software
education module

Ministry of Science, ICT
and Future Planning

KOFAC
Korea Foundation for
the Advancement of Science & Creativity
한국과학창의재단

Problem-Solving Activities for Computational Thinkers ❽ Smart Medicine

software
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08

Faster and More Accurate

Smart Medicine

Cyborg Now a Reality

Smart Diagnosis and Telemedicine

Bioinformatics Extend Lifespan

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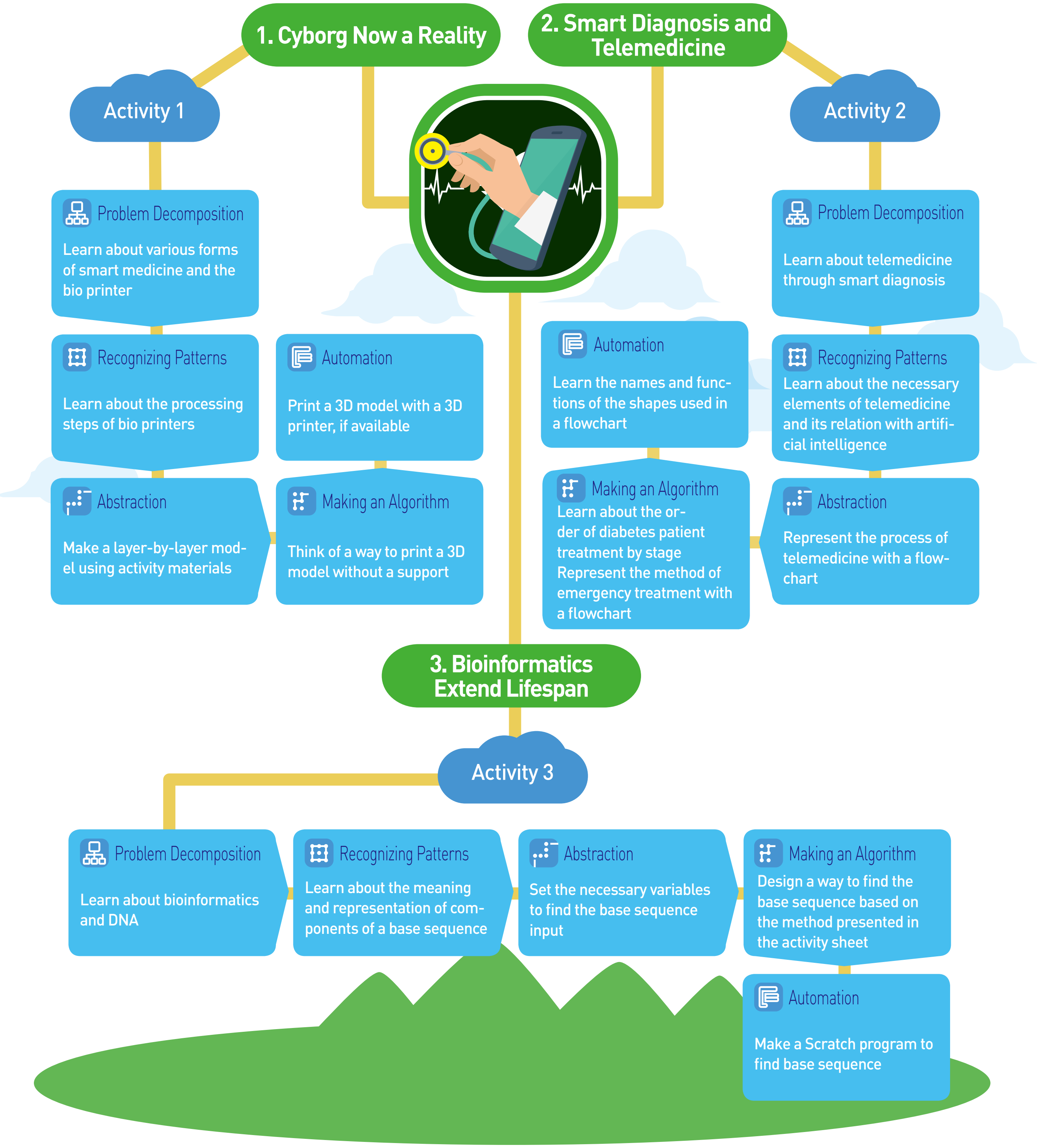
How to Use This Program

Software is changing the world. The programs installed in computers and apps that make it more convenient to use smartphones are all software. Software is in every part of our lives, so it is difficult to find areas where we are not affected by software.

The state-of-the-art science and technology that we see in the news is also helped by software. In turn, progress in math, science and technology advances software further. As such, math, science and technology are closely related with and cannot be separated from software.

These module series were created through collaboration between experts in related fields and software education, and its suitability for classrooms has been verified. As students follow teachers' direction through each module, they will be able to better understand the world that has been changed by software.

Computational Thinking Map



1. Cyborg Now a Reality

Activity 1

Problem Decomposition
Learn about various forms of smart medicine and the bio printer

Recognizing Patterns
Learn about the processing steps of bio printers

Abstraction
Make a layer-by-layer model using activity materials

Making an Algorithm
Think of a way to print a 3D model without a support

Automation
Print a 3D model with a 3D printer, if available

2. Smart Diagnosis and Telemedicine

Activity 2

Problem Decomposition
Learn about telemedicine through smart diagnosis

Recognizing Patterns
Learn about the necessary elements of telemedicine and its relation with artificial intelligence

Abstraction
Represent the process of telemedicine with a flowchart

Making an Algorithm
Learn about the order of diabetes patient treatment by stage
Represent the method of emergency treatment with a flowchart

Automation
Learn the names and functions of the shapes used in a flowchart

3. Bioinformatics Extend Lifespan

Activity 3

Problem Decomposition
Learn about bioinformatics and DNA

Recognizing Patterns
Learn about the meaning and representation of components of a base sequence

Abstraction
Set the necessary variables to find the base sequence input

Making an Algorithm
Design a way to find the base sequence based on the method presented in the activity sheet

Automation
Make a Scratch program to find base sequence

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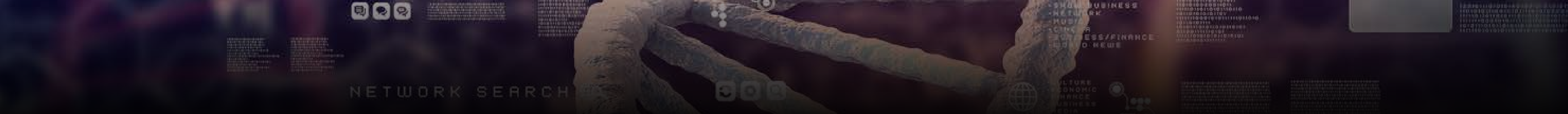
CONTENTS

Faster and More Accurate
Smart Medicine

We are in a period where living until the age of 100 is a possibility. The average life span of a human is lengthening. The development of modern technologies allows for early diagnosis and treatment. But there is much more to be done for the dream of a long and healthy life to be realized. The causes behind diseases such as cancer, dementia, or Parkinson's are unknown, and a perfect cure is yet to be discovered. We also need to develop ways to diagnose diseases at an early stage, and find treatment that is free of side effects. Now, medical technology is progressing into "smart medicine" as it is combined with IT and robot technology.
Let's delve into the world of smart medicine and learn about these life-saving technologies.



U-HEALTHCARE, A HOSPITAL WHEREVER YOU ARE

‘Beep, beep!’

The alarm on my wristwatch sounds a warning, indicating a high blood sugar level. With just a drop of blood, the kit diagnoses that the risk level is 1. That is reassuring because this level can be mitigated by taking drugs. At risk level 3, however, the diagnosis result would be shared with the hospital, which would treat me immediately after arrival. In other words, the u-Healthcare system allows people to manage their health on their own no matter where they are.

IoT, my family doctor

U-healthcare allows for ubiquitous health management and medical services using either a wired or wireless network. It includes medical devices and treatments to manage patients’ diseases as well as services that help people maintain and enhance their health. The biggest benefit of this system lies in its ubiquitous nature and real time capability. Services are available in real time, not just in hospitals but also at home, schools, department stores, parks, and even on the road or at distant mountainous locations.

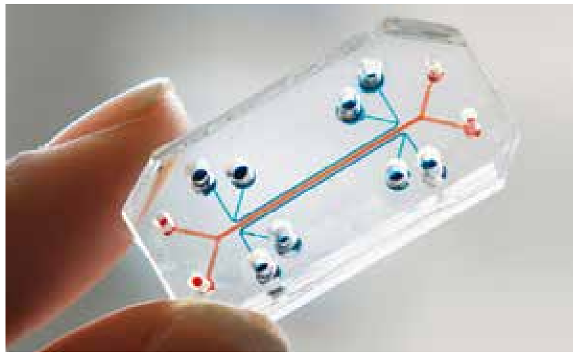
Thanks to U-healthcare, ill and disabled patients, as well as those otherwise confined to hospitals or nursing facilities can enjoy richer, more varied lives. Also, people with debilitating physical conditions have the opportunity for a better quality of life as they can enjoy socializing with other people. Moreover, busy people can enjoy medical services anytime and anywhere even when they are pressed for time.

One of the core technologies that make this service possible is Internet of Things (IoT). IoT allows things to receive and send data wirelessly through embedded sensors, which check and detect changes in body temperature, heart rate, and blood pressure in real time. A patient with a heart condition can have his/her heart rate checked at any time, and then be notified immediately if anything unusual was detected. Medicine or other necessary actions could then be taken. If symptoms are grave, the information will be shared with the hospital for telemedicine. In some cases, the patient can visit the hospital where a physician will treat him/her. This quick diagnosis and treatment is not only money- and time-saving, it also helps to catch illness or disease as early as possible.

* Blood sugar levels that are too high or too low cause health problems.

Diagnosis using a single drop of blood

A visit to the emergency room usually requires a number of diagnostic procedures, including blood tests, X-rays, and CTs, depending on the patient’s condition. Treatment begins only after test results are out, and then the doctor closely examines the patient for an accurate diagnosis. The detection of the causes and symptoms of diseases by internal examination is called in vivo diagnostics, which is a universal method. However, for emergency patients whose survival may be measured in minutes or seconds, depending only on in vivo diagnostics may lead to loss of the golden time.



