Science Communication 2026

Skills for sharing the wisdom of science in English

Hiroshima University High School

Foreword

Presenting your research is just as important as doing the research itself. During a presentation, the audience listens, thinks, and then asks questions on the spot. The presenter also needs to answer these questions immediately. This flow—presentation, questions, and answers—is common at academic conferences. It can be shown like this:

Flow of a Conference Presentation
(1) Presentation → (2) Audience's questions → (3) Presenter's answers

If time allows, (2) and (3) may repeat.

On February 20, 2026, at "SSH Day," our students presented their research in Japanese and English using posters. After the presentations, they also answered questions from the audience. This is the same flow as a real academic conference. Here, I would like to point out the students' strengths and challenges.

The main strength was step (1) Presentation. Students became much better at presenting their research. Here is an example. Which presentation do you think considers the audience more?

Presentation A: *Our research topic is "Drought Stress Response of Hyaline Cells and Pores in Sphagnum palustre under Natural Conditions." First, let me introduce our study species. Sphagnum palustre is a moss….*
Presentation B: *OK. Let's start with an easy question. Do you know a sponge? … Our study organism, Sphagnum palustre, acts like a natural sponge.*

Presentation A is not bad, but Presentation B is better at catching the audience's interest. It uses something everyone knows—a sponge—to explain the research organism. This helps create a common ground of understanding between the presenter and the audience. Presentation A was prepared in July 2025, and Presentation B was prepared in January 2026. In six months, students learned how to create this common ground much better.

The challenge is in steps (2) Audience's questions and (3) Presenter's answers. This relates to what the Ministry of Education is focusing on. In the 2018 Course of Study, "speaking" was divided into "Speaking [Presentation]" and "Speaking [Interaction]." This is because students need more practice speaking spontaneously in a foreign language.

In poster presentations, both presentation abilities and interaction abilities are necessary. You can prepare your presentation in advance, but you cannot prepare the exact questions you will receive. You must answer them immediately. I feel students still need to improve this "interaction" part. *Science Communication* will help you.

ONO, Akira (Ph.D.)
Principal of Hiroshima University High School

Table of Contents

Part 5: Oral Presentations to Written Papers

Part 6: Supplements

Part 7: Worksheets

Introduction

Presentation

Day 1 Types of Presentation

[Lecture]

1. General purpose of the course

This course aims to help high school students to learn and improve linguistic and paralinguistic skills in making presentations in science and technology. Then, what is a presentation? The first three definitions in an English dictionary goes:

1. a meeting at which something, especially a **new** product or **idea**, or a piece of work, is shown to **a group of people**
2. the act of **showing something** or of giving something to somebody
3. the way in which something is offered, shown, **explained**, etc. to others

[*Oxford Advanced Learner's Dictionary* 10th edition]

As far as your presentations are concerned, which will be about your research projects, you should take note of the words in bold letters; your presentations will

explain new ideas,
be for a group of people,
and include not only telling but showing.

2. Types of presentation

Presentations are made by different people in different situations for different purposes, thus resulting in different types of presentations. The three broad categories are ceremonial, informative, and persuasive presentations. The ceremonial presentation is given at formal gatherings such as the entrance ceremony of a school, a formal wedding party, and a church service. What is said in the presentation is rarely the point of discussion. The only important thing is that the speaker says the right thing at the right place at the right moment and maybe in the right manner.

The persuasive presentation is more interactive and varied in its style and content. It is made mainly in business settings where the speakers try to talk the listeners into buying their products or making contracts with their companies. The speaker needs not only to give correct information but also to affect the listeners' thoughts and behaviors.

The informative presentation introduces new ideas to the listeners that they do not know. The speaker wants the listeners to share his/her own ideas and look at the subject in question in the same way as he/she does. Academic presentations fall into this category, and so do yours on your research projects. As the speaker, you try to **change** the way your listeners see the world, however small the change may be.

[Comprehension Check]

1) The presentations you make on your research project should be for a group of listeners, and you should **[ ]** not only by **[ ]** but also by showing.

2) When you give a presentation on your own research project, you should try to **[ ]** how your listeners look at the world so that they can **[ ]** your own perspectives.

Day 2 Presentation Messages

[Lecture]

1. Three kinds of presentation messages

A presentation conveys the speaker's ideas to the listeners. How? There are three vehicles:

1. Physical message
2. Story message
3. Visual message.

These three together are called "presentation messages."

The physical message is, in short, "body language." It includes gestures, postures, eye contact, and voice. While these cannot express the content of the presentation, they can show the speaker's **attitudes** towards it, helping the listeners understand the speaker's emphasis.

The story message is the core of the presentation. What was already known, what was not, and what the present study has revealed or is going to reveal about the unknown. The speaker tells them in a coherent story. The story is, of course, not like those written for entertainment. But still, it can be, and should be, as entertaining.

The visual message is something that goes with the talk to show ideas and concepts in pictures, movies, charts, and diagrams when they are hard to verbalize. Posters and slides often carry visual aids that help the listeners understand what the speaker says, and when it is appropriate, actual things like the samples or the apparatus can be shown.

2. Linguistic and paralinguistic measures

The story message is linguistic, that is, it is expressed in words. The other two are paralinguistic, that is, they are expressed in means other than words. Both are important. Combining linguistic and paralinguistic measures strengthens the speaker's message and helps the listeners to understand the messages more fully.

The three messages require their own skills, so you will have to learn them one by one. At the same time, however, you should always think how you can combine them to convey your message in the best way.

[Comprehension Check]

1) The speaker's ideas are communicated to the listeners through three kinds of presentation messages. They are **[ ]**, **[ ]**, and **[ ]**messages.

2) The most important element of a presentation is the story message, which lays out the study in a context that progresses from the **[ ]**to the **[ ]**.

3) While language plays an important part in a presentation, it is not the only vehicle of message. It is accompanied by other means of communication than language such as **[ ]** and**[ ]**.

Part 1

Physical Message

Part 1: Physical Message

Day 3 Pitch, Pace, Projection, and Voice Inflection (1)

[Lecture]

Your voice matters. No matter how carefully you plan your presentation script, it cannot work as you expect it to if your voice doesn't measure up. Your control of voice contributes to the intelligibility of your speech. Intelligibility means how clearly your ideas are understood, which is the most important factor in a presentation. Then, how can you control your voice and let it work for you? Below are major skills that should be in your toolbox.

1. Pitch

Pitch is the highness or lowness of your voice. Everyone has their own "natural" pitch that they were born with, but you can also vary your pitch to complement, or sometimes even contradict what you are saying in words. The patterns of such use of pitch are called "intonation." The same sentence can mean quite the opposite when said with different intonations. For example, the second utterance in the conversation below has different meanings depending on whether it is said with rising or flat intonation.

e.g.) I passed the exam at last! – Wow, that's great!

a) falling intonation ↘

b) flat intonation →

There are three basic intonation patterns: falling, rising, and flat. The falling and rising intonations are sometimes combined to make the falling and rising intonation and the rising and falling intonation.

2. Pace

Pace, or speed, means how fast you speak. Just like pitch, everyone has their own natural pace. But in a presentation, you need to consciously control your pace. Be especially careful at the beginning. Your listeners are still not quite sure what you are going to talk about, and they may not be familiar with the technical terms you use. They need extra time to understand what you say and feel comfortable being there among the audience. Therefore, "**start slow**" is the golden rule. No matter how eager you are to present your material, remember that the presentation is not for you but for your audience. Control yourself and slow your pace.

Being slow all the time, however, is not good. The pace of your speech shows how much emphasis you are placing on the subjects you are speaking about. A slow pace often implies that you are being careful to deliver the information in a way that listeners can easily follow, while a faster pace implies that the information is "lighter" or not so important because it is just an example or a bridge to more important words. Varying your pace can also create a more comfortable rhythm in your speech and help your listeners to stay focused on your presentation.

[Comprehension Check]

1) The **[ ]** or **[ ]** of your speech is called pitch, and the combined use of pitch is called **[ ]**.

2) Intonation can make the meaning of the sentence clearer. Sometimes it even helps mean the **[ ]** from what the sentence says literally.

3) At the **[ ]** of your presentation, you should speak slowly so that your audience can fully understand you and feel comfortable.

[Practice]

A. Say the sentences below with different intonations.

1) *The sound level depends on the speed at which the blades close.*

2) *The sensory test showed that the chickpea meringue was inferior to egg white meringue in flavor and sourness.*

B. Imagine the passage below is the beginning part of your presentation. Read it aloud.

The purpose of our study is to develop a new cost-effective biodegradable material that is easily decomposed in the soil. For this purpose, we attempted to composite vegetable fibers with chitosan nanofibers to produce a biodegradable film. This film was not high in strength and moisture resistance. But when it is coated with chitosan, its strength and moisture resistance improved while it maintained its biodegradability.

（出典：大島梛・奈良定志穂（2022）「生分解性を有する新素材の開発」
広島大学附属高等学校『スーパーサイエンスハイスクール課題研究論文集 18』pp.49-58 所収）

Day 4 Pitch, Pace, Projection, and Voice Inflection (2)

[Lecture]

3. Projection

Projection is the volume and **clarity** of your voice. To focus on the content of your presentation, your audience must hear your voice easily. It does not mean you should shout but your voice should be readily audible.

As for the volume, a good criterion is whether the person at the farthest end of the audience can hear you without difficulty. You may think your voice is loud enough for them to hear, but you often need to increase your volume by two more grades. If you are not good at doing this, you must practice how to control your breath.

Clarity is another factor that contributes to audibility. You must articulate your words carefully so that your listeners can catch what you're saying. **Consonants** are especially important for them to grasp your message. When you're trying to sound like a native speaker of English, you may sometimes blur or drop consonants. However, if this happens in the wrong place – and it often does – it hinders communication. For example, what incorrect sentence might a listener hear if the following sentence is pronounced poorly?

Correct: *Calcinating of diatomaceous earth and acid leaching are considered effective in improving silica purity.*

Wrong: ?? *Cow slating of diet meat should earthen a sea urchin's sealer effect in pooing sickability.*

4. Voice inflection

Related to the above three is **voice inflection**, which is how you change your way of saying words. This course presents four patterns of voice inflection: (1) stressing, (2) stretching, (3) pausing, and (4) repeating.

(1) Stressing: You emphasize the words you want to highlight by pronouncing them strongly. Stressing includes a greater volume and a higher pitch. In written English, this is often expressed in *italics*, **bold**, or CAPITALS.

(2) Stretching: You pronounce the words – more precisely, their vowels – for a longer time. Stretching usually accompanies stressing almost automatically in English, but it is advisable for Japanese speakers to do this intentionally because the Japanese language does not use stretching as often.

(3) Pausing: You put a short silence before the words you want to emphasize. The silence attracts the listener's attention before going on to the important words.

(4) Repeating: You repeat the words you want to emphasize. When you say the words the second time, you can pronounce it differently from the first time.

[Comprehension Check]

1) A good projection comprises the **[ ]** of voice and the **[ ]** of pronunciation.

2) For a better audibility, you should articulate **[ ]** clearly.

3) The Japanese language does not use **[ ]** as often as English does.

[Practice]
Read aloud the following passage in several different ways by combining different skills of controlling your voice. When planning voice inflection, use the symbols below.

Stressing: word Stretching: word⟷ Pausing: / word Repeating: word ×2

Understanding the Theory of Relativity

The theory of relativity, developed by Albert Einstein in the early 20th century, changed how we understand the universe. It is divided into two parts: Special Relativity and General Relativity.

The core idea of Special Relativity is that the laws of physics are the same for everyone, but measurements of time and space can change depending on how fast you are moving. The only thing that never changes is the speed of light. For example, if you traveled on a very fast spaceship, time would actually pass more slowly for you than for people back on Earth. This is known as "time dilation."

General Relativity explains gravity in a new way. Instead of thinking of gravity as an invisible pull, Einstein imagined space and time as a fabric called spacetime. Imagine placing a heavy bowling ball on a trampoline; the ball curves the fabric around it. According to Einstein, massive objects like stars and planets warp spacetime in the same way. When a smaller object moves near a large one, it follows these curves. This is what we feel as gravity.

Einstein's famous equation, $E = mc^2$, also comes from this theory. It shows that energy E and mass m are actually different forms of the same thing.

(Text originally written for this coursebook)

Part 1: Physical Message

Day 5 Gesture, Posture, and Eye Contact (1)

[Lecture]

Your body talks, sometimes as eloquently as your words. In many cases, body language goes along with the words to complement or strengthen the literal message. However, a classical experiment revealed that when a person's words and their body language contradict, such as when the person says, "Thank you" while looking away from the other person, you will know it is not a real "Thank you." Controlling your body language helps you get your message across more efficiently. In this course, we will look at three types of body language: gesture, posture, and eye contact.

1. Gesture

The first thing to note here is that there is no fixed rule of whether, or what gestures should be used. Everyone has their own way of using their body while speaking, and people are flexible enough to understand those differences. Therefore, the following are only basic principles based on which you can develop your own style of communicating ideas.

Firstly, remember the movement of your body is likely to look smaller than you think when you speak in front of a large audience. You might have to spread out your arms, turn your body, and nod your head to the degree you feel you are exaggerating. Good advice is to video-record your presentation and watch it yourself. This is certainly a little embarrassing but helps you have an objective image of your own speaking.

Secondly, this may seem contradictory to the first point, but your gestures should appear natural. It is not advisable to "plan and apply" gestures that you don't use in everyday situations. It will make you look clumsy or awkward and signal to listeners that you are not being yourself. Practice speaking and see what gestures come naturally. Then, control them so they serve your speech.

Using tools can be helpful. A pointer stick is handy for poster presentations. You can use it to point to different parts of the poster, show degrees by holding it horizontally, and demonstrate increases or decreases by holding it diagonally. Depending on your presentation topic, other tools, as simple as a ruler or a compass, may also be useful (this is where the physical and visual messages overlap). Look in your toolbox for anything that might help.

[Comprehension Check]

1) When someone's body language contradicts their words, the listener is more likely to believe the message conveyed by **[ ]**.

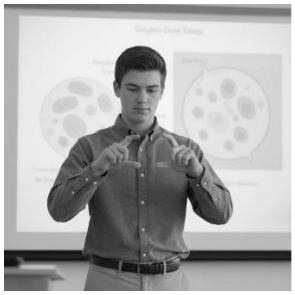
2) When using gestures in a presentation, you should use them in an **[ ]** manner in a sense, but they should also come **[ ]**.

3) It is effective to **[ ]** such as a pointer stick together with gestures.

[Practice]

1. Imitate the following gestures.

1)

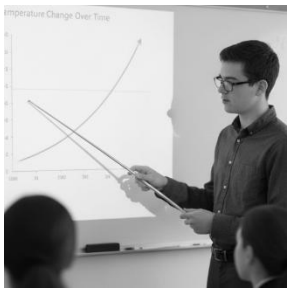


"It's about this size."

2)

"The results are shown in this graph."

3)



"There was a sharp increase [decrease]."

