A New Story About Iron (vol.3)

This picture book was written with the idea of making our “iron world” a better place to live in. Thank you for picking it up. Here at Nippon Steel Corporation our goal is to make products using iron, products that are both useful and the stuff of dreams. Iron is an everyday metal and one that you can count on. Its potential is still being discovered. This “iron” has created the idea for a new story. It’s a story of dreams and adventures. So let’s begin.

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A New Story About Iron

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The BIG BANG!
It was a huge explosion, beyond your wildest dreams.
The universe was created by this big bang 15 billion years ago.
After a while, all the atoms began joining together to create a host of new planets.
Scientists believe that our planet, the earth, was born 4600 million years ago.
Did you know that the stuff that forms the earth’s core, the bit that’s in the center of our planet, is actually iron?

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Iron, which was created in a star shortly after the universe was born, played a big part in the creation of our planet.
Iron is believed to account for one-third of the earth’s weight.

P5

Aside from the iron in the earth's core, a lot of iron was left in the earth's crust (that's the bit near the surface).

This is iron ore, the raw material that's used to make all the iron and steel products we use.

P6

Our time, the twenty-first century…

P7

Iron gets into lots of things.

It's in the high-rise buildings that line our cities; the huge bridges that span our rivers.

It's in cars, railways, boats and electrical products, in soft drink cans and paper clips, in fact, it's busy in every corner of our lives.

Iron is a present that we got from the universe a long, long time ago.

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A bag of knowledge all about iron

Hey, how are you doing?

My name's Socratetsu.

I'm on a mission. I've got to beat my brains and test the powers of my imagination to figure out how to put iron, one of the earth's most important materials, to use in our society.

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Iron is the champion that has supported the development of our civilization.

A long time ago, people found ways to use iron for hunting and farming, making these jobs a whole lot easier. There's proof too. Did you know that archeologists are still digging up ancient iron tools and ornaments from sites around the world?

P10

So tell me, have you all heard the word "steel"?

P11

Steel is the stuff that's made from iron ore.
It's been given lots of useful properties like strength, toughness and flexibility, so that people can use it. Let me fill you in. Steel is an alloy of iron and carbon. After scientists discovered the technology to make huge amounts of steel, the human race was able to advance by leaps and bounds.

P12
"Without iron there'd be no civilization…"
That's right, and the 20th century was known as the Age of Iron.
I love iron!
I like using iron to build all kinds of things.
Why? Because iron is a magical metal.

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Iron is great stuff. You can use all kinds of tricks to change its nature, like heating it or cooling it, or adding other elements to make alloys.
Heave ho! Heave ho!

P14
Make it stronger! More flexible!
More beautiful! Lighter!
Make it a bigger part of all our lives!
I guess what I want to tell you is that iron isn't "square" at all,
it's a material that's still evolving.

P15
The 21st century is your century. It's up to you to make it.
Iron is part of the natural world. It's in you too, an essential element that's working hard to keep you alive. What's more, it will play a big role in the work you do to create the society of the future.
All right then, are you ready for what we're about to begin? Take a deep breath…

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Socratetsu's bag of knowledge 1

THE BIRTH OF IRON

The universe was created in a huge explosion, you know, the Big Bang. Hydrogen atoms that were scattered by the explosion joined together and a star was born. Inside the star, elements were created one after another, starting with the lightest and getting progressively heavier: carbon, oxygen, alkali metals…and in due course, iron, the most stable element of them all, was born. Then, the star died in a big explosion, scattering its iron throughout the universe. Once again, pulled by gravity, the iron joined together and the earth was born. Iron truly is our present from the universe.

8 Siderite

Siderite is a type of meteorite that falls to earth every now and then, even now.

9 An iron ore quarry(Overseas)

THE EARTH IS MADE OF IRON!