A lung-on-a-chip is a type of lab-on-a-chip, which can diagnose a disease anywhere and at any time using a small chip.
© Dong-eun Huh/Professor, University of Pennsylvania

This is why much research is being conducted on in vitro diagnostics, which allows faster and more accurate diagnosis. In vitro diagnostics detects a disease, condition, or infection by testing samples of blood, urine and stool, and sputum.

The leading methodology is called lab-on-a-chip (LOC) technology. An LOC is a device that integrates several biosensors on a single chip. With minute amounts of fluids like blood, sputum, or stool, all laboratory functions for diagnosing illness can be performed on a single chip. The biggest advantage of LOC lies in the faster analysis time and low fluid volume consumption. In emergency situations, a patient’s condition can be ascertained and additional tests or treatments determined using LOC. This technology is well suited for u-healthcare as it allows for a number of fluids to be analyzed at the same time and offers great portability.

Preparing for an aging society

U-healthcare is also effective in preventing a disease. For example, the smart belt sets off an alarm if the user is seated in the same position for too long, signaling the need for movement. Patients with chronic diseases can also check their physical conditions and get treatment in real time, enabling more rapid recovery.

U-healthcare is also a way to prepare for an aging society. Japan has already entered a super-aging society as of 2006, and Korea is expected to move from an aging society to the supra-aging era in 2026. Given the large numbers of the elderly with chronic disease, there may be a close correlation

TREATMENTS WITHOUT SIDE EFFECTS!

between aging and the increase in chronic diseases. Therefore, u-healthcare could help members of a society to live healthy lives, and reduce the social costs of medical services and welfare.

As the average lifespan increases thanks to advances in medical technology, people's interests have moved from how long they will live to how healthy a life it will be. While it is important to diagnose disease or infection in real time, it is equally important to provide the correct and effective treatment. Scientists are actively researching treatment methods with the least side effects.

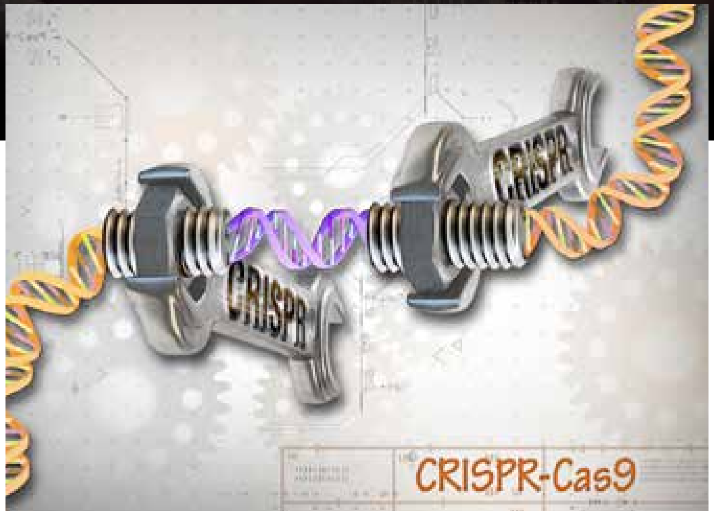
Pigs' organs to replace humans'

What are your options if you are sick but treatment seems unlikely because one of your organs is damaged? The most effective treatment in this case would be to get an organ transplant. At the end of 2015, there were 27,444 patients awaiting an organ donation in Korea, and the average waiting time was five years. The number of patients needing an organ transplant is on a rapid rise, but the number of organ donors remains low. In the United States, there are over 120,000 patients awaiting a transplant, and 22 persons die every day due to the lack of donors. No wonder heterogeneous organ transplantation has received much attention as a technology to provide replacements for failing human organs.


Developed by the National Institute of Animal Science, 'Sarangi' are pigs with altered immunodeficiency traits. Due to the removal of the functions of the immune system, the pigs show no rejection of human organ transplant. © National Institute of Animal Science

Heterogeneous* organ transplant is a procedure that transplant an organ or tissue taken from an animal. This method has been studied since the 1960s. The pig is a suitable candidate for heterogeneous organ transplant because the size, function and genetic makeup of the organs are similar to those of humans. Prior to any human transplants, transplant experiments of pigs' organs to primates are currently taking place.

A recent experiment to transplant pigs' hearts to baboons set the longest survival record. A research team at the U.S. National Institutes of Health (NIH) announced that it had transplanted pigs' hearts to five baboons, with an average survival of 290 days-the longest being over 900 days. The longer the survivability period in the primate experiment, the sooner pigs' organs can be transplanted into humans.



A conceptual map showing genome-editing scissors CRISPR. Certain disease-related genes can be cut out with CRISPR for prevention and treatment. © Wikimedia

CRISPR's genome-editing scissors

The problem with transplants is immune rejection, which occurs when a transplanted organ is recognized as a foreign body, triggering attack by the recipient's immune system. This can result in severe side effects such as blood clotting and organ destruction. Scientists began using the so-called CRISPR's genome-editing scissors to resolve this issue. If CRISPR can cut out pigs' genomes that cause immune rejection in humans, it will be possible to create problem-free organs.

Editing a pig's genome has normally taken years, but this can be reduced to less than a year using CRISPR's genome-editing scissors. Different parts of genomes can be edited simultaneously with the CRISPR, ensuring production of organs suitable for humans.

An era of 3D bio printing

3D bio printing is also considered an appropriate technology for making body parts or organs. This technology allows for the layer-by-layer construction of an organ structure using bio ink, which contains gel with live cells. Hydrogel is a material that melts at human body temperature (36.5℃). It offers key nutrients to cells and an environment necessary for their survival. It also prevents cells from dying at high temperatures.

A research team at Wake Forrest University in the U.S. has used a combination of living cells, special gel, and a nozzle to print out living human body parts—including ears and muscles. The team produced an artificial ear the same size as that of a human and planted it under the skin of a mouse. They also transplanted artificial muscles and observed no special neural changes in the recipient mouse. This highlights the possibility of using body parts printed on a 3D printer for organ transplants.


An artificial ear made with a 3D printer. © Princeton University

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* **Heterogeneous:** Different in kind

PART 1

Recommended target
Primary & secondary curriculum
Elementary school

Relevant subjects
Elementary 5th grade science
Structure of Our Body

Cyborg Now a Reality

The movie Captain America features the protagonist Winter Soldier with a robotic left arm. Indeed, Winter Soldier is capable of completing a variety of missions using his robotic arm, outperforming a human limb. The idea of a prosthetic arm was also introduced in an earlier Star Wars movie. Luke Skywalker loses his arm in a duel with Darth Vader, but has no problem thanks to a transplanted robotic arm. Robotic arms are no longer confined to movies but are gradually becoming a reality. In the same way, it won't be long before life-saving organs will be commonly used.

Prosthetic Luke Arm

With so many people losing their limbs in accidents or wars, the robotic prosthesis "Luke Arm" offers renewed hope for amputees. Set to hit the market in late 2016, the Luke Arm was designed by Dean Kamen who developed the two-wheeled electric vehicle Segway. The arm was approved for commercialization by the Food and Drug Administration (FDA) in 2014. The prosthetic uses electrodes placed on the amputated limb to pick up electrical signals from the user's muscles. When the user tenses or flexes their arm, the Luke changes its position and grip. This is much more intuitive than more basic prosthetics, which are generally controlled with switches or buttons, or adjusted manually by the wearer.

A man drinks water with his Luke arm. The biggest advantage of this prosthetic arm is that it does not require a special mechanism such as buttons; it can be controlled just like a real arm. © Medgadget

This prosthetic limb system can pull up a zipper, squeeze toothpaste to brush teeth, and pick up objects as delicate as a small, flat coin. There are four independent motors in the hand, offering the dexterity necessary to securely grip anything from a glass of water to a single egg. The shoulder, elbow, and wrist are individually powered, allowing the wearer to reach over the head and behind the back.

*** Cyborg**

A cyborg is a being with both organic and biomechatronic body parts. In short, it is a combination of cybernetics and organism.

Will artificial organs be a solution for organ donation?

The fusion of software and electronic engineering with biology and medicine has brought the cyborg concept closer to reality. In 2013, the UK's Channel 4 showed a documentary on the creation of the first ever complete bionic man named Rex. Of course, Rex is not a human cyborg, but a sophisticated human model with robotic arms, legs, artificial heart, kidney, and lungs. Currently being developed by universities and research institutes, the bionic man is 70 percent artificial organs, except for the brain and digestive system. While the exact number of artificial organs that could replace human organs is yet unknown, it is certain that they will be an important tool in future medicine.

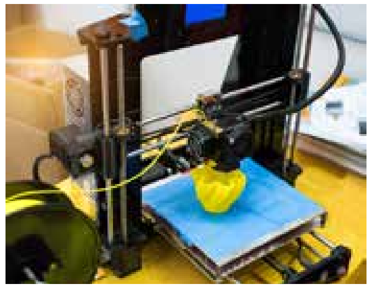
The bionic man created by a UK broadcast channel. Seventy percent of its organs are replaced by artificial ones.
© Smithsonian Channel

According to the Center for Disease Control and Prevention, at the end of 2015, there were 27,444 patients awaiting organ transplants, while there were only 2,565 organ donors, which is about 9.3 percent of the demand. Live donors of kidneys and livers account for 78.0 percent, while organs harvested from brain dead donors account for 19.5 percent.

An increase in the number of people who donate their organs could lead to more people being saved or restored to health, but at the present time, many cannot find a donor in time. Can advanced science and technology resolve this issue?

Artificial organs meet three-dimensional printing

3D printers may be a solution to the shortage of organ donation.



3D printers produce outputs by building successive, thin layers of material.

With these printers, artificial organs are created with successive layers of material. 3D printing requires software called a "slicer," which converts the model into a series of thin layers and produces a file containing instructions tailored to a specific type of 3D printer.

3D printing is hailed as a technology that will fundamentally change the landscape of future industries. Currently, most products are mass produced in big factories. This allows for controlled quality and lower costs. However, some people may not welcome the idea of using the same products as everyone else. Moreover, when it comes to artificial organs, the mass production method is unworkable because each individual requires the correct shape and size organ.