4)

"It happened exactly at this point."

(*Images created by Google Gemini*)

2. Say the following sentences with gestures.

1) *After 290 seconds, the reaction began to slow down.*

2) *This insect is this small, but it plays a huge role in this area's ecosystem.*

3) *The simulation produced a prediction that was completely unexpected.*

Day 6 Gesture, Posture, and Eye Contact (2)

[Lecture]

2. Posture

Posture refers to how you stand when you speak. Like gestures, you don't need to do anything unnatural for you. Just relax and be yourself. Your posture is sometimes affected by the physical setting of where you speak. For example, if there is only a large screen on the stage and no podium or microphone stand, you may want to pace while speaking. If there is a podium to put your laptop on, you may want to stand behind it for most of your presentation. For a poster presentation, you will stand beside the poster, but you may want to walk away from it briefly to show items to your audience. Essentially, do what feels natural in the given situation.

One thing to keep in mind when controlling your posture is to always relax. You may feel nervous standing in front of a large audience whom you are not familiar with. Your body may tense up before you know it. This is a natural reaction for inexperienced speakers. Nevertheless, you should try to open up to your audience. In general, you should stand with equal weight on both feet. Your hands should be placed on the sides of your body just naturally, or if they need somewhere to rest, fold them lightly in front of your body, just below your waist. Breathe slowly and deeply. One thing to be careful of when breathing is to focus more on exhaling than inhaling. Focusing on inhaling causes your body to tighten. Focusing on exhaling has the opposite effect and relaxes your body.

As a high school student, it is not advisable to speak like a renowned professor or CEO of a tech company. You should be polite because, in many of your presentations, you will receive instruction and evaluation from more experienced researchers. However, you should also be confident. Believe that what you are saying means something to your audience. So, don't close, but open up.

3. Eye Contact

Making eye contact can be challenging for introverts. Some people avoid making eye contact even during everyday conversations, so they may find it even harder to look their listeners in the eye during a presentation. Nevertheless, remember that eye contact matters. Not only does it help your audience focus on your speech, it also helps you gauge how much they understand.

The general advice is to look at one person for two seconds and then move on to the next person. When speaking to a large audience, look around in a "Z" pattern to make eye contact with everyone.

You may be holding a script paper in your hand. But you should look away from it and speak to the people in front of you. Look at your paper only when you really need it. Using a smartphone instead of paper is highly inadvisable.

[Comprehension Check]

1) A speaker's posture may be affected by the physical setting in which they speak. During a poster presentation, for example, the speaker may **[ ]** to interact with the audience.

2) When it comes to breathing, focus more on **[ ]** than **[ ]**.

3) A good way to make eye contact with a whole group of listeners is to **[ ]**.

[Practice]

1) arms naturally down beside the body

2) hands met in front of the body

3) making contact with the audience

(*Images created by Google Gemini*)

Part 2

Story Message

Day 7 IBC and IMRaD

[Lecture]

In the broadest sense, a presentation is about explaining a new idea. The speaker introduces something that was previously unknown to science. Therefore, to help the audience understand the new idea, the explanation should start with what they know and gradually progress into the unknown. This flow of explanation creates the "story" of a presentation, and there are a few frameworks shared by scientists around the world.

1. IBC

One of the simplest frameworks for storytelling in science is the three-part structure: **Introduction**, **Body**, and **Conclusion** (IBC). Introduction provides background information and motivation for the study, including a summary of previous research. The speaker identifies a research gap and defines the question they will answer.

Body is the main part. The speaker illustrates the procedures used to address the defined question. All the necessary information to understand and evaluate the study is presented here, including the materials, experimental apparatuses, procedures, and measurements used. At the end of Body, the speaker presents the results of the surveys or experiments and discusses how they answer the question.

Conclusion does what its name says: it concludes the presentation. The speaker states what has or has not been clarified through the study and proposes an answer to the question. They often comment on what remains unanswered and requires further research, offering suggestions for their own and other researchers' future research.

2. IMRaD

IBC is plain and simple. It is a general framework applicable to presentations in many different fields. When you focus on science, you find an equally general but more fit-for-purpose framework, **IMRaD**. IMRaD stands for **Introduction**, **Materials and Methods**, **Results**, and **Discussion**. Body and Conclusion in IBC are divided into three, more science-based parts, M, R, and D.

Introduction is no different from that in IBC. Materials and Methods describes the physical or objective conditions in which you conducted your study along with survey or experimental procedures. Results literally presents the results of the surveys or experiments as objective information, which allows the audience to examine the speaker's work. Then, the speaker offers their own interpretation of the results in Discussion. This part may also include references to alternative interpretations of the same data and remaining issues to be addressed in future studies.

[Comprehension Check]

1) What does “IBC” stand for?

2) In the Introduction, the speaker may refer to past studies. What can be the purpose?

3) In IMRaD, which parts provide objective information and which parts provide the speaker’s subjective idea?

[Practice]

1. Classify the following statements into I, M, R, or D.

1) *When discussing the jumping skills in track and field, it is generally said that taking a posture like a stick helps the jumper receive a greater reaction force from the ground.*
2) *But there has been no scientific evidence to support this claim.*
3) *To collect data in favor of the theory, we examined the reaction force that various types of sticks experience when they hit the ground after falling freely.*
4) *As a result, it was found that the sticks exert a high repulsive force, thus providing positive evidence for the stick-like posture on kicking the ground.*
5) *We also examined the relationship between vibration caused by the collision of the sticks and the steel block and the coefficient of restitution.*
6) *As a result, it was found that when the energy of the vibration after the collision is small, the energy loss of the stick is small, allowing them to receive more reaction force.*

（出典：上廣彩香・中嶋心葉・山田杷奈・山本千尋（2023）「高く跳ぶにはどうする？」広島大学附属高等学校『スーパーサイエンスハイスクール課題研究論文集 19』pp.1-14 所収）

2. Introduce your own project study in the IMRaD structure.　The results can be speculative.

Introduction	
Materials and Methods	
Results	
Discussion	

Day 8 ABT

[Lecture]

Both IBC and IMRaD are widely accepted among researchers, so your audience will naturally expect you to follow these frameworks. But why are they so widely accepted? Simply put, they follow the basic pattern of **storytelling**. In other words, content presented according to these frameworks matches the cognitive blueprints we use to process new information.

Take IMRaD, for example. Introduction presents the current state of knowledge about the topic and reveals what is unknown. To fill the knowledge gap, Materials and Methods proposes a solution and implements it. The outcome or findings presented in Results are usually something new, more effective, or more persuasive than what came before. Finally, Discussion signifies the results.

This structure, or flow, of a story corresponds to that of a typical story like a myth or folk tale. First, the setting is described. The protagonist leads a peaceful daily life. Then, evil arrives. The protagonist and the people around him suffer. He sets out on a journey to fight the evil. After a long adventure, he finally defeats the evil and returns home as a hero.

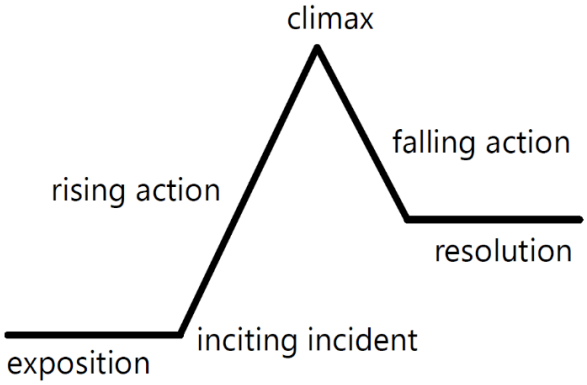
This series of ups and downs that ends in victory is a powerful way for people to understand the truths of the world because the story describes things as a chain of cause and effect. Additionally, the story contains ups and downs instead of the protagonist straightforwardly reaching the goal. This intrigues the reader or listener to follow the writer or speaker. In short, following the template of a typical story provides a psychological shortcut that helps listeners digest what the speaker says.

The "ups and downs" approach to story development is sometimes rephrased as the "**And**, **But**, **Therefore** (**ABT**)" structure:

> *Here's a research topic.* **And**, *such and such things are known about the topic.* **But** *such and such things are still unknown.* **Therefore**, *we did such and such things to find the answer.*

While IMRaD is a framework for entire papers or presentations, ABT, which describes a more general flow of ideas, can also be applied to "smaller" types of communication. For example, you can use it to impress your audience with the necessity of your study in the Introduction, or you can answer a question by following ABT. (Answering is dealt with later in the course.)

Ups and downs giving momentum to a story is a basic principle of storytelling. Freytag's pyramid, a traditional model of storytelling, illustrates this concept. See how it applies to scientific communication.



[Comprehension Check]

1) Why are frameworks like IBC and IMRaD effective in communicating science?

2) Describe the four-part structure of a typical story.

3) What effects do the ups and downs of the story have?

[Practice]

Rearrange the following passages to make ABT structures.

Note: The studies below have been created for this coursebook's educational purposes. Please do not cite or rely on this text as established scientific fact.

1)

1. *Global temperatures are rising every year, leading to an urgent need for sustainable cooling technologies in modern cities.*
2. *Urban areas absorb massive amounts of solar heat, and scientists have looked to the Silver-Back Beetle of the Sahara Desert—which reflects 95% of sunlight—as a potential biological model for cooling.*
3. *But, the microscopic structure of the beetle's shell is incredibly difficult to reproduce, and previous attempts to create a synthetic version were far too expensive for large-scale construction.*
4. *Therefore, our team developed a simplified ceramic paint using recycled glass bubbles to mimic the beetle's shell. Our results show this coating can lower rooftop temperatures by 15°C, offering an affordable solution for energy-saving homes.*

2)

1. *Modern society relies heavily on electronic devices, but our mobility is often limited by the need for charging cables and heavy batteries.*
2. *Wireless power transfer using magnetic resonance is a proven concept that can send electricity through the air, and several companies have already developed small-scale chargers for smartphones and toothbrushes.*
3. *But, as the distance between the power source and the device increases, the efficiency of the energy transfer drops significantly, making it impossible to power a laptop or a television from across a room.*
4. *Therefore, we designed a new type of "metamaterial" relay—a specialized copper coil structure—that focuses magnetic fields like a lens. By placing this relay between the source and the device, we successfully maintained 90% efficiency over a distance of three meters, bringing us one step closer to a truly wireless world.*

Day 9 The 5Cs(1) Common Ground(1)

[Lecture]

Now, let's examine ABT in more detail from the perspective of scientific communication. As discussed in the previous section, ABT can be applied both to entire presentations and to smaller portions of communication. Therefore, it is essentially a general, multipurpose framework. However, when it comes to science, you may need more specific guidance on what to say in each section based on the contents of the study to be presented.

In order to turn the ABT structure into a more science-specific framework, this course introduces one called "**5Cs**." 5Cs stands for **Common ground**, **Conflict**, **Concept introduced**, **Concrete examples**, and **Conclusion and Check**. This will help you to plan your presentation specifically based on your own contents.

Common ground

Simply put, a presentation is about explaining a new idea. A new idea is understood only when it is firmly connected to the existing knowledge. Therefore, the first thing to do is to find something that you and your listeners share. Once you have found it, you can build your explanation on it. Let's call this shared knowledge "**common ground**."

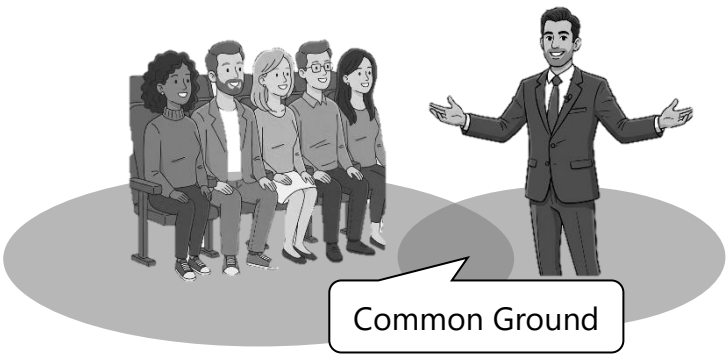


Image created by Google Gemini

For example, if the speaker begins with "Our study aims to clarify how the central pillar of a five-story pagoda reduces the structure's overall sway during earthquakes," some listeners will likely be puzzled unless they are experts on the research topic. They may not know what "the central pillar" is, or how it relates to earthquakes. They may only have a vague idea of what "a five-story pagoda" is. They will find it difficult to understand the study presented and may lose motivation to continue listening. They may even walk away from the presentation.

What if, instead, the speaker shows a picture of buildings that were damaged in a recent earthquake and says, "Earthquakes are scary, aren't they?" The listeners will respond more positively because they very likely share the fear of earthquakes. Then, the speaker could continue, "Many different measures have been taken to protect buildings from earthquakes over the history." This statement is also understood and accepted quite easily because earthquake resistance is a common interest of society. Based on this established common ground, the speaker can launch into a more detailed explanation: "The central pillar of the five-story pagoda is one of the ancient quake-resistant mechanisms..."

[Comprehension Check]
1) How do people understand a new idea?

2) What is “common ground” in a presentation?

3) What effect does establishing common ground have on your audience?

[Practice]
Find an appropriate common ground in presenting your study according to the type of your audience.
1) The audience is high school students from other SSH schools.

2) The audience is college teachers who specialize in the same field (physics, chemistry, biology, earth science, mathematics, medicine etc.)

Day 10　The 5Cs(1) Common Ground(2)

[Lecture]

Abstraction and Concretization

Establishing a common ground requires understanding your audience. If they are researchers in the same field, you may start by referring to the theory or framework you depend on; "**As you know, Liu(2024) has established a practical method to anneal substance X, and many other following studies have proved that it is also applicable to Y.** This study of mine examined if this annealing method is also applicable to Z…."

On the other hand, if the audience are non-experts such as ordinary high school students, you may refer to something they know from their everyday experiences and explain basic concepts before entering scientific discussions; "**X is a substance that is often used in kitchen utensils such as frying pans and pots. In order to make something with X, you need to anneal it. "To anneal" means you heat the substance and cool it slowly after it has been shaped. This process allows the atoms to settle in organized patterns and crystalize. This helps remove unnecessary internal pressure of the product. There have been several different methods to effectively anneal X.** Among them, Liu(2024) is considered to be the most cost effective…." In this example, you expect the audience to be familiar with kitchen utensils from their everyday experiences, and you also expect them to understand "crystallization" from their school science class.

To find a common ground with your audience, you can think about your topic in two ways. One is **abstraction**. You think of an idea that covers your topic along with other similar topics. For example, "functional category" is a linguistic term that is not familiar to non-experts. Imagine you are speaking to a group of high school students, and you want to introduce this term. You cannot expect them to know the term. In that case, you should remember the phrase "**X is a kind of Y**." Here, "functional category" goes into X. Then, what is Y? You can say, "The functional category is a kind of grammatical items." "Grammatical items" is a more general term that is more familiar to the audience. They may not know "functional category", but if they know it is included in "grammatical items," they find it more accessible.