Iron is an abundant element on the earth and forms the earth's core. Iron also remains in the surface where it is attached to oxygen and sulfur and forms layers of iron ore, that's the raw material from which iron is made. Iron is believed to account for approximately one-third of the earth's weight. Humans first came across iron around 3000 BC. Iron ornaments have been discovered in ancient Egypt and the Mesopotamia region. Then, around 1600 BC, the people of the Hittite kingdom succeeded in refining iron, and they used it to make weapons and farming tools. The techniques for producing large quantities of steel were perfected during the Industrial Revolution of the 18th century.I In Japan, Takato Oshima started modern iron production at the Kamaishi iron works in the second half of the 19th century, and the government opened the *Yahata Steel Works* in 1901.

LIFE-GIVING IRON

Blood is red because of the hemoglobin it contains. Hemoglobin contains iron ions that attach readily to oxygen and play an important role in carrying the oxygen all around our bodies. The iron ions contained in hemoglobin join together with oxygen in the lungs where they become iron oxide. The iron oxide carries oxygen around the body via the arteries, after which the iron separates from the oxygen in the cells and is carried back through the veins to the lungs again. There are approximately 5 grams of iron in a person weighing 60 kilograms.

1. Red blood cells
2. Blood vessel
3. White blood cells
4. Hemoglobin
5. Oxygen
6. Iron
7. An enlarged red blood cell

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The birth of the high-tensile robot, “Ittetsu”

This is Socratetsu’s laboratory. Its location is a secret.

Looks like Socratetsu is thinking about some pretty heavy stuff.

“Mmmm, I reckon I’m going to need a sidekick to help me achieve my mission.

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That’s it! How about a robot? Cool!” It needs to be light and flexible, with toughness and strength for those critical moments. This is what came to Socratetsu in a flash – he would build a flexible but tough iron robot. And with that, he pulled the blueprints out of his bag of knowledge.

Name: Ittetsu (soft)

Height:

Weight:

Horsepower:

Name: Ittetsu (hard)

Height:

Weight:

Horsepower:

P20-21

But Socratetsu had a hard time. It was a pretty wild idea, after all.

So first of all, he decided to investigate the structure of iron.

Thinking about it, he knew iron was as hard as a rock.
And that made him think that the atoms inside iron would be arranged in an orderly fashion (a lattice), but he discovered that there are irregular parts called “dislocations.” What’s more, when he started to apply force to the dislocated bits of the lattice, they moved and the iron began to change shape. “One…, two…, THREE!” Socratetsu also made discoveries about the work undertaken by carbon, nitrogen and other elements in the iron.

1. An iron crystal lattice
2. External force
3. Iron atoms
4. Deformation
5. Dislocations exist inside iron crystals, and when an external force is applied, the force presses on the dislocation and changes the way the atoms are linked.

External force
External force

P22-23

1. Iron atoms
2. Carbon atoms
3. Nitrogen atoms
4. I see, I see.
5. Adding carbon or nitrogen atoms makes iron harder.
6. If you stop the carbon and nitrogen atoms from getting in the way, then the iron becomes softer.
7. Titanium (Ti)
8. Niobium (Nb)
9. Nitrogen atoms
10. Carbon atoms

Adding carbon and nitrogen to the disordered areas of iron atoms and replacing some of the iron atoms with manganese or silicon makes the iron harder. And if you prevent carbon and nitrogen from entering the lattice, it makes the iron softer. “I see. So the hardness of iron can be freely adjusted and that makes it easier to form it into the desired shape.”

Socratetsu was delighted with his discoveries. He set to work making the best use of the

properties of iron and adding in other elements so that, by and by, he succeeded in producing a new “high-tensile” steel sheet with which to build his robot. And what kind of robot do you think he made by applying this technology…?

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The hard bits were harder and the soft bits were… like an octopus…?! Well, not quite, but almost. And its name? “Ittetsu” the high-tensile robot of the future. Since the robot combined strength and formability, it was very versatile. Once again, Socratetsu was thrilled with his workmanship of Ittetsu.

Mutation!

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He forgot all about sleeping and set about building a super high-performance car to get around in - the “Hiten 1”.

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Now all the preparations were done, and it was time to set off. Just where are Socratetsu and his friends heading?

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The miracle of progress

P29

Socratetsu set off to fly around the world, partly to test fly Hiten 1 and partly to see what was happening. Wow, Hiten 1 goes like a dream! Ittetsu was in high spirits too and was in soft mode.