3D printers are suitable for producing a variety of products in small numbers. The working principle is similar to that of an inkjet printer, in which droplets of ink is propelled from a cartridge onto paper to recreate a digital image. Likewise, 3D printers eject melted plastic (or other materials) from a cartridge to recreate the desired shape.

Using this method, three-dimensional data can be transformed into a real object with a variety of materials. In the beginning stages of 3D printing, only small models were created, but recently, there have been efforts to make bicycles, automobiles, aircraft, and even buildings.

What would you make if you had a 3D printer that can make just about anything?

Printing cells with a 3D printer?

What about printing human cells with a 3D printer? Organovo, headquartered in San Diego, California, commercialized the world's first bio printer that enables living tissues to be constructed using human cells. In 2013, the company produced an artificial liver using bio ink. Measuring one centimeter and formed of tens of thousands of cells, the liver remained functional for 42 days or more.

However, this work is not yet focused on human organ transplantation. Instead, these artificial liver tissues are used to inspect the toxicity of newly developed drugs, because artificial livers similar to real livers help increase the accuracy of experiments.

While bioprinting may be an innovative technology to replace failing human organs, ethical issues still remain as they involve creating organs using human cells.

NovoGen MMX bioprinter ⓒ Popular Science

How it works: a 3D printer for liver tissue

Step	Process	Description
1 Step	Engineers load one syringe with a bio-ink, and a second syringe with another bio-ink.	• Bio-ink 1 is made up of spheroids that each contain tens of thousands of parenchymal liver cells. • Bio-ink 2 contains non-parenchymal liver cells that bolster cellular development and a hydrogel* that helps with extrusion.
2 Step	A mold on which to print liver tissue is 3D printed.	The mold looks like three hexagons arranged in a honeycomb pattern.
3 Step	The first syringe is positioned.	The syringe is positioned using a sensor.
4 Step	The first syringe fills the honeycomb with bio-ink.	Bio-ink is injected in the mold using the tip of the syringe.
5 Step	The output is placed in an incubator*.	In the incubator, the cells continue fusing to form the complex matrix of a liver tissue.

* **Hydrogel:** A soft and transparent material supporting the growth of cells

* **Incubator:** Nutrient designed to support the growth of microorganisms or germs

Activity ❶

How a 3D Printer Works for Artificial Organ Printing

A 3D printer allows for layer-by-layer construction of structures using materials like melted plastic. When making artificial organs, the technology uses bio-ink, which contains live cells, and not plastic. In this activity, you will make an artificial organ model using paper design. Through this process, you will learn about the layer-by-layer construction method of a 3D printer.

What to prepare Activity material 1–①, 1–②, scissors, glue, heavy cardboard

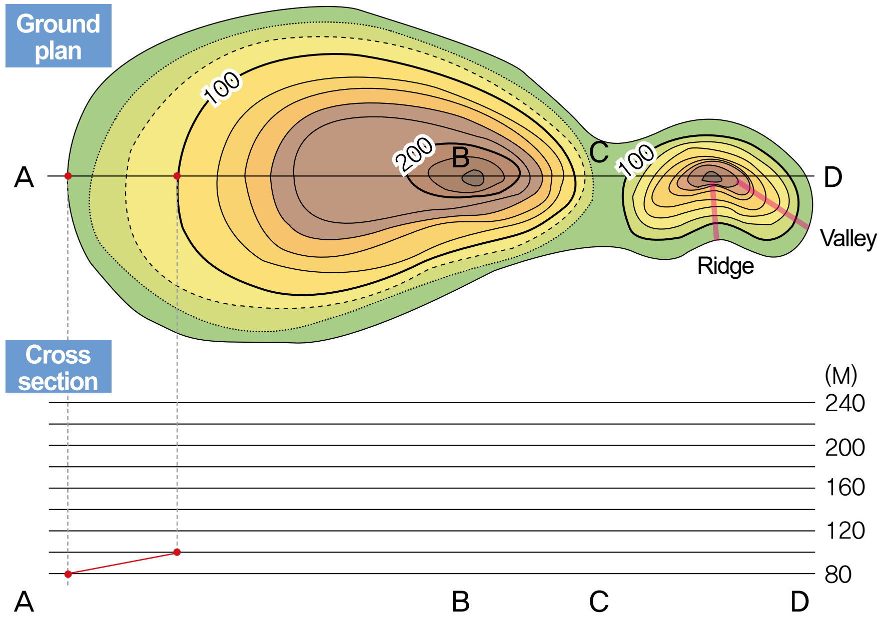
Activity

1 Use contour lines to infer a topography

A 3D printer builds a structure by stacking layers. A three-dimensional structure is made using plane data. But it is not easy to infer the shape of a dimensional structure from plane data. So first, let's practice using contour lines. A contour line is a curve along which all the points have the same altitude. This is similar to the plane data of a 3D printer. Let's draw a cross section using contour lines.

① The elevation difference between contour lines is 10 meters. From the points on the ground plan where the straight line meets contour lines, draw a line down to the corresponding altitude on the cross section below.

② Connect the dots to complete the cross section.



③ Based on the contour lines and the cross section, make a sketch of the actual topography.

2 Experience how an artificial organ 3D printer works

Let's make an artificial organ. You will find the related designs on pages 15 and 17, but it would be difficult to know what shapes they really are by looking at the designs alone. The complex calculation to deduce plane data from dimensional data can be done by computer.

① Cut out activity material 1-① and 1-②. Imagine how they would look like when stacked in order.

② Paste the materials on heavy cardboard and cut out the frame.

③ Refer to the instructions on page 14. Find the piece that matches the number and build them in order layer-by-layer.

Assembling (stacking) **the pieces**

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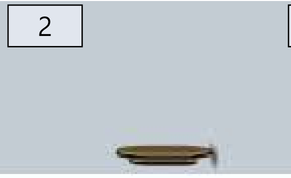

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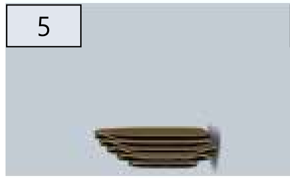

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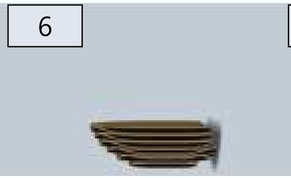

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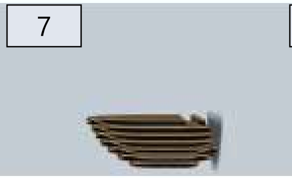

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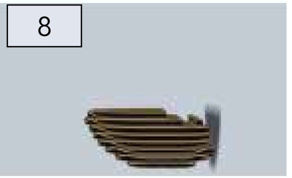

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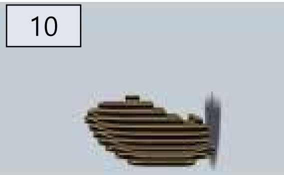

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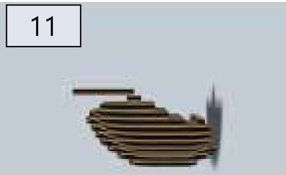

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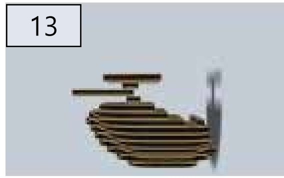

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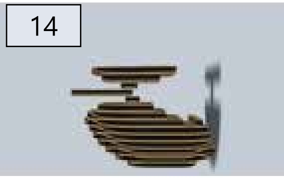

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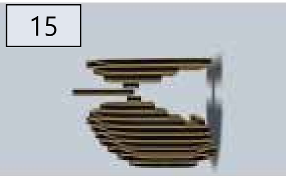

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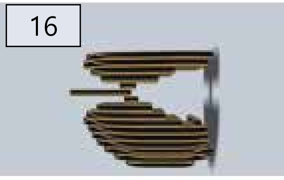

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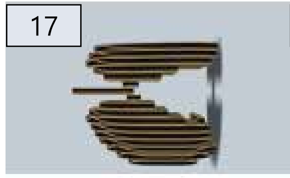

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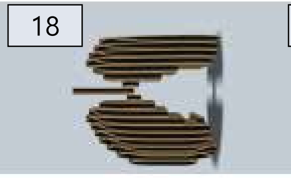

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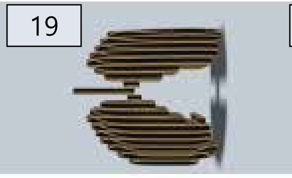

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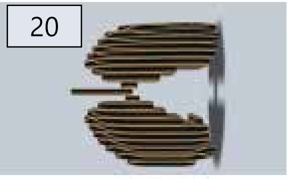

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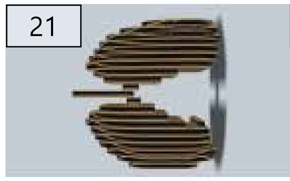