The other way to find a common ground is **concretization**. This is exactly the opposite of abstraction. You give concrete examples that represent the target idea ("**An example of X is Z**"). For example, you can say, "Functional categories include tense, person, and number." High school students will understand grammar such as the past tense, the third person, and the plural *-s*. If they learn these are functional categories, they will also find it more accessible.

In either case, the bottom line is that **all new knowledge is built upon what comes before it**. Put it another way, it is **the "Known to Unknown" principle**.

[Comprehension Check]

1) What are the two ways to find a common ground?

[Practice]

Set up a common ground for explaining the following concepts to elementary school students.

1) centrifugal force

2) supercooling

Day 11　The 5Cs(2) Conflict

[Lecture]

Conflict

The second element of the 5Cs framework is "**conflict**." Just as a hero in a story faces and solves problems, researchers in science identify problems to solve. They may be observations that contradict traditional explanations, subjects that have not been addressed in current research, or new phenomena that have not been reported.

The common ground was, by definition, familiar to the listeners. However, once something unknown or unexplained is introduced, they become intrigued and want to find the answer to the mystery. This explains why the present study is needed and sets a stage for you to present your own approach to those problems.

The conflict can be introduced by pointing out gaps in the earlier studies that have not yet been covered. Or it may be identified by presenting subjects or phenomena that cannot be explained by current knowledge. For high school students who have just started their projects, the former needs extra caution. Even if you think there are no previous studies that addressed the subject in question, very often there are, in fact. You may only have been searching the wrong journals, or papers with seemingly unrelated titles may contain exactly what you are looking for. Therefore, you should be very careful when you say "This has not been investigated in earlier studies."

The identified conflict directly relates to the study's research question. The research question is the goal of the study stated in the form of a question. If a particular subject X has not been investigated in the previous studies, you may ask, "Does X respond to treatment Y in the same way as Z (though the past studies have never examined it)?," or "How can we explain X from the perspective of Y with the limitations of Z (though the past studies have proposed a different explanation)?" Then, you propose possible answers as hypotheses, and you test them through surveys and experiments. Thus, answering the research question is expected to fill the gap in the research.

During the actual research process, you can develop more than one research question, and you can delete, change, or combine them. However, when presenting, you should pose only one or a few research questions and focus your discussion on them.

About research question, refer to Part 6.

[Comprehension Check]
1) What is the purpose of the “Conflict” section?

2) How does the “Conflict” relate to a research question?

[Practice]
Review the previous studies about your research topic and identify at least one question that needs further research.

Part 2: Story Message

Day 12　The 5Cs(3) Concept Introduced and Concrete Examples

[Lecture]

Concept introduced

Once you have established common ground with your audience and introduced a conflict to be solved, you have invited them to join your exploration. They will see things from your perspective and wonder how they can answer the research question alongside you. The stage is set. Now is the time to finally develop your discussion.

You propose an answer to the research question. This is the **hypothesis**. If there are more than one research question, or if there are more than one answer, then you may propose two or more hypotheses.

Your audience wonder if your hypothesis is correct, so you provide evidence for them to examine the hypothesis for themselves. The evidence includes the data from your surveys or experiments. In some cases, you may present the raw, or near-raw data as it is, expecting your audience to be able to understand it. However, you are more likely to summarize the raw data into other forms of information, such as graphs and charts, so that your audience can understand what the data means. Even in that case, though, presenting only the summary is not sufficient for the audience to understand and agree with your discussion. To validate your discussion, you also present some examples from the survey or experiment. The examples may be pictures taken of the experiment, samples collected in the survey, or some other forms of raw data.

In this way, to answer the research question, you propose a hypothesis and evidence to prove it. In this course, we name these parts of presentation as "**Concept introduced**" and "**Concrete examples**." Since these are the core of the presentation, there are many different ways to organize them. You can invent your own way to communicate your points. In whatever way you do it, one thing to remember is that you should always try to be accurate. It's science, after all.

[Comprehension Check]
1) What is a hypothesis?

2) What do you do with the raw data in most cases to help your audience understand your point?

[Practice]
Write down one of the research questions you have developed and propose a hypothesis to answer it.

Day 13　The 5Cs(4) Conclusion and Check

[Lecture]

Conclusion

You have reviewed previous studies, identified gaps in them, developed a research question, and proposed hypotheses to address the gaps. You have also illustrated your approach to proving your hypotheses using sufficient data and examples. Have you done enough to convey your message?

Not quite. You may think you have said everything you need to, but your audience may not have understood it all. Here is some famous advice for speakers:

Tell your audience what you are going to tell them.

Tell them.

Tell them what you have told them.

You cannot emphasize your points enough. Before closing your talk, clarify once again what your presentation has been all about. You can either repeat the main findings of your study or summarize the entire presentation. You could also ask your audience questions to ensure they understood your message. Whatever measures you take, make sure your audience understands your points. This is the "**Conclusion**" of your presentation.

Check

After you finish your presentation, you typically invite your audience to ask questions or share their thoughts. Let's call this part "**Check**," since it checks your audience's understanding. Many high school students say, "Do you have any questions?" This isn't a bad phrase. However, this course advises you to say, "**What questions do you have?**" instead. This phrase shows your assumption and expectation that your audience has questions and that you are ready for them. You appear more positive and eager to communicate with your audience.

You will practice asking and answering questions in later sections of this course. One thing to remember is that receiving a lot of questions is a good sign of success as a speaker. It means your message has reached your audience and intrigued them. Answering questions is the second part of your presentation, where you may receive helpful advice, find another topic to pursue, or ignite your audience to develop their own research, eventually contributing to science in general. Therefore, you should be happy to take questions.

[Comprehension Check]
1) What is the purpose of the “Conclusion” in your presentation?

2) How can you conclude your presentation? Name a few ways.

3) What effect can be expected from inviting questions from your audience?

[Practice]
Invite your classmates to ask questions about your project study. You must answer them in whatever way you can. Do not say, “I have no idea” or “Give me some time to think about it.”

Part 2: Story Message

Day 14　Throughline, Big Idea, Take-home Message

[Lecture]

The message

We have looked at how to construct a presentation in the past sections. It may seem a daunting task to prepare contents to fill in the frames of IBC, IMRaD or 5Cs. It is partly true, especially when you are in the beginning stage of your research project. You have not read many articles about your topic, or you have not planned your experiments sufficiently. Then, making one full presentation will seem impossible.

However, as you go on with your project, things will turn to the opposite. You not only gather more data but you face new challenges. You find more and more past studies that may relate to your own. Your first research question may have changed more than once and become more sophisticated. In short, you have too much to say in one presentation.

Clearly, it is not wise to say everything. You may want to, but you shouldn't. For one thing, your audience will not enjoy it. Remember, your presentation is not for you, but it is for your audience. For another, it will blur your point. Your audience will not see what you want them to take from your presentation. You should always try to make clear what you want your audience to remember. What is "the message"?

You must define "the message" in each of your presentations. It is named in several different ways by presentation instructors. Some call it a "**take-home message**" because it is the message that the audience literally take home. Others call it a "**big idea**" because it is often an abstract idea that overarches everything discussed in the presentation. And still others use the term "**throughline**" because it is the central string or line to which all the other details attach. The focus being slightly different in each name, they say essentially the same thing. "You must be able to express the core message of your presentation in simple terms."

From now on, this course uses "throughline" because it has a clear definition in one literature, but other terms are not completely excluded.

According to Anderson (2016), "throughline" is **one sentence in about fifteen words that condenses and distills the core idea of the presentation**. It is the central string to which all the other parts are connected, and it is what you want to leave in your audience's mind. It should answer the question, "So, what's your point?"

Remember the previous section, which discussed Conclusion. At the end of your speech, you are expected to repeat your points to impress on your audience. The throughline exactly does this. You must always define the throughline in making a presentation.

[Comprehension Check]
1) Why is it not good to say everything you want to say in a presentation?

2) How can the throughline (big idea, take-home message) help your audience?

[Practice]
Define your throughline in your most recent presentation.

Day 15　Elevator Pitch

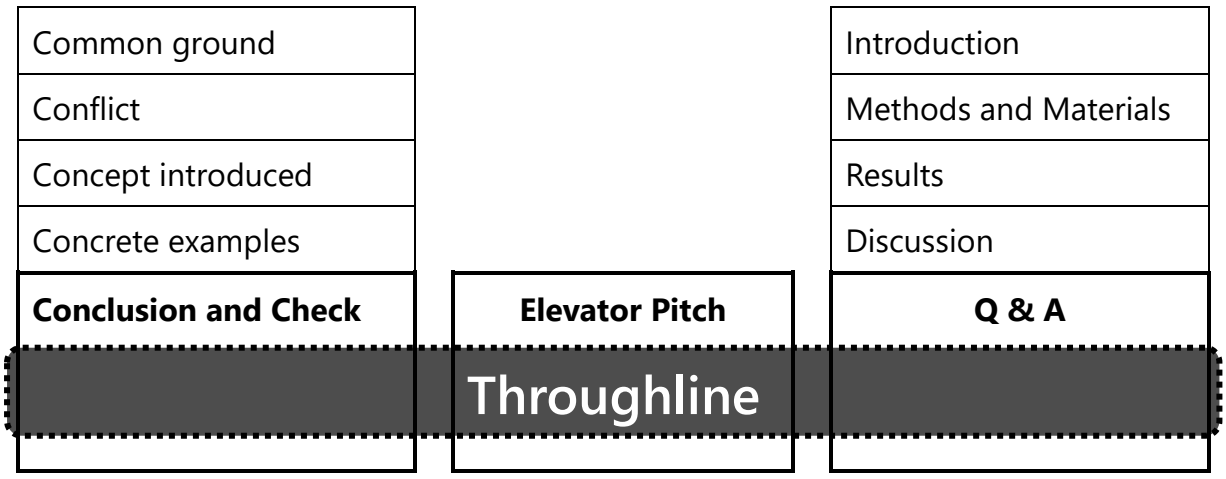
[Lecture]

Condensing your message into a throughline is not only for constructing a full-scale presentation, but it is also an independent presentation itself.　A short presentation that is made in a very limited time like 1-2 minutes is sometimes called an "**elevator pitch**."　A "pitch" is synonymous with a "talk" or "speech," which is often used in business settings. Businesspeople are often required to explain their ideas to their bosses, who are much busier than themselves.　The only opportunity for them to talk to their bosses may be while they are in the elevator.　That's why such a short presentation is called an elevator pitch.

In academic settings, too, you are often required to explain your study in a very short time. It may not be in the elevator, but it is not uncommon someone asks you, "What's your research interests?", "What's your research project like?", or "Would you just share some of your findings?"　To answer these questions, you need to distill your contents and condense it into a few sentences.

Distillation and condensation can be done with IMRaD or 5Cs, but in a shortened way. To shorten your explanation, you need a throughline.　First and foremost, you need to give your throughline.　You must think you have no time even for establishing a common ground before entering your main points.　So, you must get to your points directly from the beginning.　If you are allowed to speak more, then you can add a bit of details.

You never know when you are required to give such a talk, so it is a good exercise to prepare a 1-minute version of your presentation.　It is almost impossible to improvise an elevator pitch.　It also helps you prepare for the Q&A, which will be discussed in a later section.



[Comprehension Check]
1) What should an elevator pitch in academic settings include?

2) How differently should you make an elevator pitch from a full-scale presentation?

[Practice]
Create a one-minute [two-minute] elevator pitch about your study. Since you cannot speak about the entire project, focus on one specific topic within it.

Part 3

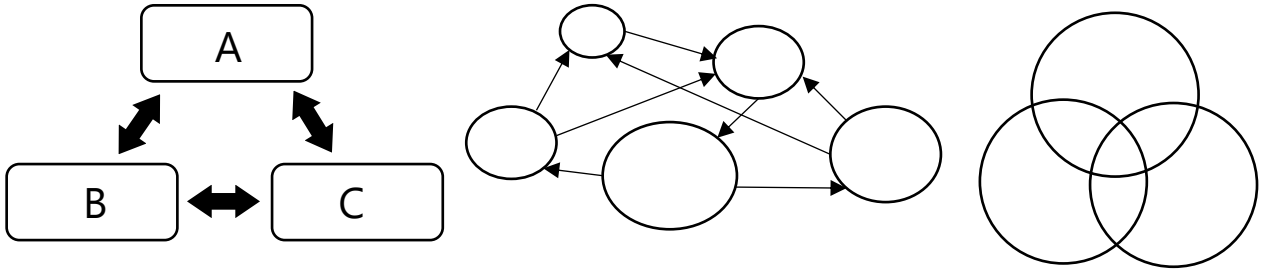
Visual Message

Day 16　Graphic Organizers

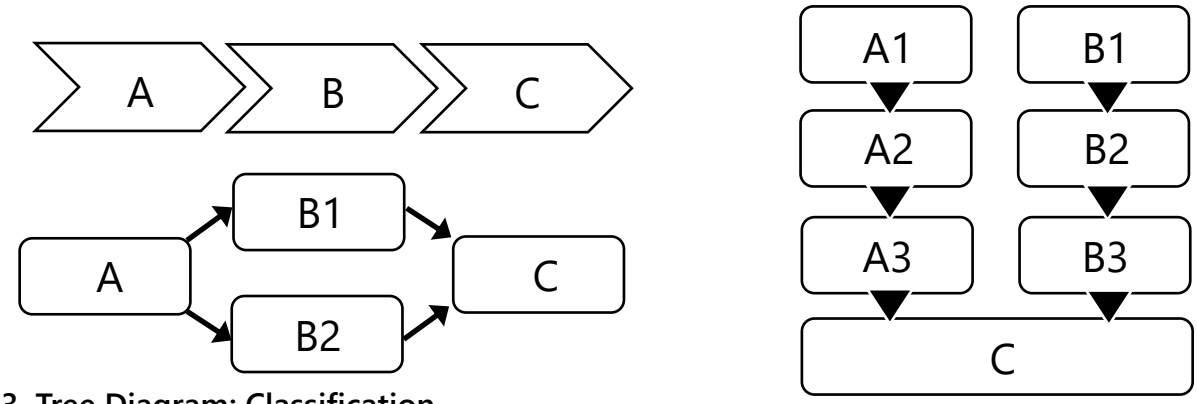
[Lecture]

The third type of presentation message is the visual message. It is no less important than the story message in conveying your thoughts to your audience. While the story message is linguistic and linear, the visual message is paralinguistic and planar, conveyed by 2-dimensional figures. While the linguistic message appeals to the audience's logical thinking, the paralinguistic message appeals to their intuitive understanding. The difference in dimensions allows presentation messages to be expressed differently according to their characteristics. Those figures that organize information for intuitive understanding are called "**graphic organizers**." Though many different graphic organizers are used in scientific communication, they are essentially classified into three categories.