P30-31

They flew over Africa, Europe, America and finally over Asia…
But they couldn’t believe their eyes as they looked down from the sky;
the world was full of cars!
They also came across many traffic accidents during their travels.

P32

Somewhere along the line, Socratetsu and his friends lost their high spirits and grew melancholy. “Isn’t there any way to make cars safer so as to protect the people inside them…?”

P33

The spirit of challenge began to rise like a bubble in Socratetsu’s mind. He decided to do some more research on the pliable high-tensile steel that he’d used to make Ittetsu and Hiten 1.

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First he used the high-tensile steel for the bodywork, making it thinner and stronger. He knew that would make the steel lighter and improve its performance, while making the car’s bodywork more durable.

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“If I make use of the soft properties of the high-tensile steel when forming the car’s bodywork, then it should be possible to create all kinds of different shapes!” Socratetsu worked really hard. Ittetsu had a hand in everything, and Hiten 1 chipped in support too.

P36

Finally, they succeeded in producing a high-tensile steel that had both strength and softness and was easier to form. With this material it is possible to make really cool cars. What’s more, if the car crashes the steel changes its character, becoming hard and strong just when it’s needed. The bodywork absorbs the shock of the collision and protects the lives of the people in the car.

With time, the high-tensile steel came to be used all over the world.

Safe because of the high-tensile steel body!

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That’s right; cars are now tougher and safer to drive.

And just for good measure, there’s something else to be happy about…

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Because cars made using high-tensile steel are very lightweight they use less fuel too. That means less carbon dioxide from exhaust fumes, which helps to prevent global warming. At last, the smiles were back on the faces of Socratetsu and his friends.

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And they were determined to keep on developing high-tensile steel so that they could help the people and the planet.

P40-41

Socratetsu's bag of knowledge 2

IS IRON REALLY CRYSTALLINE?

Steel accounts for approximately 70 percent of a car's mass. More than 100 different types of steel are used, each for a different purpose. The steel that is used to make a car's bodywork must be strong so that the car is safe, lightweight so that the car is economical on fuel, and formable, which means that the steel is soft and easily shaped. The key to solving this very tricky problem is to control the iron crystals. By controlling the areas inside iron atoms that are not arranged in regular order, it is possible to make steel to match the intended end use.

1. High-tensile steel is used for all these different car parts
2. Growing use of high-tensile steel sheets in automobiles
3. Tensile strength (MPa)
4. Body
5. Soft steel
6. Under body

CRYSTAL CONTROL = SOFT IRON + HARD IRON

Iron atoms consist of a crystal lattice that looks a bit like a jungle gym. If nitrogen and carbon enter this lattice then the iron becomes hard, but if you reduce the amount of carbon and nitrogen and add titanium and niobium, these elements will stabilize the carbon and nitrogen making the iron soft and easy to form (ultra-low carbon steel). On the other hand, there are various "techniques" that are used to manufacture stronger and harder iron, like adding nitrogen, carbon, silicon and manganese, or even larger precipitates (titanium carbide, etc.), or inserting carbon and nitrogen where the crystal lattice has been stretched (or deformed) by heat treatment.

MAKING “HARD BUT FLEXIBLE IRON” VIA TINY ADJUSTMENTS TO ELEMENTS & TEMPERATURE

The world needs iron that is soft and formable as well as being hard and strong. One example of this type of iron is called dual-phase steel. This iron is like Jekyll and Hyde; it has both hard sections and soft sections. Another example is known as TRIP steel (which stands for **TR**ansformation **I**nduced **P**lasticity). With this steel, the temperature is skillfully controlled so that small quantities of a very stretchy (deformable) crystal lattice “austenite” are retained inside the soft crystal lattice “ferrite” and the harder crystal lattice “bainite”. When an external force is applied the austenite is transformed into tough “martensite”, hardening the whole steel sheet. By making minute adjustments to the elements contained in the iron and to the temperature used in manufacturing, it is possible to make steel materials that match their intended purpose.