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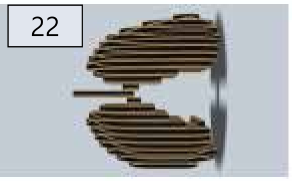
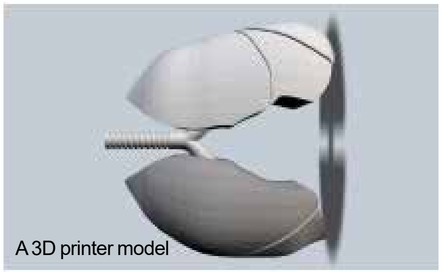
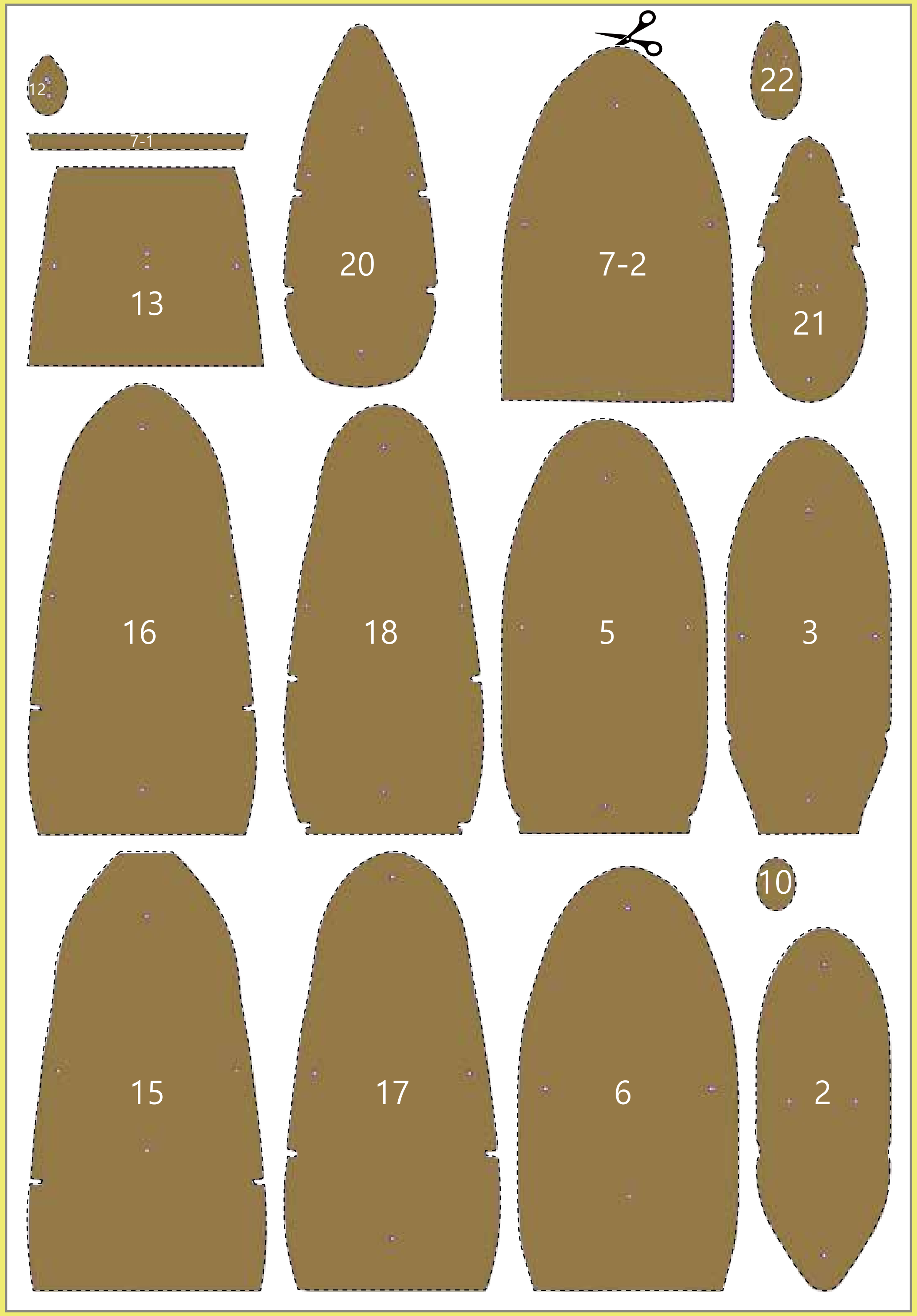
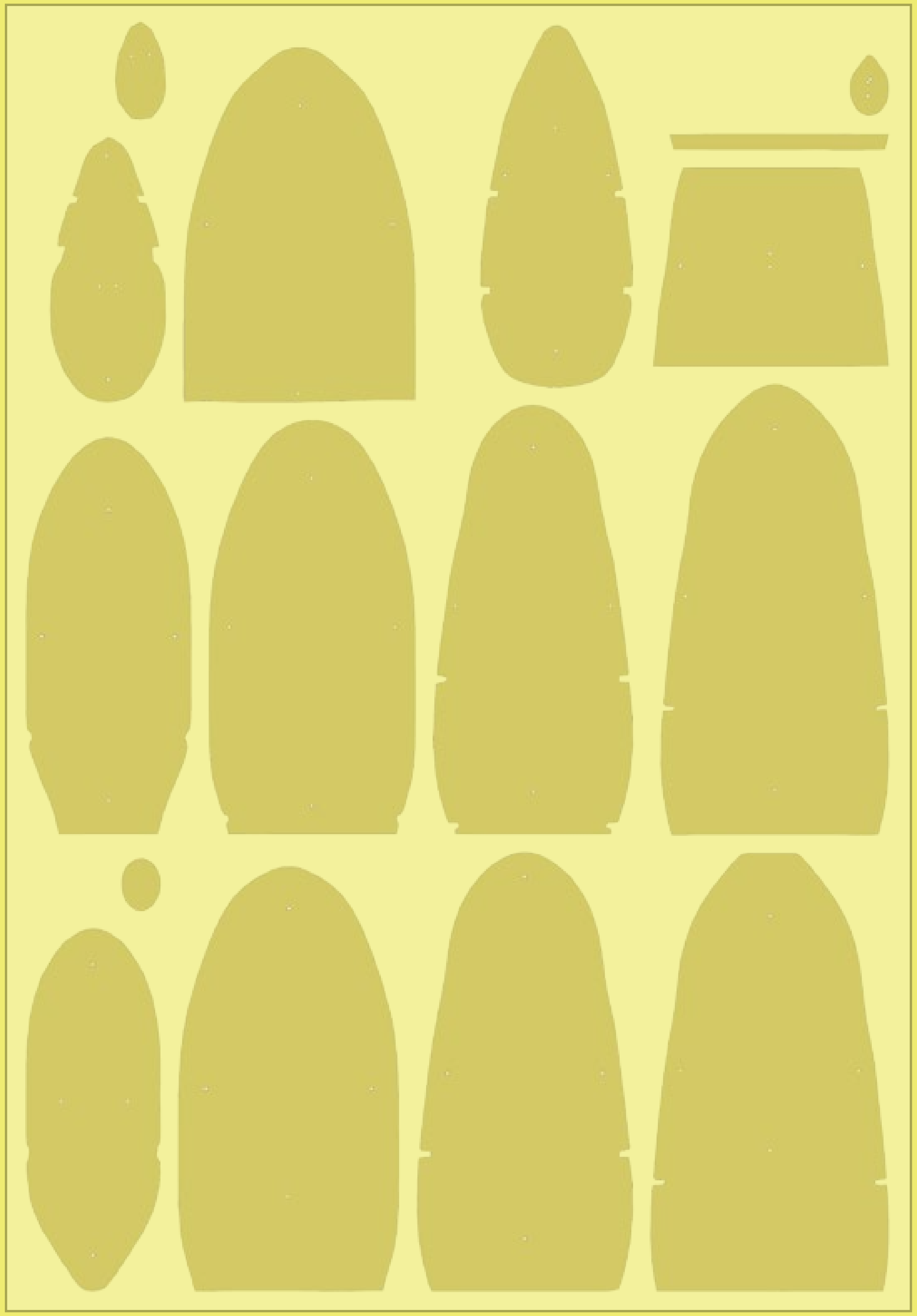



A 3D printer model

Activity material 1–①

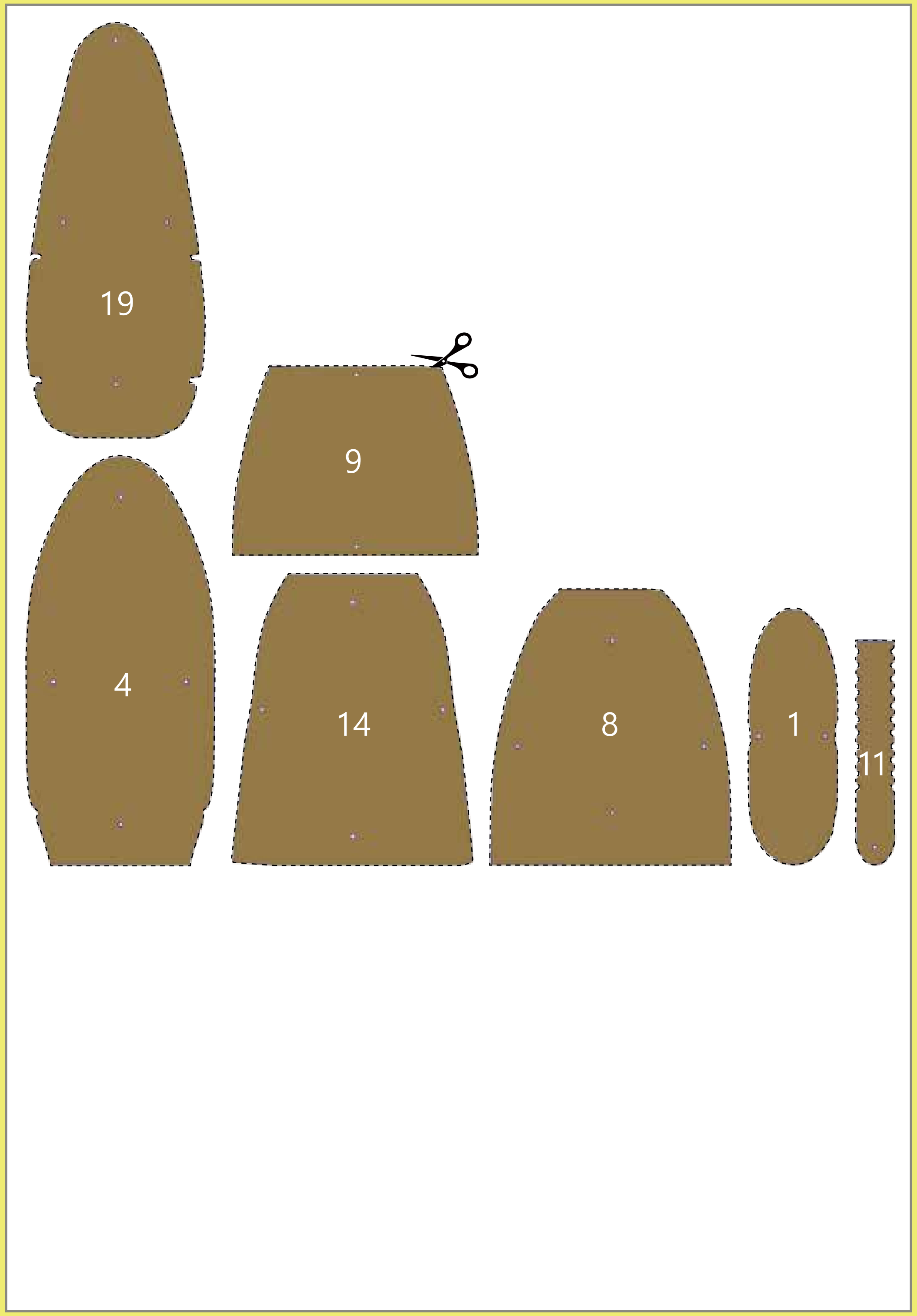
Organ model (lungs)

