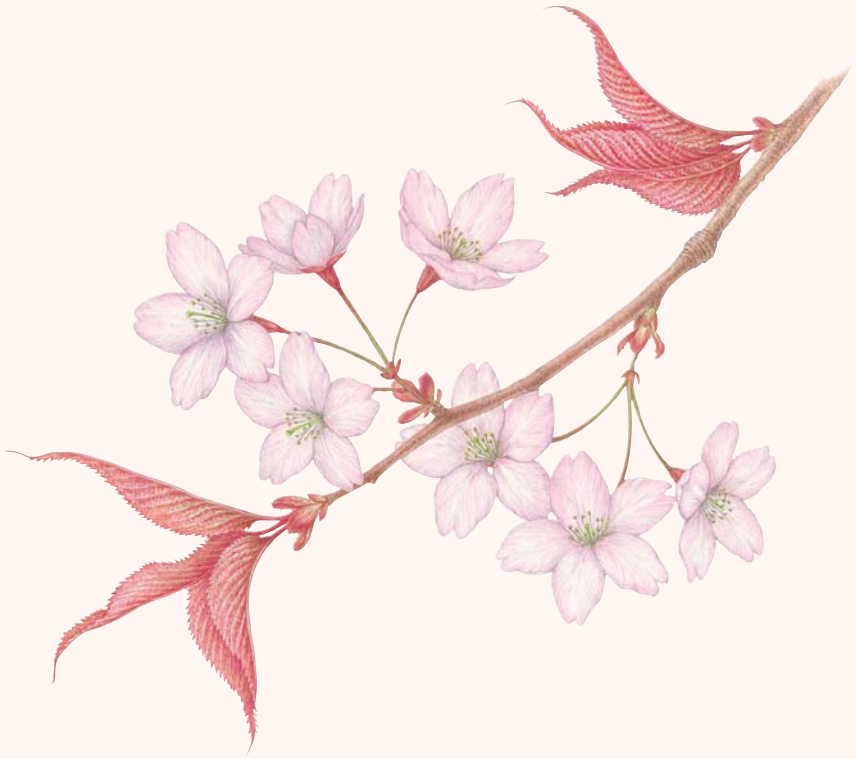
科学技術振興機構
Japan Science and Technology Agency

Biological Heterogeneity



Yama-Zakura

Prunus sargentii
(wild)

Somei-yoshino

Prunus x *yedoensis*
(caltivated)

illustration: Kazunori Maeda