1. TRIP steel transforms instantly and hardens quickly
2. Austenite
   Martensite
3. Hard and soft sections coexist in dual-phase steel
4. Ferrite
5. Martensite
6. Bainite
   Ferrite
   Austenite
7. Iron crystal
8. This microscopic image was created using a color etching technique developed by Nippon Steel Corporation (a method of color-coding in which a special liquid is used to corrode the iron).

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The battle with rust – iron’s long-standing enemy

Recently, Ittetsu, the high-tensile robot of the future made a friend.

His friend is a female robot called “Tetsumi” who lives in Iron Town, a place where everything is made of iron.

One day Ittetsu received an e-mail from Tetsumi.
“Here in Iron Town it’s been raining FOREVER.

P43

I’m seizing up. HELP (>_<)”
A town made of iron is not very good at standing up to the rain.
Why? Well, the moist air makes everything go rusty and if you don’t do anything about it the whole place will fall to pieces.

P44-45

I can’t stand by like this!
Ittetsu leapt into Hiten 1 and raced off to Iron Town.

Mutation!

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He couldn’t believe his eyes when he saw the spectacle that was awaiting him.
Just look! All the iron buildings and apartment complexes, the bridges and pylons, the railways and cars and bicycles, everything has started to rust.
What was worse, Ittetsu hunted high and low, but he couldn’t see Tetsumi anywhere!
“This is impossible. I’ll have to go back and tell Socratetsu about this.”

P47

Ittetsu returned to the laboratory and found Socratetsu napping away without a care in the world. Ittetsu shook him awake and launched headlong into the story of Iron Town. “Is that so?” said Socratetsu. “That is a challenge! I must do something…”

P48-49

But why does iron rust? Socratetsu pulled a big fat book out of his bag of knowledge and began to read. The book was “The Encyclopedia of Iron”. What’s this? Rust is iron’s biggest weakness?!
This is what it said.
Iron exists in the natural world where it is linked to oxygen. The iron ore that is used to make iron is actually a great knot of rust. In other words, when iron starts to rust what it’s doing is

trying to return to its natural form. This reaction is called oxidation.

1. Iron ion
2. Water
3. Iron ions dissolve
4. Oxygen
5. Iron
6. Rust

Water

Oxygen

Iron

When iron comes into contact with water and the oxygen that's in air, it triggers a chemical reaction that causes elements called iron ions to dissolve. If these iron ions bind even more closely with oxygen then an iron oxide is created.

Is that right? Water and oxygen are to blame. What an absentminded old fool I am!

Socratetsu set his mind to work. Finally, he decided to go to the local iron works and ask them about ways to conquer rust.

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He rushed off to the iron works where the engineers quickly gathered for a meeting. This is what they said.

To stop iron from rusting, the surface processing technology known as "plating" is absolutely indispensable! It hardly ever rains in Iron Town so maybe they just forgot?

Plating is a technique used to cover the iron with a protective film. There are two typical methods. In one, a metal that oxidizes and dissolves more readily than iron, like zinc, for example, is used to cover the iron; this metal is "sacrificed", dissolving first to protect the iron. In the other, a metal that oxidizes less readily than iron is used as a barrier to prevent water and oxygen from coming into contact with the iron.

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1. The sacrificial anti-corrosion mechanism
2. Zinc ion
3. Water +

4. Plating layer
5. Zinc
6. Iron
7. A metal that oxidizes and dissolves more easily than iron (zinc or aluminum) is used to plate the iron; this metal is dissolved first, protecting the iron.
8. The barrier anti-corrosion mechanism
9. Oxygen
10. Water
11. Coating layer
12. Metallic coating
13. A metal that is less corrosive (rusts less easily) than iron (like tin) is used to coat the iron, excluding water and oxygen from the iron surface.
14. Iron

P52

“Mmm, I see. Either we protect the iron with a metal sacrifice or we repel rust with a metal barrier. Got it!”

“Can we save Iron Town by plating it…?” Ittetsu asked with a worried look on his face. The engineers nodded.

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“Right! We have to hurry!”

Hiten 1 had just been waiting for the go ahead and set off at a blistering speed.