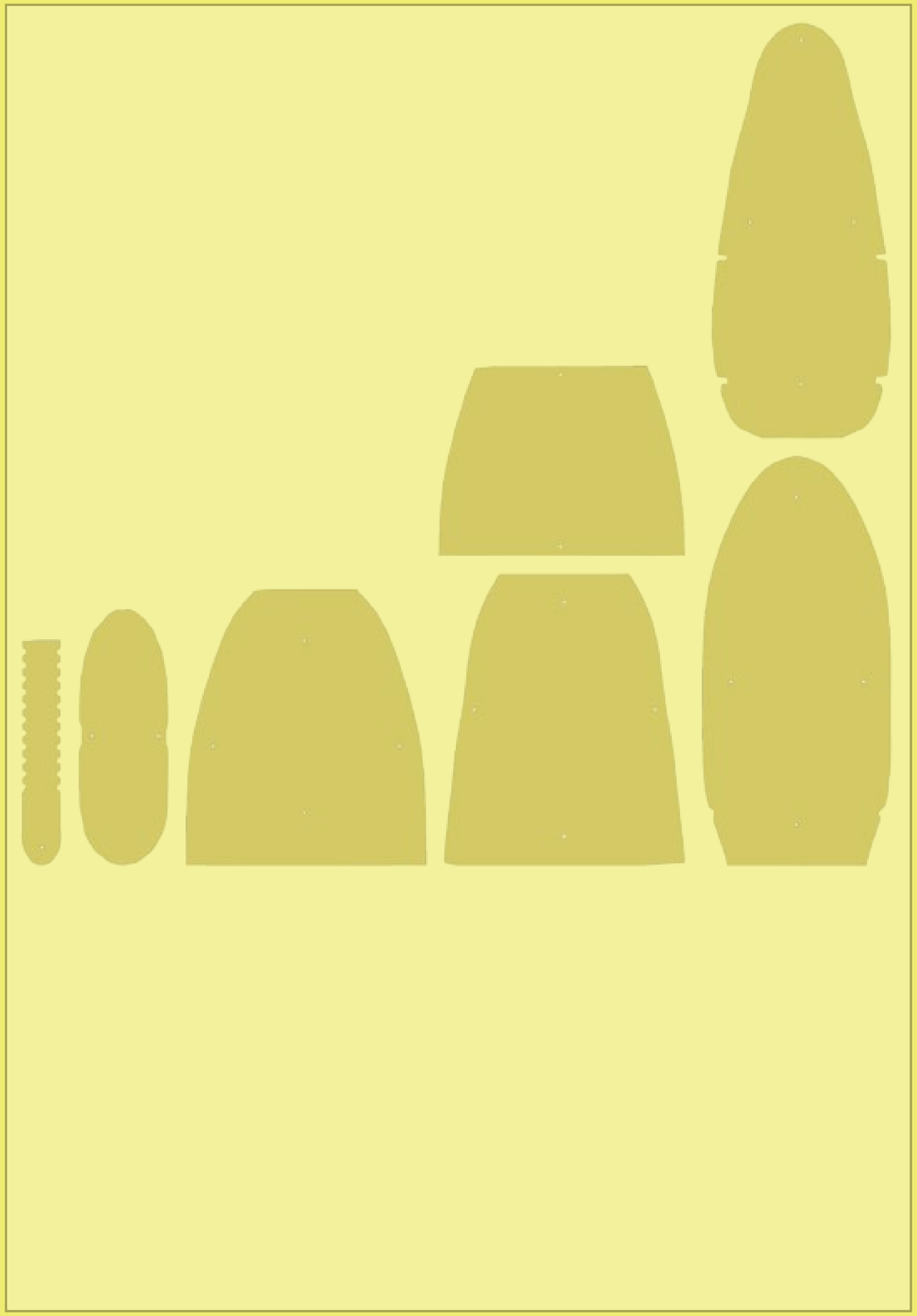




Activity material 1–②

Organ model (lungs)





3 Think

① Think about the following as you make your model.

Were some parts more difficult to build than others?	
Why were they more difficult to stack?	
How did you solve the problem?	

② Let's use a real 3D printed output to see how you did. This photo shows the same model made with a 3D printer. In the animal in the center, you will find sticks protruding below the animal's jaw down to the bottom. What are these sticks for?

③ What would you do to avoid any unnecessary structures when making a sophisticated artificial organ? In the table below, select the method that seems most appropriate and explain why you think so.

Which of the following is the best method?	Why?
1. Make a perfect 3D design from the start which does not require any extra structures.	
2. Develop new materials that would allow printing without the extra structures.	
3. To avoid the extra structures, print 3D models in several pieces and combine them later.	
4. The structures are necessary. Find a way to easily remove them later.	

PART 2

Recommended target
Middle school free semester

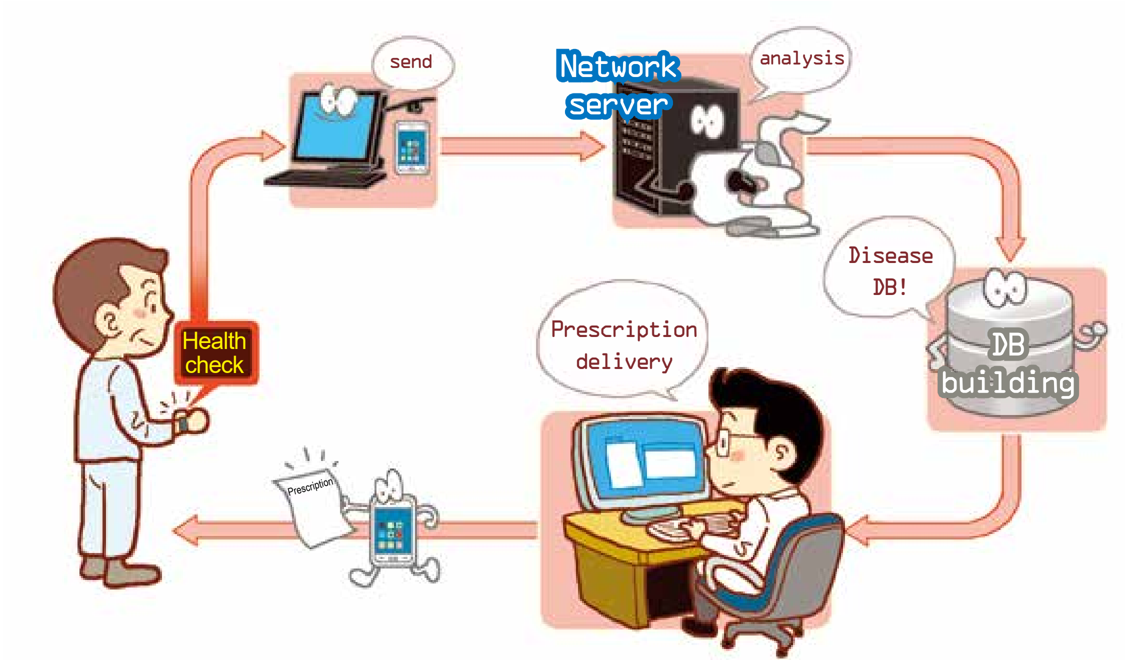
Relevant subjects
Science and human civilization,
3rd grade science

Smart Diagnosis and Telemedicine

Do minor illnesses justify a visit to the hospital? If a doctor could remotely check a patient's condition and administer a prescription, then the latter could be treated without a trip to the hospital. Telemedicine would be especially beneficial for patients with diabetes or other chronic diseases who need to visit the hospital regularly.

Telemedicine through smart diagnosis

Telemedicine refers to the delivery of healthcare information and services from a remote location. In other words, the system allows for remote healthcare services for patients living far from a hospital or with difficulties visiting a doctor for other reasons. The first telemedicine system was created in Nebraska in 1959. The Nebraska Psychiatric Institute in Omaha and the state mental hospital 112 miles away used a closed-circuit television for consultation and treatment. Several unsuccessful attempts were subsequently made to further develop this initial system. Telemedicine only developed considerably in the 1990s, with services expanding not only to homes but also to prisons, military, and remote areas with limited access to medical services. Recently, various data, including images, videos, and medical records can be easily transmitted using advanced computer and data communication technologies.



Telemedicine flow chart

Biosensors check patient conditions

A doctor needs a number of data to diagnose a patient's condition. The patient has his/her body temperature and blood pressure checked at the hospital. The doctor uses a stethoscope to listen to the sounds from the lungs and the digestive system. If necessary, blood is drawn for special tests.

Such a series of procedures can also be made remotely, and this is where biosensors come in. Biosensors check health-related data such as body temperature, blood pressure, heart rate, and blood sugar level and turn them into electric signals.

The measurements must be sent to the doctor, and this is where telecommunications come in. Today's telecommunications is so fast that sending data can be done without issues. However, because medical data contain patients' personal information, a rigorous security system must be in place to prevent data theft or leakage to third parties.

*** Biosensor**

A biosensor measures biological data, such as body temperature, blood pressure, heart rate, and blood sugar level. Telemedicine becomes possible when biosensors are connected online to send bio data to a doctor.

Issues faced by telemedicine

However, a number of issues must be resolved for telemedicine to become universal. Patients with a high blood pressure must have a tonometer (120,000 won), heart rate monitor (100,000 won), and gateway (150,000 won). Diabetes patients also need a blood sugar monitor (100,000 won), heart rate monitor (100,000 won),

and a gateway (150,000 won). Simply put, patients must pay around 400,000 won to buy the necessary equipment. While telemedicine can benefit those who live on an island or find it difficult to move, the high cost of purchasing equipment can be burdensome.

