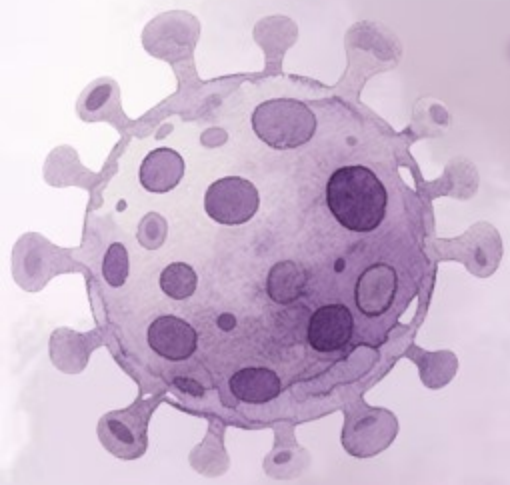
CJUH-JLU-China

# Synthetic Biology IN Seven Days

## -Basic Edition

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CHAPTER 1

# iGEM Introduction

iGEM is a cool competition where friends from all over the world will form teams and work together to solve life's puzzles with bio-magic!

They use the "life parts" to build working "life robots" in the lab! For example, some teams wanted bacteria to help them eat rubbish, while others wanted bacteria to help eat garbage, and still others wanted microorganisms to detect if water was contaminated.

The goal of iGEM is to build new living systems in cells from biological "parts" that can be used for useful tasks, such as cleaning water and detecting air.

**Cells** Tiny units of the body, like factories of life.

## 1.1 Basic Information

Founded：2003

Founder：Massachusetts Institute of Technology (MIT ), USA

Participants：Now extended to undergraduate, graduate and high school students

**MIT** Massachusetts Institute of Technology, a very famous university in the United States, where many scientists have studied.

## 1.2 Purpose of the competition

The iGEM competition hopes that you will: love synthetic biology , love science, learn to solve problems with knowledge, learn to work with your hands, cooperate and be brave to innovate, and become a person who can help society in the future!

**Synthetic biology** Synthetic biology is like putting the "building blocks" back together, like building Lego! Only these blocks are small parts hidden in the cells!

## 1.3 History

In 2003, the competition started; in 2005, it became an international competition, with more and more partners joining; in 2013, it became a non-profit-making organization dedicated to helping people to learn science and do research; in 2019, a branch in Europe; in 2020, the launch of the 'Startups' programme to support students to start their own companies.

**Startups** Small companies that are just getting started!

## 1.4 Competition rules

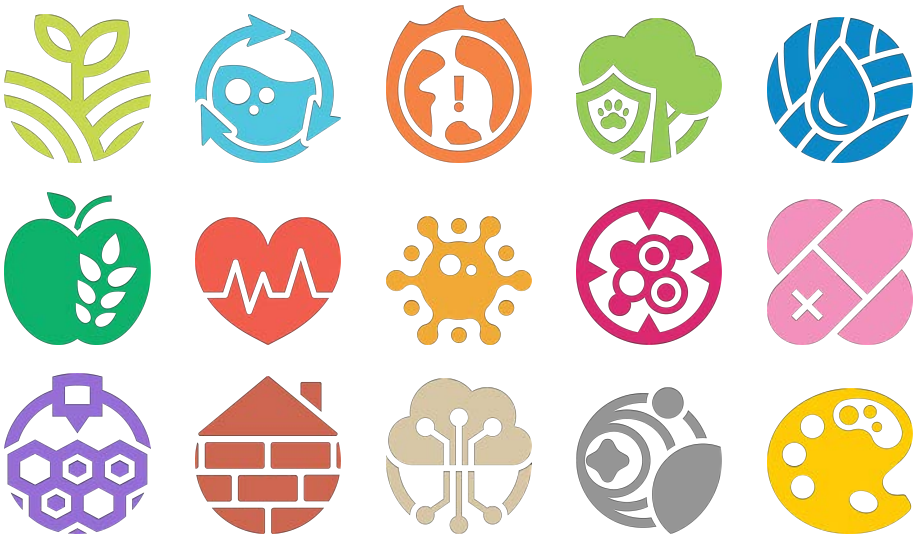
### 1.4.1 Contents of the competition

The competition requires you to put the biological "parts" together into a working system, design it, experiment with it, and observe the results to see if you have achieved your goal!