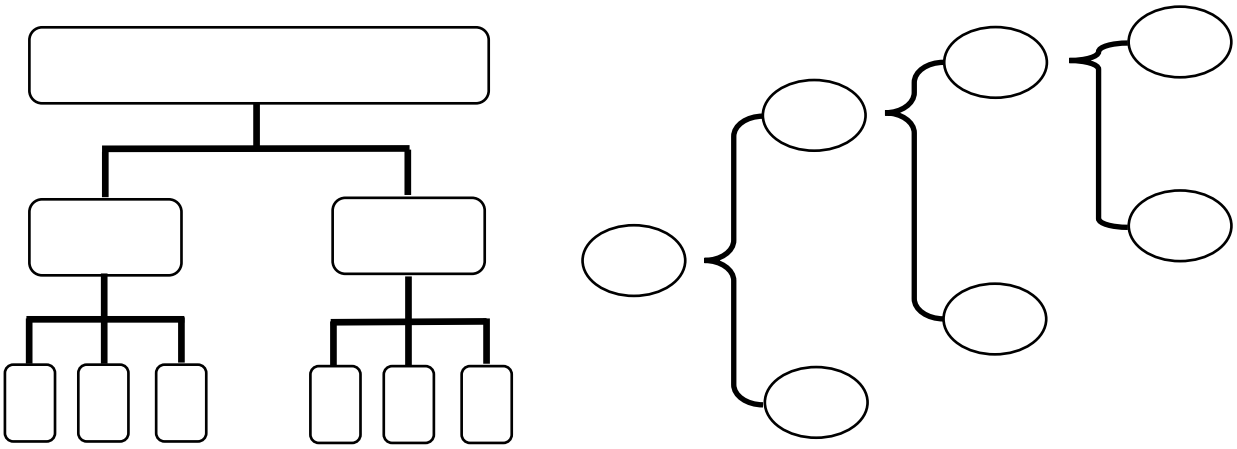
1. Relational Chart: Relationship of elements



2. Flow Chart: Sequence



3. Tree Diagram: Classification



[Comprehension Check]
Explain the difference between story message and visual message.

[Practice]

1) Create a graphic organizer based on the abstract below.

In recent years, plant-based foods have been attracting attention because of their lower risks of causing allergies and higher compatibility with the SDGs. We focused on meringue made of boiled chickpea broth. We examined (1)the meringue's stability and (2)its foaming power. To determine its protein content and composition, we conducted (3)protein quantitative analysis and (4)SDS-PAGE. We compared the four sets of data with those of egg white. As a result, we concluded that chickpea meringue is best suited for whisking at a pH of 5.0. We also found that the protein content of chickpea broth is about 1/12 of that of egg white, and the composition is completely different. Sensory test showed that the chickpea meringue is inferior to egg white meringue in flavor and sourness. We concluded that these must be improved in order to popularize the chickpea meringue.

（出典：小堀瑠華・齋藤真緒・仲間頼音・原田愛斗（2023）「ひよこ豆を用いたメレンゲ代替素材の検討」広島大学附属高等学校『スーパーサイエンスハイスクール課題研究論文集 19』pp.43-58 所収）

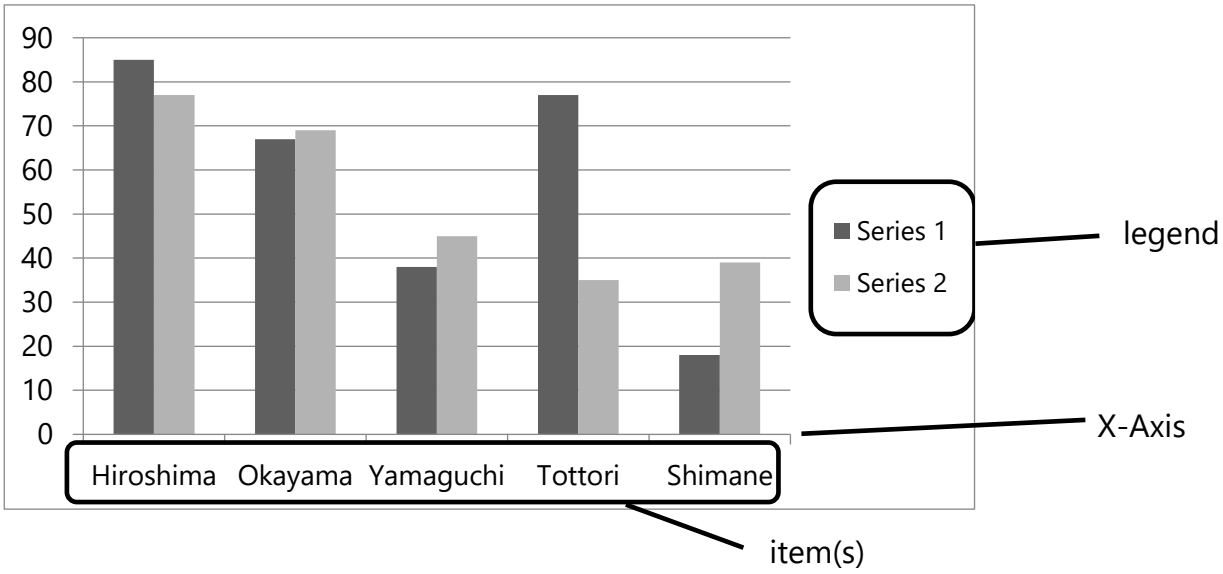
2) Create graphic organizers that describe your research.

Day 17　Graphs and Charts

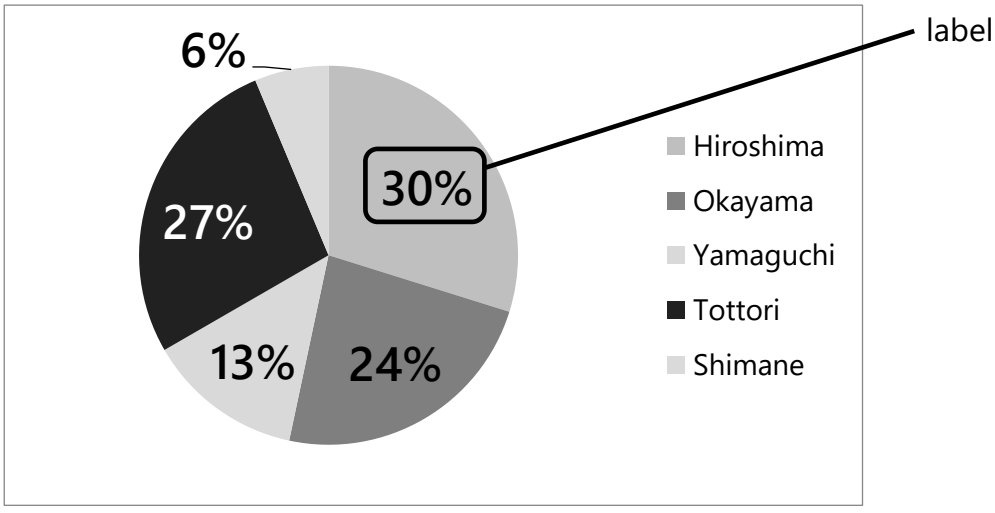
[Lecture]

Scientific inquiries almost always depend on statistics to verify their hypotheses, whether they are simple descriptive statistics or sophisticated inferential statistics. Statistics presented only in numbers are not friendly to the audience unless they are experts in handling those numbers. In most cases, on the other hand, the statistics are "translated" into visuals that are more accessible to the audience, namely graphs and charts. Just like graphic organizers, graphs and charts come in various kinds, and they are fitted for different purposes. Below are a few typical examples.

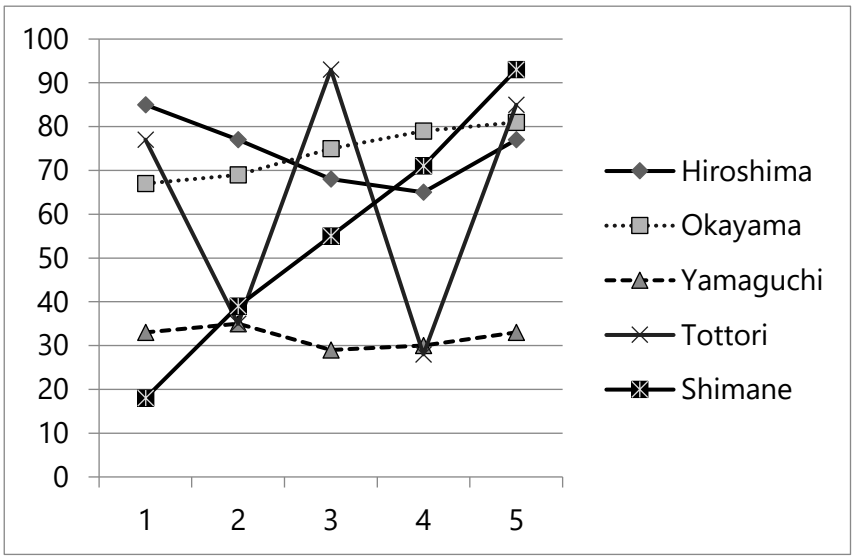
1. Bar Chart [Graph] : used to show **different values of different items independently of one another**



2. Pie Chart : used to show **the proportion [percentage] each item occupies in relation to the other items**

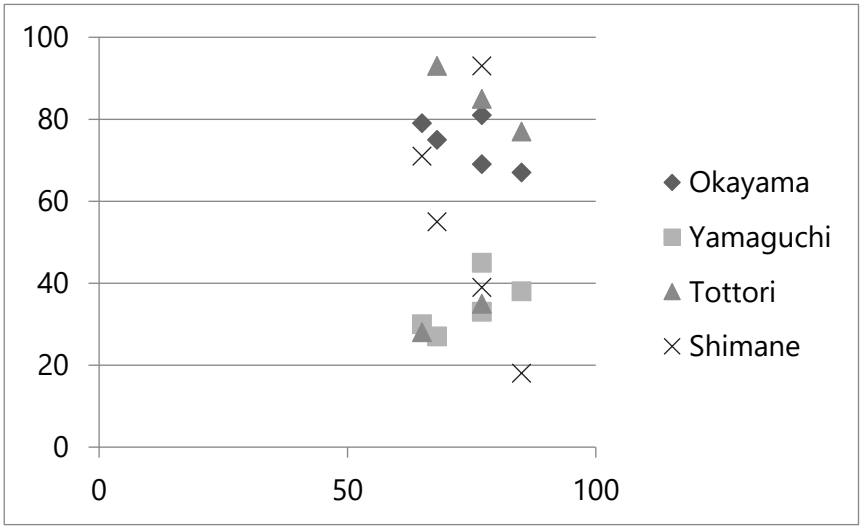


3. Line Graph : used to show **changes of different items over time**

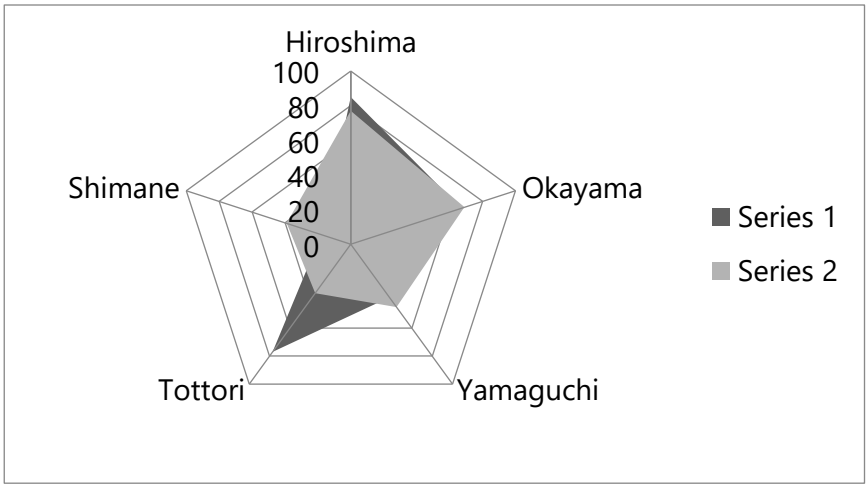


solid line　　dotted line　　broken line

(4) Scatter Diagram : used to show **correlation between two variables**



(5) Rader [Cobweb] Chart : used to show **balance among different variables**



[Comprehension Check]

1. When you want to show the precipitations of five different cities in Japan, what kind of graph or chart is the most appropriate?

2. Provide one example of data that is best represented by a line graph and one that is best represented by a scatter diagram.

[Practice]

Create different kinds of graphs and charts based on each of the tables below.

1)

	Series 1	Series 2	Series 3	Series 4	Series 5
Hiroshima	85	77	68	65	77
Okayama	67	69	75	79	81
Yamaguchi	33	35	29	30	33
Tottori	77	35	93	28	85
Shimane	18	39	55	71	93

row

column

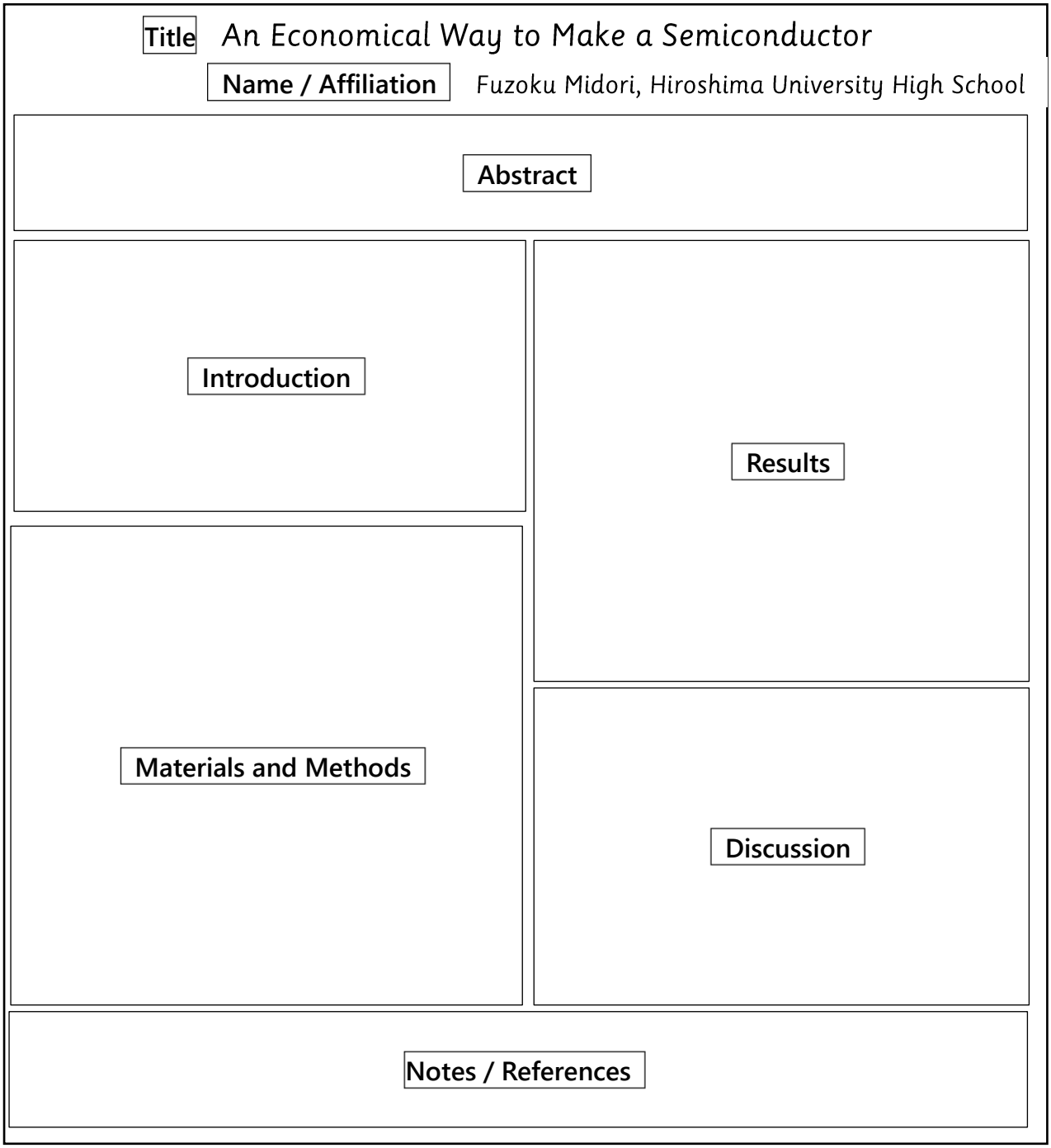
2)