Also, practitioners may find telemedicine as being an infringement upon their interests. It must also be determined to which practitioners the authority to conduct telemedicine should be given. Due to these economic challenges and need for social consensus, there is still a long way to go for telemedicine.

Telemedicine enables medical services to be offered online. A disease can be diagnosed and treated without a face-to-face meeting between a patient and a doctor.

Artificial intelligence assists medical decisions

A doctor makes a medical decision based on knowledge and experience. What treatment to follow and how much and what drug to administer must be determined. Doctors have different levels of treatment experiences and ability, so at times they can make the second best decision and, in some cases even a wrong decision.

Artificial intelligence technology can assist doctors to make more informed medical decisions. Watson, IBM's cognitive computing system, has come to the assistance of leading U.S. medical institutions like MD Anderson Cancer Center, Memorial Sloan Kettering Cancer Center, and Mayo Clinic. The Gachon University Gil Medical Center is the first medical institution in Korea to adopt IBM Watson for cancer patient diagnosis and treatment in October 2016. The technology is expected to assist medical doctors in reaching a more accurate diagnosis as it can identify the right treatment based on a quick analysis of big data such as medical books, theses, and medical records.

Research also began for potential medical applications of Google's AlphaGo program, which became famous after beating World Champion Lee Sedol in the game of Go. Google's joint research with Imperial College London showed that medical staff responses were 37% faster, and post-operation efficiency were up by 50%.

Medical practice deals with human life, so the final decision will be made by doctors. However, it is likely that the quality of healthcare services will be significantly enhanced if AI can help medical doctors make the right decision based on accurate facts.

If you had a choice between a prescription given by a robot, which makes an accurate medical decision based on big data, and one given by a skilled doctor, which one would you choose? Why?

Activity ❷

Understand a Medical Treatment Flowchart

To develop a telemedicine program, you need to understand the medical treatment procedures. First, follow a flowchart to learn about its functions. Then, make a flowchart for an emergency patient.

What to prepare Activity material 2–①

Activity

A flowchart is a type of diagram that represents an algorithm, workflow or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. Flowcharts feature various shapes, but this exercise only uses the following three shapes.

Shape	Name	Description
▭	Process	Something is performed or data is moved
→	Flow line	A process flows in the direction the arrow points to
◇	Decision	A decision is made based on conditions

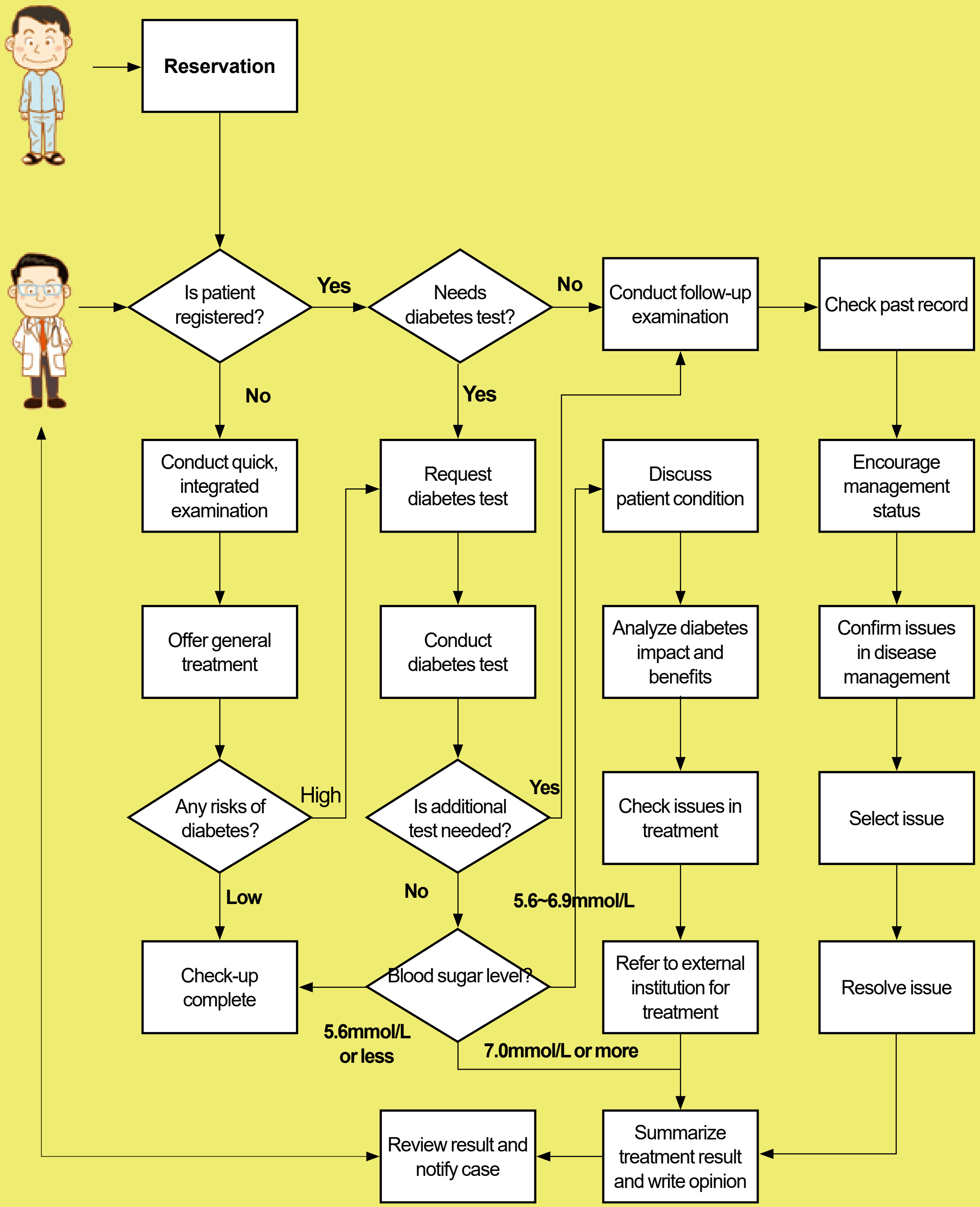
1 Follow a flowchart

Treat the following patients using the activity sheet on the right. Follow the flowchart and draw lines with a colored pencil or highlighter.
For the last two lines in the box, discuss a patient's condition with your friends and do the same thing.

Patient	Hospital visit	Diabetes risks	Blood sugar test	Result
A	1st	High	Yes	7.5mmol/L
B	2nd	Normal	Yes	6.0mmol/L
C	1st	Normal	Yes	5.0mmol/L

Activity material 2–①

Diabetes patient treatment flow



2 Draw a flowchart for emergency treatment

The following shows the seven steps in the emergency action plan for adults and teenagers. Let's develop a program for a robot (computer) to execute orders based on this plan. A flowchart would allow the flow of orders to be viewed at a glance.

Category	Description
Danger	Check the situation (casualties, bystanders, etc.) and determine risk factors.
Response	Assess the level of consciousness. Can you hear me? Open your eyes! What's your name? Squeeze hands.
Send for help	Call for help. Use your phone or designate someone to send for help.
Airway	Check, clear and then open the airway. Place one hand under the head to tilt it back slightly. Look inside for any foreign matter.
Breathing	Check if normally breathing. Yes: Place the patient in comfortable position. No: Start CPR.
Circulation	Do CPR with the 30:2 rule. 30 compressions and 2 ventilation ratio.
Defibrillation	If AED available, attach it by following the directions.

① Summarize the necessary steps below and check if they are a 'process' or a 'decision.'

Category	Type	
	Decision	Process

② Show the start and the end. Depending on the results of ①, add flow lines to complete the flowchart.

③ The following are precautions to be taken for a child. Modify the flowchart above by adding these steps.

Category	Description
Defibrillation	Is an AED necessary? Yes: 5 cycles of CPR after using AED one time. No: Continue CPR

PART 3

Recommended target
Middle school free semester
Relevant subjects
Science and human civilization,
3rd grade science

Bioinformatics Extend Lifespan

Bioinformatics is a term for the body of biological studies that use informatics. It is an interdisciplinary field that develops methods and software tools for understanding biological data. It is essential in collecting, analyzing, managing, and making use of huge volumes of bio data.

Huge growing volumes of bio data

Bio data is being accumulated at an incredible pace every day. The human genome has approximately 3 billion bases. Scientists took up the Human Genome Project to determine the sequence of nucleotide base pairs that make up the human DNA and map all of the genes of the human genome. Launched in 1990, this project was completed in 2003 and involved numerous researchers and a huge budget. These days, a person's whole base sequence can be analyzed in just a day. The same goes for the genetic code of flora and fauna.

A living organism's genetic code is contained in its base sequence, but the knowledge by itself does not change anything. Based on the sequence, protein is made for various functions. There is so much information that must be understood, including the form of the protein, how it reacts with other materials, and the role it plays.

It is now important to understand which of the huge bio data is absolutely necessary and what they mean. Bioinformatics can help improve this understanding. Because the size of data is too large for human capability to handle, the help of computer science becomes inevitable.