### 1.4.2 Groups and categories

Groups: Graduate, undergraduate and high school groups.

The project will be divided into different villages.



### 1.4.3 Prizes

There are gold, silver and bronze medals; village awards; special awards; and there will be a winner, runner-up and third-place finisher from the gold medal-winning team.

Grand Prize: The first, second and third place winners will be selected from the team of gold medalists.

Village Awards: Winners and nominees.

Medals: Gold, Silver, and Bronze.

Special Prizes:

## 1.5 Impact of activities

By 2024, 4,578 teams with 86,961 participants from 66 countries and territories will have competed.

Many famous magazines and TV stations have covered the event every year.

For example, Science, Nature and BBC.

## 1.6 Competition Flow

Preparation stage: Small groups of people work together to come up with ideas, conduct experiments, create videos, and build websites.

Defence stage: The team members go on stage to tell what they have done and answer questions from the judges !

There are also lots of trivia games, souvenirs, and fun activities.

The judges will grade carefully to see if everyone's work is creative, professionally experimented and clearly presented!

**Defence** In the competition, each team has to get up on the podium, explain their project clearly and answer questions from the judges.

**Judges** they are science teachers or experts who score teams and make suggestions to help everyone improve.

CHAPTER 2

# Little Experiments, Big Magic

## 2.1 How do the judges pick a winner?

The judges start working weeks in advance as they do this:

(1) Watch videos of the projects that people have done, and read the wikis full of stories about the projects;
(2) Scoring the projects before the competition starts to see which projects will win medals ;
(3) During the competition, the judges discuss the projects;
(4) At the end, the judges write down their thoughts on each project and choose a winner .

**Wiki** These are magical pages of pictures, text and animations that can be seen on your computer or tablet.

**Medals** The shiny prizes for the best performers in a competition.

**Winner** The child who has done a particularly good job in the project and has been praised by everyone.

## 2.2 What are the awesome projects? Why did they win awards?

### 2.2.1 Global awards: the best of the best programme

What kind of project wins this award?

(1) A project that clearly tells what it does;
(2) It helps people, teaches them something new, and makes something meaningful ;
(3) Tells a good story and makes a connection to the world we live in;
(4) The entire project was thought up and done by the students themselves.

**Meaning** Like a little secret that something is hiding, telling us why it's important and what it's for.

**Information Kit**

**Heidelberg team's project for 2024**

The team made a set of "genetic gadgets" called PlCasSO, which are like building blocks that can be put together to help change the way

genes look. They also made a computer model called DaVinci, which is like a map for playing games, to help people use these tools better.

#### Gold, silver and bronze medals: base medals

The Bronze Award is going to do all of this:

(1) What you need to complete the competition: project web page, presentation video, score sheet, and participate in a question-and-answer session with the judges;
(2) Tell everyone what everyone in the team did and how others helped;
(3) Leave something useful for future teams in the competition, such as a good method or tip.

The Silver Award also requires all of these:

When doing something, do it one step at a time.

(1) Use the "design-do-test" step at least once in the project, just like building a block to figure out how to build it first, and then build it to see if it's stable, and then modify it if it's not;
(2) Explain why the project is good for the world and will not have a negative impact.

The Gold Medal also has to do all of these:

(1) Do exceptionally well in synthetic biology, picking at least one of the three special awards to show what they do best.

### 2.2.2 Special awards

Various prizes with special features, here are some examples:

#### City University of Hong Kong Project 2024

**Summer camp** a group activity held in the summer that allows children to participate in a variety of activities (such as games, learning, outdoor adventure, etc.) together, which can enhance their abilities and make new friends.