	Treatment 1			Treatment 2		
	Before	After	Change	Before	After	Change
Sample 1	44.6	47.8	3.2	96.2	96.3	0.1
Sample 2	49.2	52.6	3.4	104.3	104.9	-0.1
Sample 3	41.3	49.9	8.6	98.8	99.0	0.1
Sample 4	42.8	51.5	8.7	95.7	96.1	0.4
Sample 5	44.9	52.3	7.4	101.1	101.3	-0.1
Sample 6	45.0	41.2	-3.8	99.5	114.2	14.7
Sample 7	50.2	44.4	-5.8	92.6	117.1	24.5
Sample 8	47.7	38.0	-9.7	93.8	99.8	6.0
Sample 9	39.8	19.1	-20.7	98.9	195.8	96.9
Sample 10	46.7	45.5	-1.2	102.4	120.0	17.6

Day 18　Poster

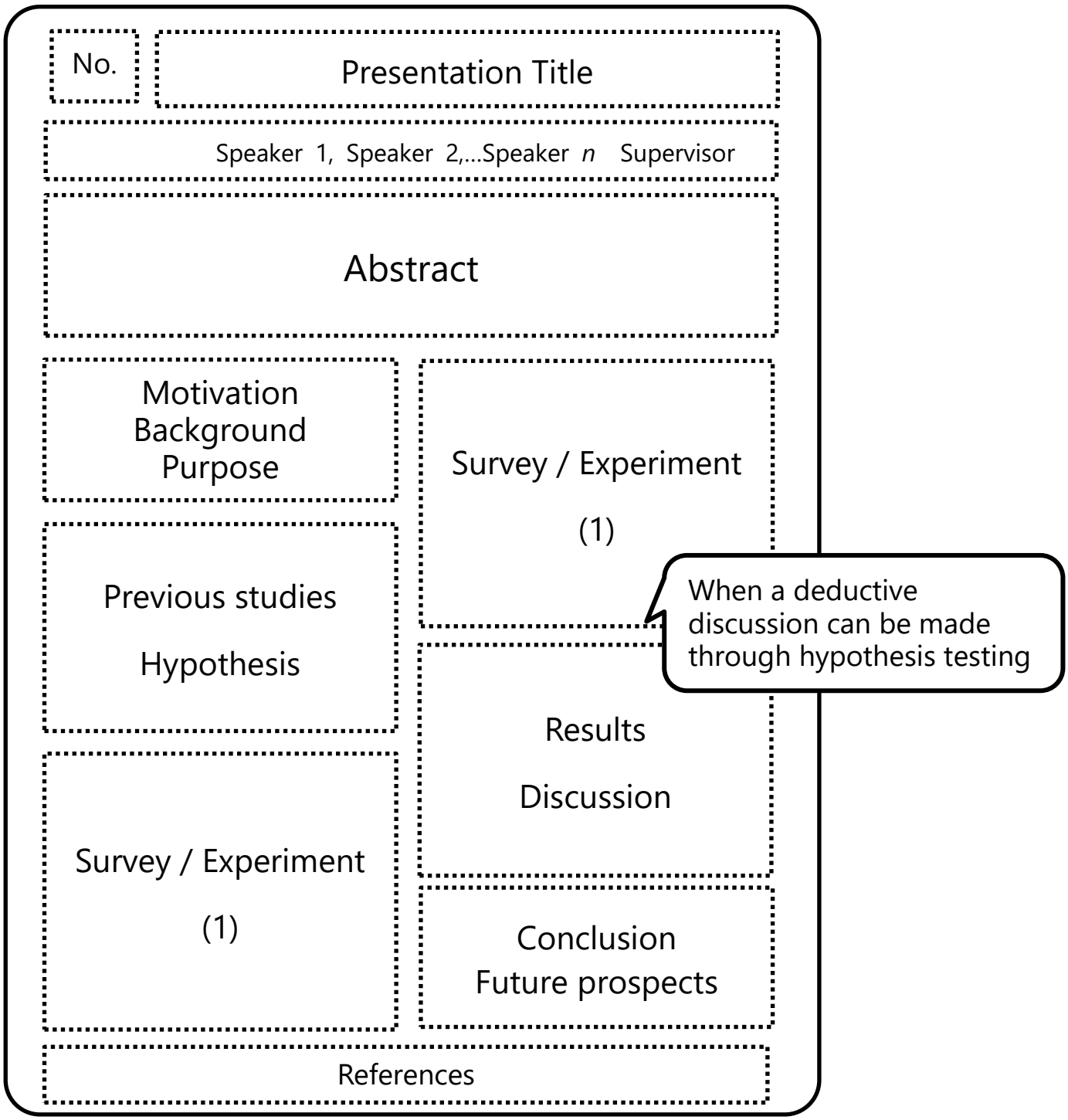
[Lecture]

A poster is a large sheet of paper that carries information about your study to help your audience to understand it.　In a poster presentation, you stand beside the poster and speak, pointing to the relevant parts on the poster.　A poster can be organized in many different ways depending on your specific focus, though some fora impose strict regulations on design and layout.　It usually follows the IMRaD structure and carries visuals and words to help the audience to understand the presentation.　Below is a typical layout.

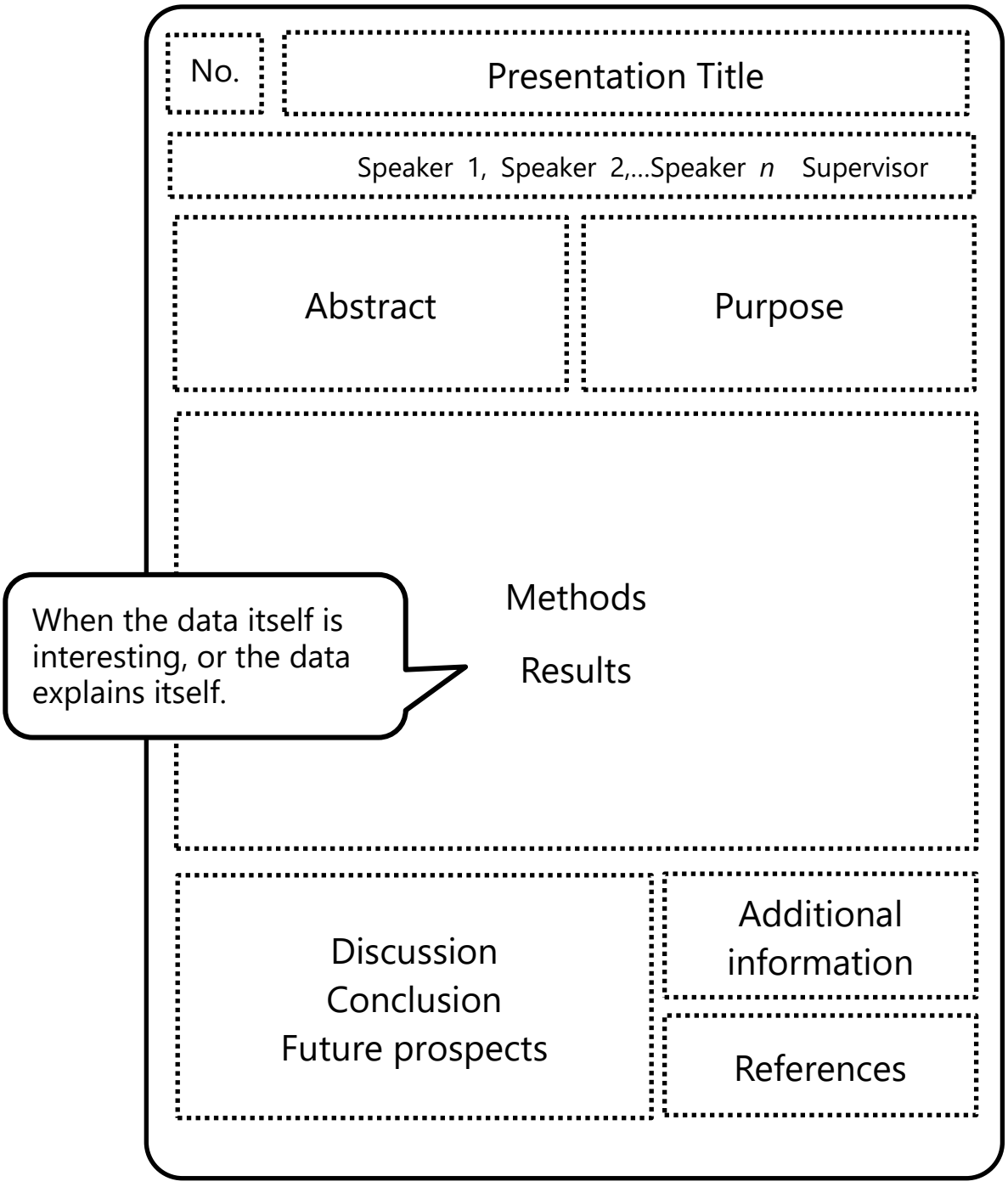


An advantage of a poster over slides is that it shows the entire structure, or the "big picture," of the presentation. Because of this, the audience can go back and forth on the poster to ensure their own understanding. On the other hand, since a poster needs to be looked at from a certain distance, words printed in small-size letters are hard to read. Therefore, while you should include necessary information on the poster, you should also think what not to include. Several different layouts are shown below.