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In Iron Town, the rain was still pouring down. Socratetsu put his foot to the floor and flew Hiten 1 over the entire city. “Oh no! Look, there’s a wounded robot down there!” It was Tetsumi, curled up between two buildings. She had hidden herself there to try and keep at least some of the rain off.

P55

In a flash, Ittetsu leapt out of Hiten 1 and went to rescue Tetsumi, giving her the plating treatment he’d learnt about at the iron works.

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Plating is like makeup for iron. It put new life into Tetsumi before their very eyes.

“Wow! She’s bbbbeautiful…” Ittetsu murmured to himself.

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After their adventures in Iron Town, Socratetsu and his friends continued to work very hard. Again and again, Ittetsu used his amazing powers to help the people. Iron Town was rebuilt using newly plated iron until finally the whole city had been transformed.

Now the town shines so brightly that it’s almost blinding. And before they knew it, the rain that had fallen for so long, stopped.

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“We’re not afraid of rain anymore!”

“Oxygen, do your worst!”

Everyone shouted as they turned their faces up to the sky.

Look! It’s an iron phoenix!

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“Thank you Ittetsu,”

Tetsumi said as she gazed lovingly at Ittetsu.

But iron and rust are old, old rivals.

The never-ending battle to create an iron that can control rust goes on.

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Socratetsu’s bag of knowledge 3

SOME STUFF ABOUT PLATING

There are a number of techniques for “applying cosmetics” to the surface of metals such as iron. You can plate the surface with a metal like zinc or aluminum (give it a metallic coating), cover the surface with glass or ceramic, paint it, or use a chemical treatment. There are two types of plating: “sacrificial rust protection” and “barrier rust protection.”

WHY IS ZINC USED FOR IRON PLATING?

Zinc is more soluble than iron. It acts as a stand-in for iron and dissolves in water, but it

dissolves very slowly, which means that a little zinc will be sacrificed over a long period of time to protect the iron. Also, its melting point is lower than other metals (zinc: 419^{o}C, aluminum: 660^{o}C) and that means less energy is needed for the plating process; in other words, zinc is an excellent metal for protecting iron from rust.

1. Poor ionizers
2. Gold
   Copper
   Hydrogen
   Iron
   Zinc
   Aluminum
   Magnesium
3. Copper ionizes less readily than hydrogen = less soluble
4. → not easily oxidized
5. Standard
6. Iron ionizes more readily than hydrogen = more soluble
7. → easily oxidized
8. Good ionizers
9. Metal ion

HOW DO YOU PLATE IRON WITH METAL?

Hot dip galvanizing and electroplating are typical plating methods. With hot dip galvanizing, the material to be coated is immersed into molten zinc to form a coating that is metallurgically bonded to the surface. You can apply a very thick metal coating with this technique. Hot dip galvanizing is primarily used for the bodywork of cars, fuel tanks and construction materials, which need to be highly durable because they are used in highly corrosive environments. With electroplating, a steel sheet is passed through a solution that contains the ions of the coating metal; the steel sheet is charged with an electrical current, which allows the plating metal to become attached. This technique makes it possible to apply a very, very thin coating. Electroplating is mainly used for drink cans and household electrical goods, which require an ultra thin coating. Tin plate, which has been plated with a thin layer of “tin”, a corrosion resistant metal, is used to make drink cans.

1. The hot dip galvanizing mechanism
2. Galvanizing layer
3. Wiping nozzle, which uses gas to control the thickness of the plate
4. Cooling
5. Annealing furnace
6. Steel sheet
7. Molten zinc
8. The electroplating mechanism
9. Electrical current
10. Rectifier
11. Metallic coating layer
12. Coating liquid
13. Positive electrode (anode)
14. Steel sheet
15. Positive electrode (anode)
16. Negative electrode (cathode)
17. Metal ions
18. Electrical current
19. Rectifier

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The story in this picture book was created from materials published in advertising in the monthly "Bungeishunju" magazine and the "*How Things Are Made – the World of Science*" series published in the "Nippon Steel Monthly" public relations magazine. If you want to learn more about iron and steel making please access the "*Working Picture Books*" website. We hope you look forward to reading more from the Nippon Steel Corporation "*New Story*" series.

We're waiting to hear your opinions and comments.

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