They prepared fun activities for different people:

(1) **For children**: designing the science comic "Guardians of Animal City", and making a synthetic biology-themed Snakes and Ladders chess game, learning while playing;
(2) **For high school students**: summer camps and online lectures with

universities in other countries, attended by high school students from 11 countries, and made a small video on biosensors ;

(3) **For university students and the general public**: preparation of practical manuals, ethics manuals, production of science picture books with other teams.

**Lecture** An activity in which experts, scholars or people with specific experience systematically explain and share their insights on a certain topic, usually with interactive sessions that help the audience gain a deeper understanding of the relevant knowledge or ideas.

### Team Rochester's 2020 project

When they realized that some people couldn't understand science because they didn't speak the same language, they translated online posts into 10 languages and also used sign language in their videos, adding subtitles so that people who couldn't hear could understand.

### Stanford 2024 project

They researched how to stop something called DUX4 from making muscles smaller. They asked teachers, then experts , and had seminars to listen to patients' ideas, and based on those opinions, they took the project one step at a time.

**Expert** It's someone who is particularly good at something

CHAPTER 3

# Building with Life Blocks

## 3.1 What is iGEM?

iGEM is a super fun science competition where people use a skill called "synthetic biology" to build cool new things by using living things as building blocks!

## 3.2 What is synthetic biology?

Synthetic biology is like playing with building blocks: scientists take apart the small parts of living things (such as genes and proteins) and put them back together again according to the right ideas, so that they can become new small machines that can help us do more useful things!

**Information kit**

Let microorganisms help make medicines and skin care products
Make plants grow better and more resistant to pests
Let bacteria help clean up polluted environments.

## 3.3 How does synthetic biology work?

### 3.3.1 Experimenting like building blocks

Scientists break down biological parts into "modules", each with its own speciality. Some modules can light up, some can sense temperature, and when they are put together, they have new skills!

### 3.3.2 Design, make it, try it, change it again

This is the "magic step" of synthetic biology:

(1) **Design**: think about what we want to do (e.g. make a small bacterium

**Bacteria** tiny invisible creatures, some are good for us, some are bad!

that detects spoiled milk).

(2) **Make it**: use tools to put the biological parts together to make it look the way we want it to.

(3) **Try it**: see if it works (milk goes bad, do the little bacteria change colour).

(4) **Change it again**: if it doesn't work, adjust the parts and try again.

## 3.4 What can synthetic biology do?

(1) Help us make more effective medicine so sick people get well faster!

(2) Make plants grow more tasty fruit without fear of bugs.

(3) Make a river clean by making bacteria eat dirty things.

(4) Make a 'bio-detective' that can detect illness (some bacteria change colour when they get sick).

## 3.5 What to look for when playing?

While synthetic biology is fun, scientists take extra care:

(1) You can't just change animals and plants; you have to protect nature.

(2) Doing experiments should be safe and not let dangerous things get out.

(3) Ask people's opinion on whether this is the right thing to do.

CHAPTER 4

# Tiny Builders Inside Cells

## 4.1 Minor experiential basis

What is synthetic biology? It's like building blocks, where scientists take apart the biological "parts" and put them back together according to the right ideas, and then use maths and experiments to see if they work.

## 4.2 Specific experimental tips

### 4.2.1 Gene cloning – copying small genes

Like a photocopier copying a picture, scientists "photocopy" the desired gene and put it into a cell to make it work.

**Photocopying** Photocopying is the process of turning a painting into many identical copies.

The steps are simple:

(1) **Split**: find the gene and "carrier" (the little box that holds the gene) to be copied;
(2) **Cut**: use special "little scissors" (enzymes) to cut the gene and the carrier apart;
(3) **Connect**: Use "glue" (DNA Ligase) to stick the new gene and the carrier together;
(4) **Transfer**: delivering a new gene to a cell after it has been glued;
(5) **Selection**: finding the "lucky one" with the new gene from many cells.