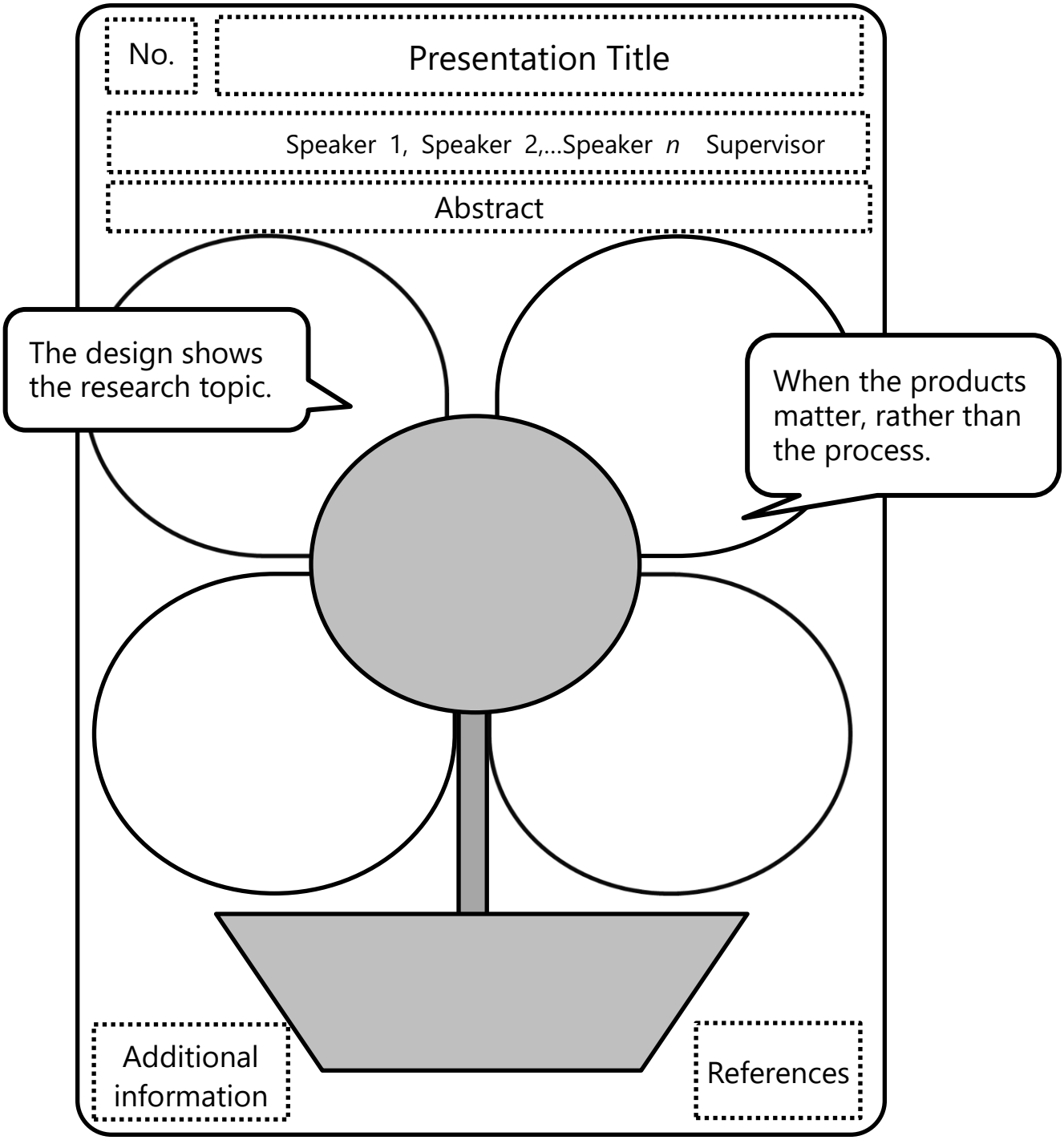
1) Deductive



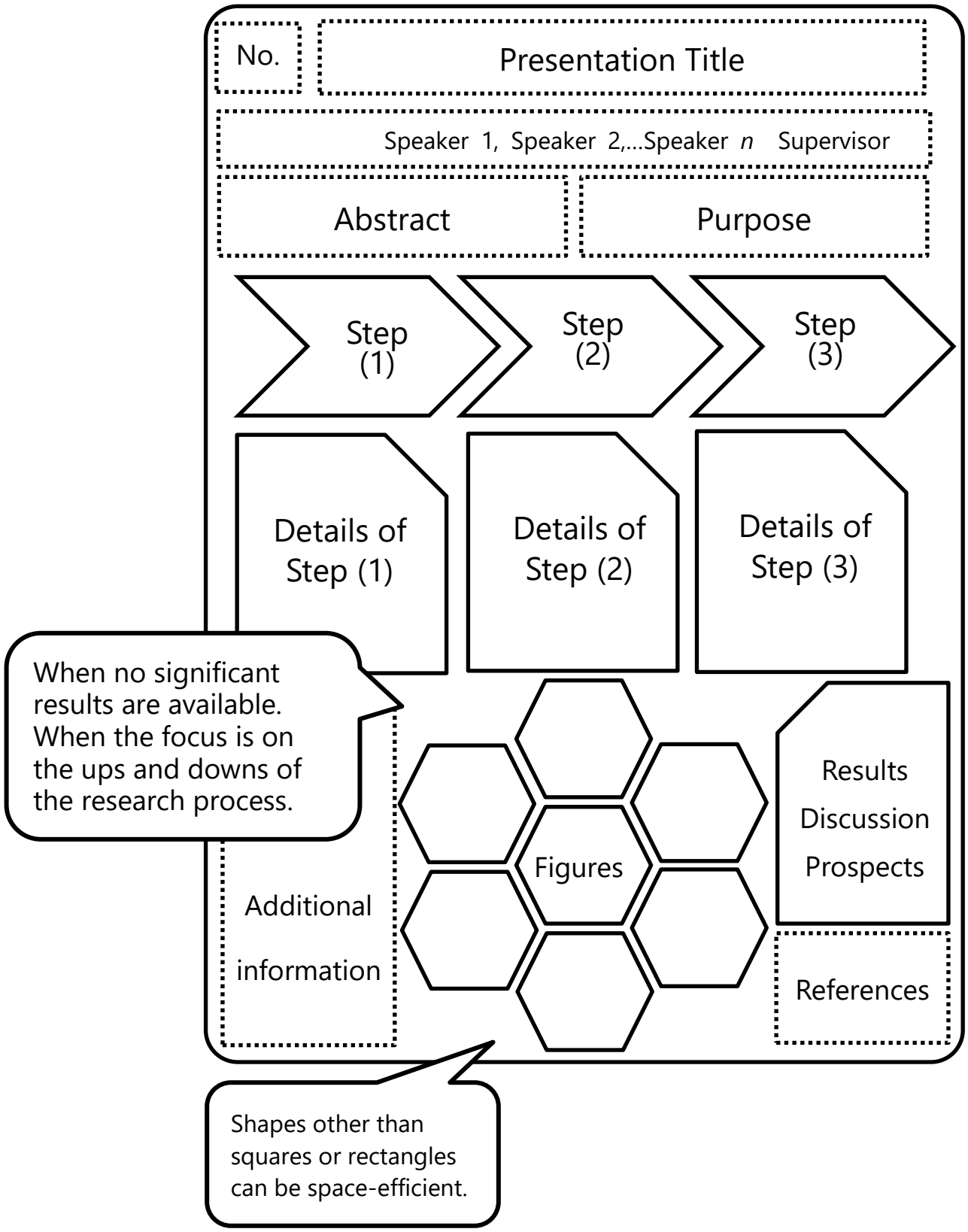
2. Focus on the methods or the data



3) Focus on the products



4) Focus on the trials and errors



Whatever design you employ, it should be logical; it must align with your story message in the presentation.

[Comprehension Check]
What advantage does a poster have over a deck of slides?

[Practice]
Design a poster plan for your next presentation.

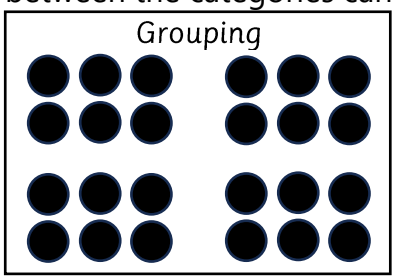
Day 19　Slide

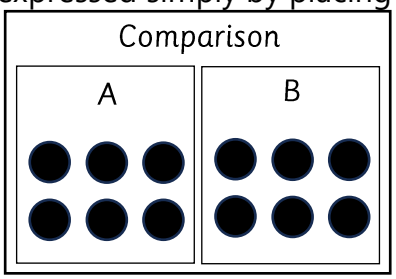
[Lecture]

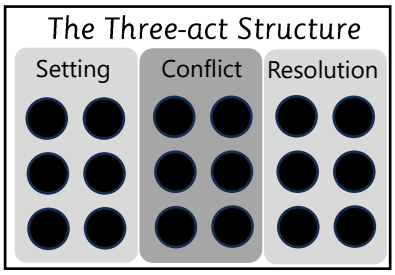
A slide is a visual aid used in presentations to support the speaker's talk with text or images. The information is usually divided into different slides that together form a complete set, or "**deck**," which tells the story of the presentation. Since there is no limit to the number of slides in a presentation, it is much easier to control the amount of information shown on each slide than it is with a poster. Therefore, it is vital.

Although software for creating slides such as PowerPoint, Keynote, Google Slides, or Canva, allows for practically infinite flexibility, there are some principles for creating audience-friendly slides. First, just as in a poster, font sizes matter. Considering the audience look at the slides from a certain distance, the letters must not be too small. As a general rule, letters of 24pt should be the minimum.

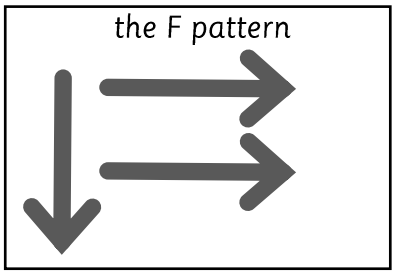
Second, the information should be organized logically, and the layout should be simple. For example, placing items of the same category closer to each other shows the groupings without using tables or other visually complicated measures. The logical relationship between the categories can be expressed simply by placing boxes behind the items.

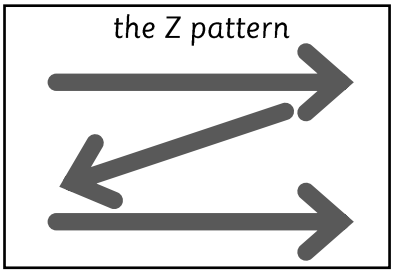


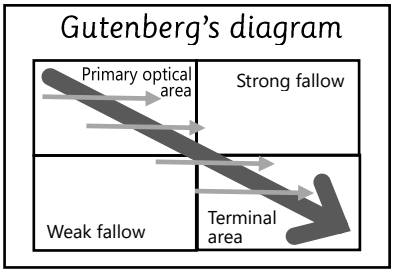




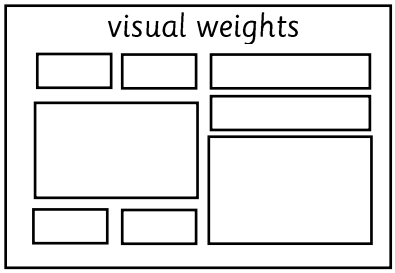
Third, the layout should align with the natural movement of the human gaze. People naturally see things from left to right and from top to bottom. They find a slide easy to understand when the elements are placed according to this natural movement. Basic patterns of such layouts include **the F pattern**, **the Z pattern**, and **Gutenberg's diagram**.

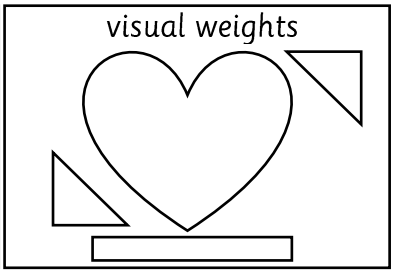






One thing you must remember about these patterns is that they work when there is little or no **visual hierarchy** on the slide. If you make **focal points** by giving **visual weights** to some of the elements, then you can guide your audience's eye in different patterns. You should also consider where and how much blank space to leave. Blanks make a difference.





[Comprehension Check]
Answer five points you should consider in creating slides.
1)

2)

3)

4)

5)

[Practice]
Design a slide that shows the outline of your research project.

Part 4

Question and Answer

Day 20　Questioning

[Lecture]

An academic presentation is usually composed of two parts: the speaker's speech and the question-and-answer session that follows. This course is for high school students to learn the skills of giving a presentation, but this section focuses on the skills required of the listeners because the speakers are also listeners at academic conferences. In fact, a researcher has more opportunities to listen to other researchers' presentations than making their own. Therefore, learning to ask questions, or good questions if possible, matters.

As a premise, asking questions is not merely important but vital for science communication. At the bedrock of the philosophy of science is the idea of any claim must be **falsifiable** to be truly scientific. Therefore, questions, however "tough" they may be, should be asked to test the falsifiability of what the speaker says. The speaker, in turn, should welcome these questions as opportunities to validate their claim.

This does not mean, of course, the questioner has the upper hand; you must always remain polite and respectful. Furthermore, asking a question itself is a polite thing to do when silence fills the air. A lack of questions can often be misinterpreted as a lack of interest, which is considered impolite in a professional setting. It may be rare for Japanese high school students to ask questions one after another, but this is usually due to unfamiliarity rather than a lack of curiosity. You should be praised for being the "first penguin" to dive in. It is very likely that you are not the only one who has the question.

Then, what questions can you ask? If you already have one that you would really like to learn from the speaker, then just ask it away. If you missed or don't understand something about the presentation, then just say so. A problem occurs when there is nothing particular that you want to know. Or, there may be something in mind but only vaguely. In that case, you must "create" questions. But how?

Cubing

There are many different frameworks for creating ideas. **Cubing** is one of them. As the name suggests, the name comes from "cube." A cube has six sides, so cubing means looking at something from six different points of view; describe, compare, associate, analyze, apply, and argue. By adopting various perspectives, the framework is expected to help you to come up with new ideas.

Let's apply it to creating questions. By looking at the presentation messages from different perspectives, you can find something to ask. It is not that your questions always need to be from one of the six perspectives but that trying to look at the subject in different ways helps you to make the interaction more fruitful.

Cubing

Point of view	What you think	Example
Describe	How does it look? What do you see when you look at it at a short/long distance?	*What's the size of the crystal? Do all individuals of the species have the same body color?*
Compare	Is there anything similar to or different from it?	*Does it behave in the same way when it is heated? / What's different between those living in the water and those living on land?*
Associate	What has a close relationship with it?	*The characteristics of X remind me of Y. Are they related?*
Analyze	What is it made of? What can be added, eliminated, or changed?	*How is the pattern formed? What is it composed of?*
Apply	How can you use it? Is there any other way to use it?	*Is it also possible to use it with alkali?*
Argue	What do you think about it? What is your own interpretation?	*I think the graph should be interpreted in a different way.*

[Comprehension Check]

Answer two reasons why asking questions is important for science communication.

1)

2)

[Practice]

Create questions about the study described in the abstract below.

Note: The study below has been created for this coursebook's educational purposes. Please do not cite or rely on this text as established scientific fact.

Abstract: Harmonic Resonance and the Betz Limit: A Theoretical Re-evaluation of Turbine Blade Topology

Author: Aris Thorne, PhD

Field: Theoretical Fluid Dynamics / Classical Mechanics

Traditional wind turbine design is governed by the Betz Limit, which dictates that a turbine can capture no more than 59.3% of the kinetic energy from wind. This study proposes a novel theoretical framework suggesting that energy-efficiency can be marginally optimized by exploiting aeroelastic harmonic resonance. Unlike standard engineering approaches that prioritize structural rigidity, this hypothesis posits that "flutter-induced" oscillations in blade topology can create localized low-pressure vortices, effectively "pulling" more kinetic energy from the airflow than static blade profiles. Through complex mathematical modeling of the Navier-Stokes equations, this research explores whether a non-linear, flexible blade geometry could theoretically bypass current turbulence-loss estimates. While this remains a purely mathematical construct, it is inherently falsifiable; the model predicts a specific 4.2% increase in torque that should disappear if the harmonic frequency is disrupted. This paper provides the foundational equations necessary for future computational simulations, shifting the focus from mechanical durability to the philosophy of fluid-structure interaction.

Day 21　Answering(1) TRAC

[Lecture]

As we discussed in the previous section, the question-and-answer session is a vital part of a presentation for the development of science.　As a speaker, you may find it intimidating to receive questions because they may reveal shortcomings of the study that you are not aware of.　You may fear that you are evaluated poorly by the audience if you fail to answer the question well.　In short, there is a great chance that you lose your confidence.

However, always remember that you don't receive those questions because your study is poor.　The truth is the opposite.　Your presentation has provoked some thoughts in the audience, and that's why they have their questions.　Therefore, receiving questions is, in fact, a good sign.　(In rare cases, someone may ask a challenging question for the sake of vanity rather than curiosity.　Just say thank you and ignore them.　The dialogue should be about the pursuit of truth, not a competition of status.)

If you understand the Q&A process in this way, then you will also understand that it is a valuable opportunity for you and your audience to share and expand your knowledge for the advancement of science.　Therefore, you are expected to address the questions directly, establish common understandings, and share whatever knowledge you can.　It is inappropriate to think that receiving and answering questions is a defensive process.　On the contrary, it is a constructive process in which you and your audience engage collaboratively.

TRAC

How can you construct the Q&A process with your audience?　One framework used for this is the TRAC method, which stands for Thank, Repeat, Answer, and Check.

First, **thank** the person for asking a question.　It may not have been so easy to ask anything in front of the other participants.　Show your appreciation and positive attitude towards receiving a question.

Next, **repeat** the question to ensure you have understood it correctly.　If you misunderstand, your answer will go off the point, which will ruin the communication.　In addition, confirming the question shows your respect and appreciation towards the person who asked it.

Then, you provide the answer.　Before delving into your response, however, you may want to lay the groundwork so that the audience understands what you have to say.　You could present the **basics** by referring to the fundamental knowledge or framework necessary to understand your response.　Based on the shared understanding, you get to the **core**.

After providing your answer, **check** if the questioner and the other listeners have received what they expected.　Always be open to further dialogue.　This will earn you trust.

TRAC

Step		Typical Phrases
Thank		*Thank you for your question.* *Thank you for asking that.*
Repeat		*Your question [point] is…, right?* *What you mean is…. Am I right?*
Answer	**Basics**	*In principle,… / In the first place,…* *From the perspective of… / The bottom line is…*
	Core	*The most important thing here is…* *Let me emphasize this…*
Check		*Does this answer your question?* *Am I clear? / What do you think?*

[Comprehension Check]
Explain why the question and answer is a constructive process.

[Practice]
Using the TRAC method, answer the following questions about your own project.
1) What differentiates your study from the others on similar topics?

2) What is the most difficult part in conducting your study?