* **Base sequence**

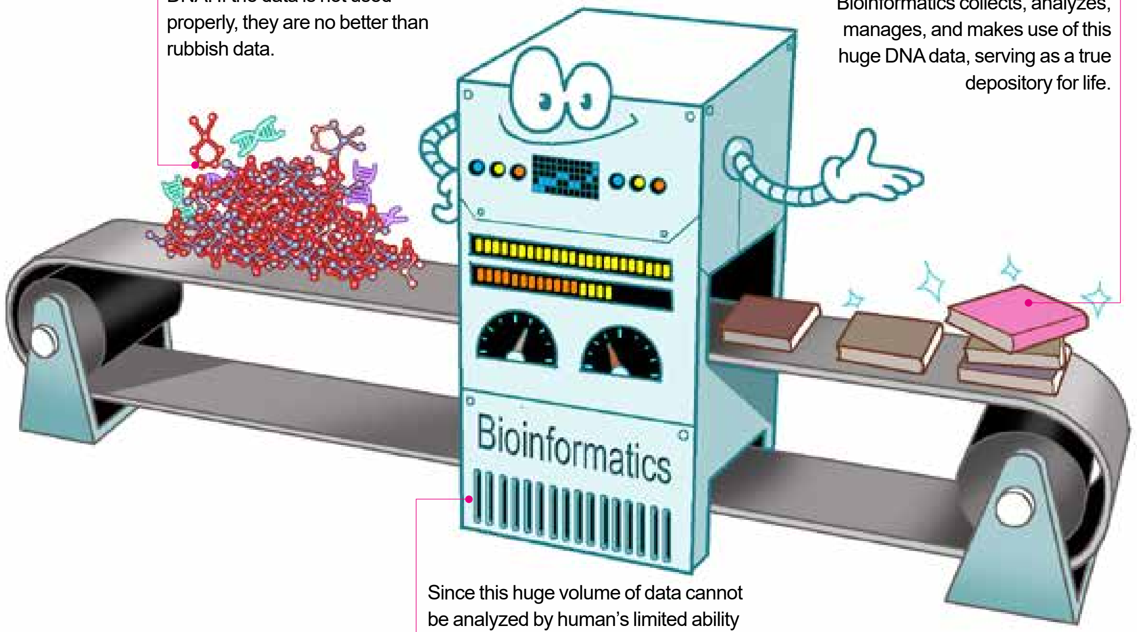
(Terminology) Base sequence DNA is a molecule carrying genetic instructions. A DNA strand has a succession of letters of the four nucleotide bases—adenine (A), guanine (G), thymine (T), and cytosine (C). This order is called base sequence, which is a code of biological data.

What bioinformatics do

Only 5 percent of the human genome's 3 billion bases are involved in the production of protein. Bioinformatics can easily locate those that produce protein and those that don't.

Certain base sequence orders the production of amino acid, which is the basic structural unit of protein. Amino acids are combined into unusual shapes inside the cells. Protein's functions vary depending on the shapes. Bioinformatics is also helpful in understanding protein's structure and functions.

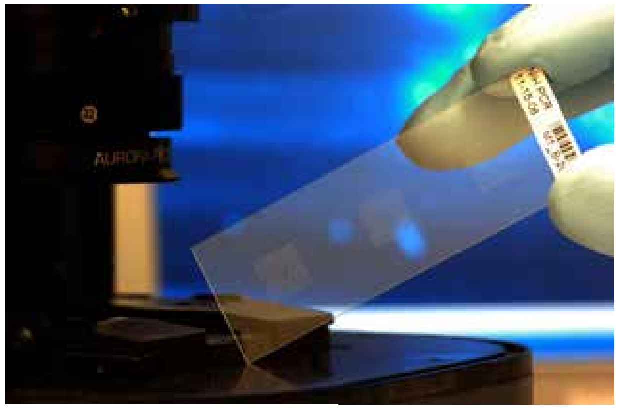
Extensive study is needed on what roles proteins perform in the body, and bioinformatics is tremendously helpful in this regard. For example, various parts of the body react differently when a protein called insulin flows into the blood. Knowing what kind of reaction certain materials cause in the cells has great implications for the development of new drugs. This knowledge can also be used to study the potential control of cancer cells or aging.



All living organisms has in store a huge amount of data in their DNA. If the data is not used properly, they are no better than rubbish data.

Bioinformatics collects, analyzes, manages, and makes use of this huge DNA data, serving as a true depository for life.

Since this huge volume of data cannot be analyzed by human's limited ability alone, computer science is used to find the necessary data.



A biochip © Argonne Laboratory

Biochip, a biological board

A semiconductor chip is a set of electronic circuits on a small flat piece (or "chip"). Similarly, a biochip is a set of organic molecules like DNA and proteins on a chip. In clinical diagnosis, it takes a lot of time to detect gene mutation that is related to cancer or AIDS. Using a biochip, this process is easier and faster.

Research is also underway on biochips that can perform new functions using the strengths of organic molecules, such as the DNA's data storage capability and the molecular recognition function of enzymes. When biochip meets bioinformatics, it can be used to collect bio data much quickly and more conveniently.

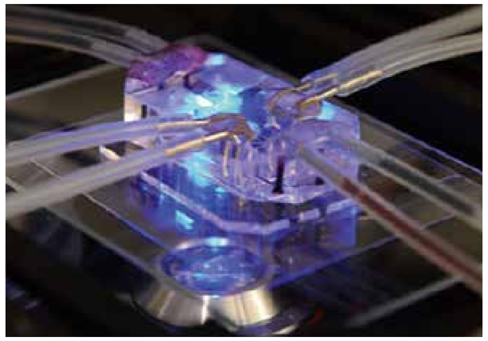
Lab on a chip!

A lab-on-a-chip (LOC) is a device featuring several biosensors on a chip. The most representative, initial form of LOC was the pregnancy test. With a drop of urine, the LOC helped determine pregnancy in a matter of minutes. This was quite innovative when it was first developed. Today's LOCs can instantly detect a disease with a drop of blood. They can also analyze several samples at the same time and they are so portable that they were likened to MacGyver's knife by the scientific journal Nature.

LOCs are also used to diagnose viruses. The timely confirmation of viruses like the Ebola and MERS—both of which are worldwide epidemics—is vital in order to prevent their spread. The Bio-Nano Health Guard Research Center of the Ministry of Science, ICT and Future Planning is developing an LOC that can catch and filter out airborne viruses, and easily determine their types without complex analysis.

A pregnancy diagnostic device that was able to check pregnancy immediately with a drop of urine was a typical device using early lab-on-a-chip technology.

Heart, liver, and lungs on a chip



An organ-on-a-chip © Wyss Institute

The development of organ-on-a-chip (OC), a device that is one step more advanced than LOC, is going at a faster pace. OC is a cell culture chip that simulates the functions of organs. For example, the lung-on-a-chip is a three-dimensional model of a human lung made with human lung and blood vessel cells. The lung cells repeat contraction and expansion as if breathing, while the blood vessel cells transport oxygen and nutrients.

The OC technology has received much attention from the pharmaceutical sector. The development of new drugs requires testing on animals or humans to predict toxicity and safety, and this entails considerable investment and time. Particularly, animal testing has long been a headache for the medical sector. Opposition to animal testing continues to grow in the U.S., Europe, and other parts of the world, and regulations against animal testing have been strengthened. Against this backdrop, OC can not only reduce the need for animals in drug testing but also save time and money. It also allows for unlimited repetitive tests under different conditions.

Of course, it will take time before OC becomes widely available. Because they deal with live cells, there are many technical issues to be resolved. Currently, the human-on-a-chip project is also ongoing to replicate the essential functions of the human body's major organs in a single plastic chip.

Organ-on-a-chip technology may be a substitute for animal testing, which has become a major ethical issue.

Activity ❸

Find a DNA

Bioinformatics is a field that collects and analyzes huge volumes of biological data using computers and software. The genetic code contained in a living organism's DNA is its very foundation. While human's entire base sequence has been analyzed, there is still a far way to go in terms of understanding their implications. Make a program that helps easily find a nucleotide sequence and see how essential software technologies have become in biology.

What to prepare Computer or notebook with Scratch (version 2.0) installed

Activity

1 Activity mission

Mission
A base sequence is made up of four nucleotide bases – A, G, T, C. First generate a DNA strand with a random sequence. Then, make a Scratch program that finds a DNA strand containing a certain sequence when inputting three sequences ([ ] [ ] [ ]).

2 Develop a project concept

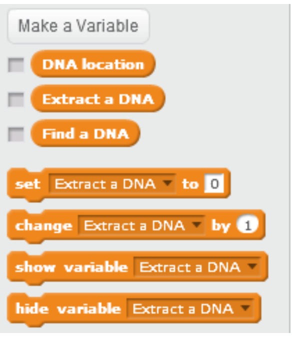
Describe in what order you want to create your program.

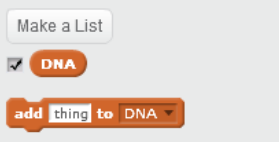
3 Create a program

① To add a backdrop, click 'Upload backdrop file,' choose a new backdrop, and click OK.

② To add a 'Pico' sprite, go to 'New sprites,' select 'Sprite Library' and select 'Pico' sprite.

③ Create a DNA location, DNA extraction, DNA search variables, and DNA list.

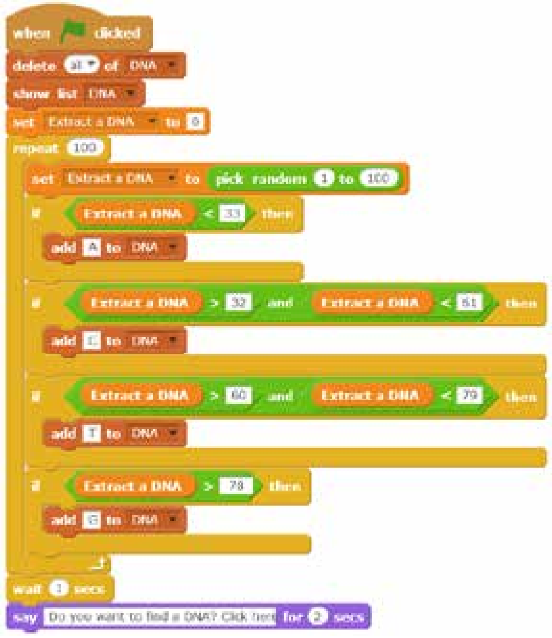




④ To randomly extract a DNA list, set random numbers from 1 to 100 as DNA extraction variables.

```
set Extract a DNA to pick random 1 to 100
```

⑤ Add A, G, T, C to the DNA list so that they can be added based on generated random number values.