### 4.2.2 Bacterial culture – raising small bacteria

Bacteria are extraordinarily small beings (you have to use a microscope to see them), and scientists raise them like flowers and use them for experiments.

So how do scientists raise bacteria?

(1) **Preparation of food**: Prepare a nutritious water called "medium";

(2) **Inoculation**: put a little bit of bacteria into the medium, just like sowing seeds;
(3) **Cultivation**: put the bacteria in a warm place (usually 37°C) and wait for them to grow;
(4) **Observation**: see how much the bacteria grow and whether the colour is right.

Cautions:

(1) The whole process should be clean! Otherwise, other bacteria will come and "steal the food";
(2) Some bacteria are afraid of oxygen, so keep them in a sealed house.

### 4.2.3 Protein extraction and purification

Proteins are the "little workers" in the bodies of living things, and scientists find them, clean them, and study what they can do.

How do scientists extract proteins?

(1) **Break the cell**: to break the cell, let the protein run out;
(2) **Separating impurities**: using special methods to separate proteins from other things;
(3) **Purifying**: further removing what is not wanted, leaving clean proteins.

CHAPTER 5

# Secret Instruction of Life

Dear children, today we are going to be "little bio-engineers" and explore the secrets hidden in living organisms! Did you know that? Just like we need to draw a plan before we build blocks and set rules before we play games, scientists also have a special "magic plan" when they study living things, which is "design modelling". Today, let's unveil the mystery of design modelling!

## 5.1 Why the Bio-Programme?

Because it's as important as drawing a picture before building a block. Have children ever played with building blocks? If you want to build a castle, don't you have to think about it first: what shape of blocks to use? Do you want to build the walls or the roof first? "Design modelling" is like a drawing before building, and is used by scientists in the iGEM competition:

(1) **Define the goal**: determine what you want organisms to do (e.g., make bacteria glow, make plants grow faster).
(2) **Take fewer steps**: think through the steps of an experiment in advance to avoid wasting time doing it wrong.
(3) **Predicting the outcome**: use the computer to do the maths and guess if the experiment will work.
(4) **Showing creativity**: draw a pretty picture of your plan and tell everyone how great your idea is!

**Information kit**

Computers are like clever little machines that help us do maths and store things.

Experiments and plans are good friends, and so are "design modelling" and "doing experiments": the plan tells the experiment "what to do", and the experiment tells the plan "what could be better". The plan tells the experiment "what to do", and after the experiment is done, it tells the plan "where it could

be better". With a plan, we don't have to try things out, and we can save a lot of materials and time!

## 5.2 "Magic Parts" of the Biological World

Every living organism has "genes", which are like instructions for a toy, telling the organism "what it should look like and what it should do". Scientists can put different genes together like a jigsaw puzzle to give organisms new skills - this is called "genetic engineering". For example, bacteria can be made to produce drugs, isn't that amazing?

## 5.3 Mathematical Modelling: "Growth Diary" of Living Organisms, Recording Changes with a "Magic Tool"

If biology is compared to a machine, then "synthetic biology" is the technology that teaches us to assemble the machine from biological parts. These parts have special names, but we can remember them like this:

(1) **Promoter**: like a "switch" that turns on and starts the gene working.
(2) **Terminator**: like a "full stop", it tells the gene that "the job is done".
(3) **Gene circuits**: like "circuits", where different gene parts are connected to perform interesting functions, such as allowing organisms to "glow in the dark and go out at dawn", like a street light!

### 5.3.1 Static Models

Have you ever recorded your height? For example, "growing 1 cm every month" is a simple "model"! Scientists use more powerful "mathematical models" to record changes in living things.

### 5.3.2 Dynamic Modelling

Like taking a picture of what the organism "looks like when it is stable" (e.g., the height of a plant after it has grown taller).