3) (random question)

Day 22　Answering(2) Redirecting

[Lecture]

Redirecting

It sometimes happens that you receive a question that you find difficult to answer. In one case, a college professor who is an expert on the topic you are presenting on may ask you about highly technical matters that you know little about. In another case, a high school student may ask a question that is completely irrelevant due to their lack of knowledge. In still another case, which is least desirable, an ill-intended person may ask you a question that does not require a genuine answer. Instead, the person asks the question to show off their knowledge and their superiority over you.

You may not be able to answer these questions well, or you may not want to. In such cases, you can use the TRAC framework with a slight twist. First, go through Thank and Repeat as usual. (Even for rude or condescending questions, pretend to appreciate them for your safety.) Then, make the twist at Answer.

In Answer, you first share the basics to understand your answer with your audience. At this point, you should admit that you cannot answer the question fully due to your lack of knowledge or insufficient progress of your research. This is a proper thing to do both as a high school student and as a researcher. However, just saying, "Sorry, I have no idea" is not good because it is unproductive. It is not only the questioner who cannot get meaningful knowledge but also the others in the audience. It does not benefit yourself, either.

On such occasions, you should **redirect** the question. It means you take advantage of some element in the question to **say what you want to say**. Here's an example:

> *I'm afraid our study has not covered that point yet, so I don't think I have a good answer to that particular question. But* ①*you mentioned the force of inertia. I think that's an interesting point of view. Well,* ②*speaking of the different forces that affect the object, we carefully controlled the conditions in our experiments.* ③*As I explained in my presentation, we used….*

At ①, you pick up a word or phrase that the questioner used.(**Hook**) It does not have to be the key word/phrase. Just pick any word or phrase that you can associate with your research. Then, you change the direction of the question at ②, and say what you want to say. In the above example, you emphasize the delicate design of your experiments. Then, at ③, you refer back to what you previously said in your presentation.(**Back announcement**) This procedure is called the **redirecting** technique.

Redirecting allows you to impress your audience with the essence of your presentation. It will benefit them by helping them understand your points and inspiring further discussion.

[Comprehension Check]

Explain the procedure of redirecting a question that you find difficult to answer directly.

[Practice]

Imagine below is the script for your oral presentation. Take hard questions from your audience(classmates) and answer them with the redirecting technique.

Note: The study below has been created for this coursebook's educational purposes. Please do not cite or rely on this text as established scientific fact.

Optimizing Diatomaceous Earth Refinement

Introduction

Good morning. Today, I'd like to present a refined laboratory protocol for the purification of diatomaceous earth (DE). While DE is prized for its high porosity and thermal stability, raw samples are frequently contaminated with organic matter and metallic oxides. Traditional refinement methods often fall short of the high-purity standards required for advanced chromatography or nanotechnology.

The Limitation of Conventional Methods

Currently, most laboratories utilize a standard "acid-wash" technique. While this removes surface-level carbonates, it is largely ineffective at penetrating the intricate micro-pores of the diatom frustules. This often results in "occluded impurities"—contaminants trapped inside the silica structure—which can lead to inconsistent experimental results.

The Proposed Method: Ultrasonic-Acid Synergy

Our proposed methodology introduces a dual-action approach: Ultrasonic-Assisted Chelation (UAC).

Acoustic Cavitation: First, the raw DE is suspended in a deionized solution and subjected to ultrasonic waves at a frequency of 40 kHz. This creates microscopic vacuum bubbles that implode, generating localized pressure. This "scrubs" the internal pores of the diatoms without compromising their structural integrity.

Selective Leaching: Following sonication, we introduce a synergistic mixture of citric acid and dilute nitric acid. The citric acid acts as a chelating agent, specifically binding to iron and magnesium ions, while the nitric acid oxidizes any remaining organic debris.

Results and Conclusion

Our data indicates that this hybrid method increases the total surface area by approximately 22% compared to the static acid-wash. Furthermore, the level of trace iron impurities was reduced to nearly undetectable levels.

In conclusion, by integrating mechanical ultrasonic energy with selective chemical leaching, we can produce a superior grade of DE in significantly less time. This method ensures a pristine substrate for high-precision applications.

Thank you for your attention. I welcome any questions you may have.

Day 23　Answering as a Mini-Presentation

[Lecture]

As we saw in the last section, answering a question is not a passive act, but rather it is a more active communication where you can put forward your idea strategically. You don't have to feel intimidated about receiving questions.

To reiterate what has been discussed so far, you can classify questions you receive into four categories:

1) A question to which you have a full answer
2) A question to which you have a partial answer
3) A question to which you have a very limited or no answer
4) A question you do not want to answer

The questions of categories 1 and 2 are less problematic. You can provide what answers you have to them. The only thing you should remember is to follow the TRAC framework. In particular, you must provide sufficient basics to understand your core message. In other words, you should establish a common ground with your audience.

Categories 3 and 4 require careful handling. As you follow the TRAC framework, you should also redirect the question to your advantage. To redirect the question, you can use "**springboard expressions**" to **leap** over it rather than hitting it hard.

> *Now you have mentioned X, let's look at Y.*
> *Speaking of X, here's something that might interest you.*
> *That reminds me of X.*
> *Your question is really inspiring. Now, let me go beyond your question to think about this more deeply.*
> *I'd like to draw your attention to X.*
> *What I would like to emphasize is that….*

By leaping over the hard questions successfully, you can go over what you want to emphasize in your presentation, or you can provide additional information that you didn't include in your presentation. This benefits not only you but also your audience because they can receive "gifts" for further thought. The phrase to remember is:

Leap over the question to reap more from it!

Additionally, remember the importance of throughline here, too. As with an elevator pitch, you are more likely to maneuver effectively if you keep your throughline in mind when answering questions.

In short, think of answering questions as a good opportunity to clarify and emphasize your core message. It can be a condensed version of your presentation.

[Comprehension Check]
Explain the reason why the throughline is important in answering questions.

[Practice]
Explain your research project to your classmates and let them ask you questions.
Classify them into the four categories and answer them accordingly.

Part 5

Oral Presentations to Written Papers

Day 24 Scientific Writing(1) Plain English

[Lecture]

The language used in scientific interactions should be clear and easy to understand. Otherwise, the scientific content cannot be communicated correctly.

This may contradict your intuition that scientific language is complicated and difficult to understand. This intuition is partly correct, but the sense of complexity and difficulty mostly stems from the vocabulary. Every scientific topic requires specific technical terms shared by researchers pursuing the same topic. This is necessary because unambiguously defined scientific concepts enable researchers to share their findings without misunderstandings. Therefore, you need to follow the vocabulary conventions of the field, but it is only because of the same principle of avoiding ambiguity.

In addition, English is now considered to be owned by everyone who speaks it, not necessarily the native speakers. In fact, in academic contexts, it is quite common for participants whose first languages are not English to communicate in English as their shared language. This necessitates the use of plain language to ensure clear communication.

3Cs and KISS

This orientation for clarity or unambiguity has several names. Among them are the **3Cs** and the **KISS** approaches. The 3Cs stands for **Clear, Correct, and Concise**. It means that sentences used in scientific or technical contexts should be clear in meaning, correct in grammar, and concise in expression. KISS expresses a similar idea in the form of a phrase, "**Keep It Short and Simple.**" Below are some of the specific perspectives to make your English more professional, direct, and effective for technical communication.

Note: The "poorer" sentences can be the desired choice depending on the context.

1. Use the active form

Poorer: *Electricity is conducted by copper wires very efficiently.*
Better: *Copper wires conduct electricity very efficiently.*

Poorer: *An unusual phenomenon was observed.*
Better: *An unusual phenomenon happened.*

2. Write in the positive

Poorer: *The second experiment did not produce the same results as the first.*
Better: *The second experiment produced different results than the first.*

Poorer: *The material is not stable at room temperature.*
Better: *The material is unstable at room temperature.*

3. Use action verbs

Poorer: *This device is a measurement tool for air quality.*
Better: *This device measures air quality.*

Poorer: *There was an increase in the amount of substance A.*
Better: *The amount of substance A increased.*

4. Use strong verbs and nouns

Poorer: *There are many things involved in this chemical process.*
Better: *Several variables influence this chemical process.*

Poorer: *It is necessary to think more carefully about the results of the experiment in order to gain a more accurate prediction about the future.*
Better: *A more accurate future prediction requires more thorough analyses of the results.*

5. Use the *-ing* form subjects

Poorer: *In order to visualize the chemical reaction, special equipment is needed.*
Better: *Visualizing the chemical reaction requires special equipment.*

Poorer: *It is difficult to measure the weight of an atom.*
Better: *Measuring the weight of an atom is difficult.*

6. Use causative constructions

Poorer: *With this new method, we can have a better understanding of how people overcome trauma.*
Better: *This new method allows us to understand how people overcome trauma.*

Poorer: *If satellite data is available, we can predict the storm's path.*
Better: *Satellite data enables us to predict the storm's path.*

7. Avoid nominalization

Poorer: *We performed an evaluation of the atmospheric pressure.*
Better: *We evaluated the atmospheric pressure.*

Poorer: *This catalyst causes an acceleration of the chemical reaction.*
Better: *This catalyst accelerates the chemical reaction.*

8. Place the main verb early

Poorer: *The data gathered from three different labs over five months suggests a trend.*
Better: *The data suggests a trend, based on findings from three labs over five months.*

Poorer: *The stars located in the furthest corner of the galaxy are difficult to see.*
Better: *It is difficult to see the stars located in the furthest corner of the galaxy.*

9. Delete "redundant" pairs and modifiers

Poorer: *The two chemicals are exactly the same.*
Better: *The two chemicals are identical.*

Poorer: *The result was completely unexpected.*
Better: *The result was unexpected.*

10. Replace ambiguous comparatives with specific verbs

Poorer: *The waste levels are lower this year.*
Better: *The waste levels declined by 15% this year.*

Poorer: *The sample size is bigger than in the first trial.*
Better: *The second trial tripled the sample size of the first.*

[Comprehension Check]
What should be the basic principle when you choose one expression over another in scientific writing? Explain in your own words. (Not just "3Cs" or "KISS")

[Practice]
Improve the following sentences from the ten perspectives.

1) *The chemical structure was identified by the research team using X-ray diffraction.*

2) *The test results were not consistent with the previous findings.*

3) *The function of this software is the encryption of sensitive user data.*

4) *The lab technician did a check of the equipment to make sure there were no problems.*

5) *It is necessary to calibrate the sensors before starting the data collection.*

6) *With a specialized filter, the technician can remove microscopic particles from the liquid.*

7) *The study carried out an investigation into the relationship between heat and friction.*

8) *The bacteria found in the deep soil samples during the summer expedition died.*

9) *The two separate groups arrived at a final conclusion that was totally different.*

10) *The efficiency of the solar panel was higher after the surface was cleaned.*

Day 25　Scientific Writing(2) Guiding Readers in a Flow

[Lecture]

From the Known to Unknown Principle

Information and ideas should "**flow**" smoothly within sentences to allow the readers to read on without being distracted by "bumpy" sentences. One major cause of bumpiness is poorly ordered information. The basic principle of a good information structure is "**From the known to the unknown**." When every piece of new information is presented in relation to what they already know, the reader finds the text easier to understand. Compare the three sentences below:

A wind lens is a specialized brimmed ring ("shroud") that surrounds the blades of a wind turbine.

a) *<u>It</u>(= a wind lens) creates a low-pressure zone behind the structure that accelerates airflow, significantly boosting the energy captured by the spinning rotors.*

b) *<u>A wind turbine</u> with this shroud can generate up to three times more electricity by concentrating the natural force of the breeze into a powerful stream.*

c) *A small motor inside the head turns the whole machine to face wherever the breeze is blowing from.*

In a), the subject pronoun "it," which refers to "a wind lens" in the first sentence, is, by definition, something that the reader already knows. In other words, this particular piece of information ("a wind lens") is **shared** between the writer and the reader. In b), too, the subject "a wind turbine" is known to the reader, thus shared information. In both sentences, the shared information opens the sentences as well as functions as a **sentence connecter**.

C), on the other hand, has very little, if not no, information known to the reader. They might be able to infer or imagine based on their general knowledge what "a small motor", "the head", "the whole machine", or "the breeze" mean, but these words and phrases have no explicit connection to the first sentence. As a result, the reader has to deal with new information from the very beginning of the second sentence. This is reader-unfriendly.

To write a text with reader-friendly sentences, connecting one sentence to another is important, and one way to do the connection is "**reusing**" a word or phrase from the previous sentence. a) reuses the subject ("a wind lens") and b) reuses the last phrase ("a wind turbine"), but other elements can also be reused. (Let's call a) "Grab the head" and b) "Grab the tail" techniques.)

Reuse of previous elements makes the information flow from the known to the unknown. This flow of information aligns with the reader's understanding process, which increases the appeal of your writing.

[Comprehension Check]
Explain how you can achieve a good flow of information in scientific texts.

[Practice]
For each question, read the Lead Sentence. Then, choose which of the following options (a, b, or c) provides the smoothest flow of information. Be ready to explain which "known" word or phrase acts as the bridge.

1) **Topic: Solar Panels**
Lead Sentence: *Most modern solar panels are made from silicon, a semiconducting material that absorbs sunlight.*
a) *It (= silicon) converts the energy from the sun into a flow of electricity through a process called the photovoltaic effect.*

b) *Electricity is produced when photons hit the surface of the cell and knock electrons loose from their atoms.*

c) *Cloudy weather can significantly reduce the amount of power generated by a residential rooftop system.*

2) **Topic: Artificial Intelligence**
Lead Sentence: *Machine learning is a type of artificial intelligence that allows computers to learn from large amounts of data.*
a) *Information stored in the cloud is accessible from almost any device with a stable internet connection.*

b) *Programmers spend many hours writing code to ensure that the security of the software is not compromised.*

c) *This data is analyzed by algorithms to find patterns and make predictions without being explicitly programmed.*

3) **Topic: Electric Vehicles**
Lead Sentence: *Regenerative braking is a system used in electric vehicles to recover energy during deceleration.*
a) *Lithium-ion batteries are the most common type of energy storage used in the automotive industry today.*

b) *This recovered energy is sent back to the battery pack rather than being wasted as heat from the brake pads.*

c) *Drivers often notice that the car slows down more quickly when they lift their foot off the accelerator pedal.*

4) **Topic: CRISPR (Gene Editing)**

Lead Sentence: *CRISPR is a revolutionary gene-editing tool that acts like a pair of "molecular scissors."*

a) *These scissors (= CRISPR) can be programmed to target and cut specific sequences of DNA within a cell.*

b) *Laboratory safety is extremely important when researchers are working with dangerous chemicals.*

c) *Scientists found the original mechanism in the immune systems of bacteria that were fighting off viruses.*

5) **Topic: Thermal Insulation**

Lead Sentence: *Double-glazed windows consist of two panes of glass separated by a layer of inert gas.*

a) *High electricity bills are often caused by heat escaping through the roof or gaps in the doors.*

b) *This gas layer acts as a barrier that slows down the transfer of heat between the inside and outside of the building.*

c) *Aluminum frames are often used in modern construction because they are lightweight and resistant to rust.*

(Texts originally written for this coursebook)

Day 26　Scientific Writing(3) Meeting Reader Expectation

[Lecture]

Reader Expectation

Reading is an active process. The reader does not just receive what is provided by the text as it is but digest it and actively predict what can come next. Of course, they cannot predict everything. (If they could, they would not need to read the text.) They still can, however, have a general idea of what could come and what couldn't. For example, if you read, "*Plants capture solar energy using a green pigment called chlorophyll*," what do you expect to come next? Compare the following two candidates.

a) *This pigment functions to convert sunlight into chemical energy for the plant's growth.*
b) *Solar power is a type of renewable energy source that helps reduce our excessive dependence on fossil fuels.*

a) would be reasonable. b), on the other hand, will strike you as a surprise. You might say, "I didn't know what would come, but at least I thought I knew what would come was not *this*." This is reader expectation. When your sentence meets the reader expectation, the reader finds it easy to process and read on without feeling stressed.