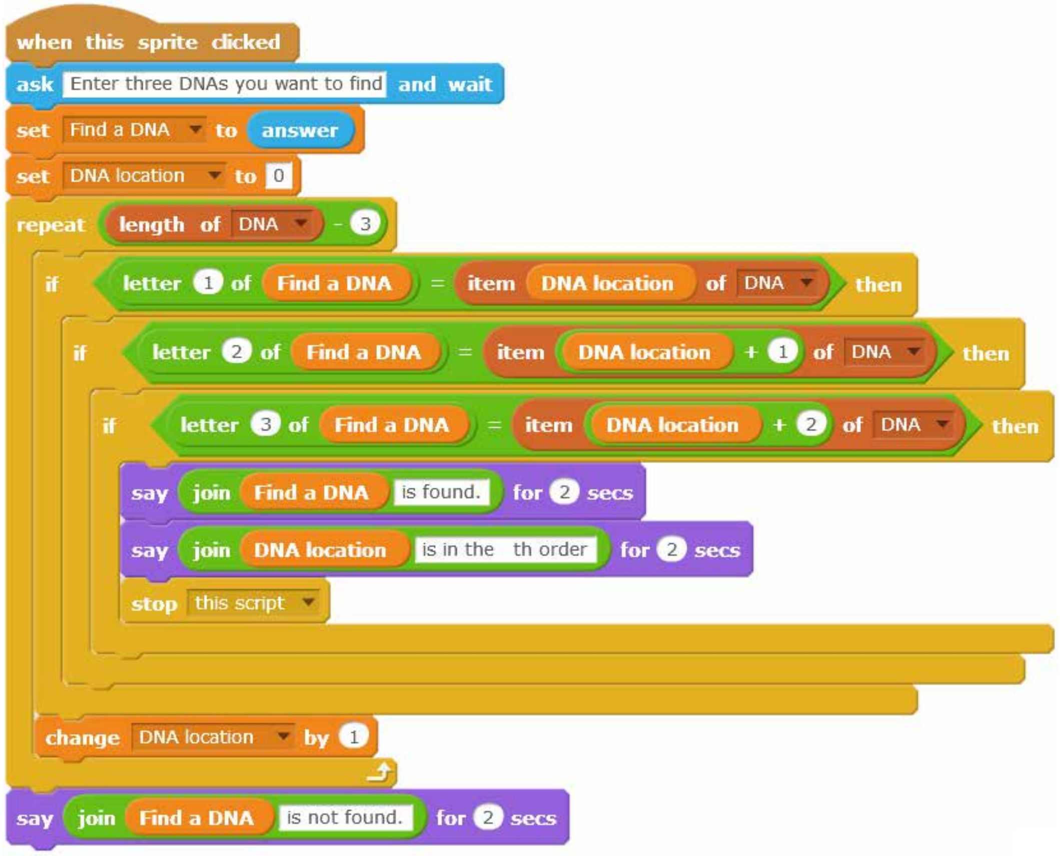


```
when clicked
delete all of DNA
show list DNA
set Extract a DNA to 0
repeat 100
    set Extract a DNA to pick random 1 to 100
    if Extract a DNA < 33 then
        add A to DNA
    if Extract a DNA > 32 and Extract a DNA < 61 then
        add C to DNA
    if Extract a DNA > 60 and Extract a DNA < 79 then
        add T to DNA
    if Extract a DNA > 78 then
        add G to DNA
wait 1 secs
say Do you want to find a DNA? Click here for 2 secs
```

⑥ Click the Pico sprite to enter the DNA value you want to find. Save it in the answer.

```
when this sprite clicked
ask Enter three DNAs you want to find and wait
set Find a DNA to answer
set DNA location to 0
```

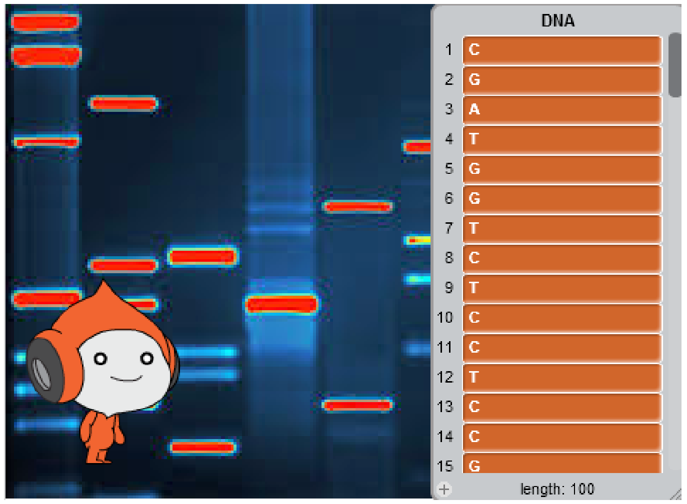
⑦ Click the Pico sprite to find the DNA. Enter three DNAs you want to find and compare the 'answer' entered in the 'Find DNA' and that on the 'DNA' list to find the location of the DNAs on the list. If the DNA is found, it will say that the DNA is found and tell its location on the list. Then the script stops. Assemble the block so that it says 'DNA is not found' when the DNA location is not found.



```
when this sprite clicked
ask Enter three DNAs you want to find and wait
set Find a DNA to answer
set DNA location to 0
repeat length of DNA - 3
    if letter 1 of Find a DNA = item DNA location of DNA then
        if letter 2 of Find a DNA = item DNA location + 1 of DNA then
            if letter 3 of Find a DNA = item DNA location + 2 of DNA then
                say join Find a DNA is found. for 2 secs
                say join DNA location is in the  th order for 2 secs
                stop this script
    change DNA location by 1
say join Find a DNA is not found. for 2 secs
```

⑧ Run the program for a random listing of DNA. Enter the DNA value you want to find and see if it is found. Make corrections if there is an error.

⑨ Program screenshot



	DNA
1	C
2	G
3	A
4	T
5	G
6	G
7	T
8	C
9	T
10	C
11	C
12	T
13	C
14	C
15	G

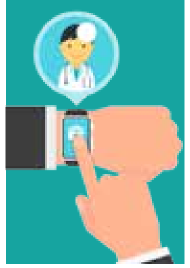
4 Change the program so that one of the following conditions are met:

① A hundred or more bases are randomly extracted.

② Sequences of DNA are associated with specific hair, eye, and skin colors, so traits change according to different input values.

5 Activity wrap-up

Briefly explain how you felt about this activity.



Smart Healthcare Specialists

Smart healthcare combines healthcare with information technology. Think about the role of medical practitioners. They conduct various tests to diagnose a disease, and administer prescriptions. If necessary, they perform surgical operations and attach an artificial organ or tissue to replace failing human parts. Some roles performed by doctors can be done by computers. Since medical practice deals with human life, important decisions are made by doctors, but computers can assist them in making the right decision. Smart healthcare is an emerging field with increased opportunities for new jobs.

What do they do?

- They develop various medical sensors to check a patient's health condition
- They develop the technology to remotely send a patient's data to a doctor; security is key as it involves personal medical data
- They develop artificial intelligence programs to analyze huge volumes of medical data for disease diagnosis
- They produce medical devices such as robotic arms that can perform elaborate surgeries
- They create artificial structures such as artificial organs and bones using 3D printing technology

Smart healthcare-related occupations

Artificial organs	Artificial organ research developer
Pharmaceuticals	New drug research developer, cytotherapy research developer
Smart healthcare	Medical sensor research developer, medical equipment research developer, IT and security specialist, smart healthcare research developer

Related majors

Medicine
Pharmaceutical Sciences
Medical Engineering
Precision Engineering
Computer Engineering

This field is a fusion of medicine and IT, so one can major in one of the two areas first and then expand his/her expertise in the other area. Information technology majors are more suited for medical sensors, smart healthcare systems, and medical device manufacturing. Medical students are more suited for new drug development, analysis of medical big data, and artificial organs. Note that collaboration with specialists in other areas is highly likely as these specialties cannot be done on one's own.

Required aptitude

- Interest in the human body, medicine and healthcare, and eagerness to learn new technologies
- Ability to research, curiosity, creativity, logical reasoning, analytical skills, and good judgment to resolve problems
- Good interpersonal skills and communication ability as this profession often entails cooperation with other technicians or specialists

Expert interview

I print circuits on wearable fabric and develop devices with built-in semiconductors that can measure brainwave and oxygen saturation in real time. The wearable healthcare device sector is emerging, so I have a lot of pride in my research. Life in graduate school was more difficult than I had expected. Sometimes, you have to stay up at night to finish your assignments, and you rarely have any time for yourself. You need perseverance and creativity to do research at the graduate level. You must not give up even if you fail again and again, and you must be able to think differently from others. When you apply for graduate school, you will find it very helpful to visit the website of the Institute of Electrical and Electronics Engineers (IEEE) to understand the working principles of electronic products and constantly read scientific magazines.

Lee Yong-su / Graduated from the KAIST Electricity and Electronic Engineering and currently in a master's program at the KAIST Semiconductor System Lab

Maker Activity

Making a Robotic Arm Model

Written by
Chang-min Choi (Dongpae Middle School)

Product overview

Product function

A robotic arm with degree of freedom showing what a medical robot looks like

How it works

Make a robotic arm with links using given design plan and foam board.
The arm can move things using the given degree of freedom.

Product picture

Product structure

Tongs frame

Power transmission

Control segment

Production overview

- **Production time** : About 6 hours
- **Needed materials and tools**

Robot arm plan	Foam board	Bolt, nut, washer, clamp	Tools
Print in actual size using A4 paper	5mm thick	3×10, 3×15, 3×20 3×25	Glue gun, gimlet, knife, ruler, driver

Key production principles

Degree of freedom

Make a robot joint using links. Use the design plan as necessary to assemble the parts. Adjust the length of the links and the distance between bolts in order to regulate the angle of movement or the gripping of the tongs.

What requires attention in production

❶ Work with the components according to the design plan and assemble using the instructions in the manual.
❷ Be careful of scratches when using a knife or gimlet.
❸ Be careful of burns when using a glue gun.
❹ Do not chat loudly or run around in the workshop.
❺ Pick up and put away tools after use; do not place tools or materials on the edges of a desk as they may cause injuries if they are knocked over.
❻ Immediately inform the instructor of any potential danger.

Required knowledge and functions

❶ Understanding of links and degree of freedom
❷ Engineering understanding of a robot arm’s movement
❸ Understanding of how to assemble using bolt, nut, washer, and clamp

SW Education Module Textbook

❶ Artificial Intelligence
❷ Driverless Vehicles
❸ IoT(Internet of Things)
❹ Virtual Reality
❺ CRISPR
❻ Space Launch Vehicles
❼ Natural Disasters
❽ Smart Medicine
❾ Game Engines
❿ Sports Statistics

Problem-Solving Activities for Computational Thinkers ❽ Smart Medicine

Faster and More Accurate Smart Medicine

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