## 5.4 Hands-on "biology experiments"

### 5.4.1 Genetic circuits: biological "mini-game rules"

We play games with rules, such as "raise your hand before you speak", and in biology, the "rules" are called "genetic circuits":

(1) **AND gate**: like "finish your homework and pack your bag before you can go out to play" - both conditions must be met;
(2) **Oscillator**: like a "pendulum swinging from side to side", which allows organisms to change in rhythm, e.g. it helps some organisms to sleep during the day and be active at night!

### 5.4.2 Metabolic engineering: optimizing the "biological production line"

Cells have many "production lines", such as turning food into energy. Scientists can "optimize" the production lines: for example, by making the bacteria produce less of what we don't use and more of what we do need, in the same way that when you organize your toys, you put away what you don't play with and leave what you use outside!

## 5.5 Summary: We are all small engineers

Today we learned that studying biology is as much fun as building blocks and playing games! Design modelling is our magic plan, genes are the magic parts, mathematics and computers are the little helpers. Next time you observe small plants and animals, you can also make a growth plan - you can also become a great little biological engineer!

**Information Kit**

An engineer is someone who takes a whim and turns it into something useful.

CHAPTER 6

# Safety First, Science Next

Dear children, do you like to do little experiments? In iGEM, a fun science competition, scientists are like wizards breaking into the world, but they have a particularly important rule: experiments must be both safe and kind! Let's learn these magical rules today!

## 6.1 Security as a protective shield for magic

### 6.1.1 Why is security important?

Just as we have to use zebra crossings to cross the road and queue up for slides, there are safety rules that must be followed when doing experiments. These rules protect us from getting hurt, and they also protect the plants and animals.

### 6.1.2 Small safety conventions in the laboratory

Do not touch the dangerous "magic materials": scientists have a special "safety level", and these materials absolutely cannot be touched.

Experimental rubbish should be "disinfected and bathed": experiments can not be thrown out, like washing toys to disinfect the treatment, or there will be small bacteria running around.

**Information Kit**

Disinfection is a way to get rid of small bacteria and viruses and make things clean.

Listen to your teacher when using the instruments: Just like you have to ask your mum or dad before you play with complicated toys, you have to let your teacher teach you how to use the instruments in the lab before you use them!

Little magic doesn't leave the lab: the special little creatures created by scientists can only stay in the lab and can't be put outside in the grass or in the creek, otherwise they will disturb nature.

## 6.2 Kindness as scientific love

### 6.2.1 Be gentle with life

Don't just get small animals to do experiments: if you need to use small animals to help, you must first tell the teacher and the special safety committee, and only after the consent can you gently do the experiments.

Respect every little life: no matter if it is a little flower, a little grass or a little bug, they are all nature's treasures, and we should not hurt them when we do experiments.

### 6.2.2 Being an honest little scientist

Don't make up the results of experiments: The results of experiments are what they are, and you can't lie about them.

Appreciate people who have helped us: If you use someone else's good idea, tell everyone "which brother or sister came up with this good idea".

## 6.3 Making Science Everyone's Best Friend

### 6.3.1 Sharing your little discoveries

After doing the experiment, tell your mum, dad, teacher and buddies about the interesting discovery, just like sharing toys, so that everyone knows how amazing science is!

### 6.3.2 Thinking about whether people like it or not

Scientists design experiments by thinking, "Will this experiment make everyone happy? Will it make the Earth more beautiful?" Just as we think "Will Mum and Dad like it?" when we draw a picture, we have to think about people's feelings when we do science, too!

### 6.3.3 Scientific summary

Have you noticed? Doing science is like being a superhero. You need to protect yourself with "safety armor" and treat the world with "kindness and love". As long as we remember these rules, we will be able to break through safely in the world of science and become smart and loving little scientists!

Next time you do a little experiment, remember to check: Did you do it safely? Are you being kind? Let's use the magic of science to care for ourselves, our lives and the Earth!

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