Three questions

To ensure every sentence you write meets the reader expectation, you should always ask yourself, "What question will my readers ask about the present sentence? What will my readers want to know in the next sentence?"

You cannot, of course, know what your readers want exactly. But it is also true that the questions your readers ask can be roughly categorized into a limited number of groups. In this course, let's think that there are three groups of questions: "**Why so?**", "**Such as?**", and "**So what**?"

The first question, "Why so?" asks for reasons or evidence that proves your statement is correct. Imagine your current sentence is "**The latest rover mission to Mars discovered evidence of ancient organic molecules in the soil.**" Applying "Why so?" to this may produce the next sentence, "**This feat was made possible by the newly developed probe.**"

The second question, "Such as?" asks for examples. Applying this to the same current sentence may produce, "**For example, researchers identified complex carbon chains that are considered the fundamental building blocks of life.**"

The third question, "So what?" asks for the consequences. Again, applying this to the same sentence may produce, "**This finding significantly increases the probability that the planet once hosted microbial life.**"

Always keep these three questions in mind when you write a text to meet your readers' expectations.

[Comprehension Check]
Why should you try to meet your readers' expectations?

[practice]
Write a sentence that follows each of the sentences by answering one of the three questions.

1. *The newly developed alloy is remarkably resistant to corrosion in saltwater environments.*

2. *Several geographical factors determine the efficiency of a wind farm.*

3. *Last year, the city saw a 40% decrease in overall carbon emissions.*

Day 27　Scientific Writing(4) Citation

[Lecture]

Citation

Scientific inquiry is sometimes described as an act of "**standing on the shoulders of giants**," meaning any scientific achievement is made possible thanks to all the findings made by the past researchers. In reporting your own research, you must make the distinction clear between what you did and what others did. When referring to the achievements of other researchers, you are ethically obliged to credit them to the original authors. Failing to do so constitutes **plagiarism** and violates the fundamental trust upon which the scientific community is built.

Direct Quotations vs. Paraphrasing

To give proper credit, researchers generally use two methods: **direct quotation** and **paraphrasing** (**indirect quotation**). While both require a citation, they serve different purposes in technical writing.

A direct quotation uses the exact words of the original author, enclosed in quotation marks. In scientific texts, this is used sparingly – only when the original phrasing is so unique or powerful that changing it would lose the intended meaning.

e.g.) *As Dr. Aris Thorne (2023) stated in her study on deep-space acoustics, "The silence of the lunar vacuum is not an absence of sound, but a unique medium for vibrational data."*

When the quotation is short, typically fewer than 40 words, an **integrated quotation** is used. You integrate the quote into your own sentence by using quotation marks to indicate which words are made by the original author. When the quote is longer, a **block quotation** is used. Instead of placing the quote in your own sentence, you separate the quote visually by placing it in a "block." An example of block quoting can be found in Day 22 of this textbook.

The other citation method, paraphrasing, is the preferred method for most scientific communication. It involves referring to the original idea and rewriting it in your own words to fit the "flow" of your specific argument. Even though the words are yours, the credit still belongs to the original source.

e.g.) *While a vacuum traditionally prevents sound, Thorne (2023: 14) demonstrated that lunar environments act as a medium for vibrational data transmission.*

The reason why paraphrasing is preferred is that most technical readers are interested in the results and data, not the specific writing style of the previous author.

The exact style of citation to be used in an article are usually specified in the submission guidelines for each journal.

[Comprehension Check]
What is the reason for using a direct quotation?

[Practice]
Cite two of the previous studies that concern your own research: one in a direct quotation and the other in paraphrasing. For the direct quotation, make both integrated quotation and block quotation if possible.

Day 28　Full Paper

[Lecture]

The Hourglass Structure

An academic article typically reports on a specific study that forms part of a broader research project. Unlike a thesis, which compiles a series of studies to "paint a broader picture" for the purpose of applying for a degree (e.g. a Master's thesis or a doctoral dissertation), an ordinary journal article focuses on a limited aspect of the entire research.

Focusing on a specific study which contains a limited number of surveys or experiments is likely to deprive the article of a sense of story. However, as Part 2 of this course discussed, storytelling enhances the readers' engagement and understanding. An article thus usually has a storytelling structure often called "**the hourglass structure**."

The hourglass structure is essentially identical with IMRaD, but it emphasizes the focus of your discussion. As the figure in the next page shows, an article is expected to have a wide focus at the beginning. It explains the "prequal," or the story preceding the current study, to establish a foundation for persuading the reader of the necessity of the study. Then, the focus narrows down to specific topics, such as the individual surveys and experiments and the data obtained from them. Towards the end of the article, the focus becomes broader again, ending with prospects for future developments of the study.

Where to begin

There is no fixed order for composing a scientific article. While you may feel like starting with the Introduction and follow the IMRaD structure chronologically, many experts recommend beginning with the most focused section: Materials and Methods. Because this section records objective facts and technical procedures, it can be written without the pressure of interpretation or personal judgment. Establishing this foundation early often makes it easier to draft the more analytical sections later.

While you may want to decide on a title and finish the abstract before writing the main body, experts advise against this. It is helpful to have several candidate titles and a rough outline in place; however, the title and abstract should only be finalized after the body is complete. This ensures there are no discrepancies between your abstract and the actual findings of the paper.

Considering the above, a commonly advised order for writing an article is: (1) Materials and Methods, (2) Results, (3) Discussion, (4) Introduction, (5) Abstract, and (6) Title. Of course, while this sequence is a helpful guide, you should always consult your supervisors and adapt your approach to the specific needs of your project.

The Hourglass Structure

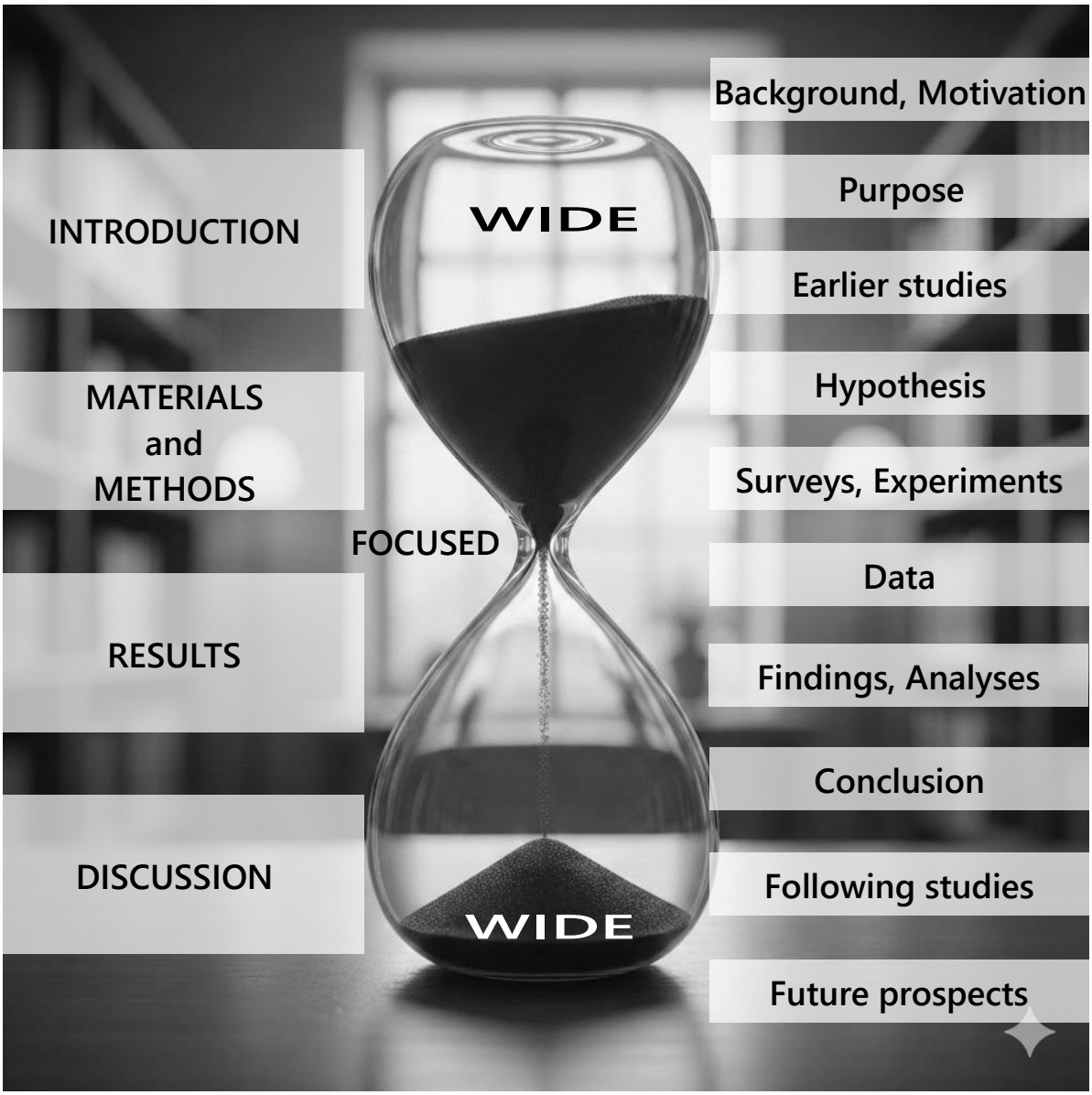


Image created by Goole Gemini with text overlaid by author

[Comprehension Check]
What does the hourglass structure advise the article writer to do?

[Practice]
Plan the main body of your next article using the hourglass structure.

Day 29　Abstract

[Lecture]

An abstract is a paragraph-length text that condenses the essence of a full research paper. It typically does not exceed 200 words and includes the essential points from each section of the IMRaD structure. The purpose of an abstract is to provide readers with an overview so they can decide whether to read the full article. Because abstracts are often displayed in databases separately from the main text, they must be written as standalone documents that can be fully understood without reference to the rest of the paper.

Writing an abstract as a standalone text requires a specific balance of what to include and what to omit.

The "No Trailer" Rule

An abstract must include the main findings and conclusions of the full paper. Unlike a movie trailer that keeps the ending a secret to build suspense, an abstract must reveal the "ending" so the reader knows exactly what was achieved.

Precision and Clarity

Although an abstract must be concise, accuracy should never be sacrificed for brevity. All abbreviations and acronyms must be spelled out upon first use to ensure the text remains accessible.

Text-Only Constraints

An abstract must not include citations, tables, or figures. Because abstracts are often published in text-only databases, they cannot support "two-dimensional" information or references to external lists. The reader must be able to grasp the entire scope of your work from the words alone.

Refer to Practice of Day 16 for an example of an abstract.

[Comprehension Check]
Explain what to do and what NOT to do in writing an abstract.

[Practice]
Write an abstract of your next research paper or oral presentation.

Day 30　Title

[Lecture]

The last piece of writing a scientific article is the title.　A title is a very short phrase that describes the most important feature that characterizes the paper.　Despite its simplicity and brevity, it requires careful consideration.

Three kinds of titles

There are three kinds of title: **declarative**, **descriptive**, and **interrogative**.

A **declarative** title is one that states the main conclusion of the paper.　An example is "Increased Light Intensity Accelerates the Rate of Photosynthesis in *Spinacia oleracea*."　It is likely to align with the hypothesis verified.　A declarative title is effective when the findings are definitive and groundbreaking.　This is because the title easily captures the readers' attention and the content of the paper is unlikely to go against their expectations.

A **descriptive** title states the topic of the study.　An example is "The Relationship Between Spectral Light Intensity and Photosynthetic Rates in Spinach Leaves."　It does not divulge the findings and leaves them to the main text.　A descriptive title is the most common in academic reports because it retains an objective tone while providing the readers with specific scope of the paper.

An **interrogative** title asks a question.　An example is "Does High-Intensity LED Lighting Enhance Photosynthetic Efficiency in C3 Plants?"　The question broadly aligns with the research question.　An interrogative title is likely to be used in semi-academic media such as a specialized magazine or a review article, but not in formal experimental reports. Some journals explicitly discourage or forbid the use of a question mark in the title, so you should refer to the instructions for the authors.

[Comprehension Check]
Explain how the three types of titles differ in terms of the information they provide to readers and the situations in which they are appropriate.

[Practice]
Create three kinds of titles for your most recent study.

Day 31　Utilizing AI Tools (1) General Guideline

[Lecture]

The advent of the AI age

The development of technology has always shaped human communication. Academic discourse is no exception. The typewriter revolutionized the way people write, later updated by the digital word processor. Presentation software such as PowerPoint and KeyNote also brought seismic changes into how ideas are visualized.

Today, the most significant shift we are experiencing is the rise of artificial intelligence (AI), especially in the form of machine learning and generative AI. Platforms such as ChatGPT, Google Gemini, Microsoft Copilot, and Anthropic Claude are evolving daily. These tools have already transformed the way we process information in both our daily and professional lives. Consequently, incorporating AI services into academic communication is no longer optional; it has become a must.

AI is an able partner, both reliable and questionable

AI is definitely a great companion to researchers. They help them generate ideas, organize information, and verbalize their contributions to science. AI as we know it today, which is built as a Large Language Model (LLM), is extremely proficient in processing language but it is not a fact database. While we can trust the quality of language it produces, its factuality should always be questioned.

A well-known weakness of AI (here synonymous with LLM) is the risk of "**hallucinations**." A typical example is when you ask an AI to list articles about a certain topic, it can give an article that actually does not exist. For the purpose of finding factual information, traditional search engines can be more reliable. Even with language, explaining grammar is not necessarily AI's specialty. Just because it can produce sophisticated language does not mean it can provide correct metalinguistic analysis.

Furthermore, **prompting** is a human factor that affects AI's performance. Poorly designed prompts earn poor response. **Prompt engineering** is something all AI users must learn.

Prioritizing information is also something AI is not necessarily trusted with. It may not recognize the emphasis you intend to place on a text, failing to distinguish keywords from non-keywords.

In short, AI is versatile but not omnipotent. Do not think you can outsource everything to AI. Instead, remember the **human-in-the-loop** (**HITL**) principle when working with AI.

To compute is AI, to compare, human

Generative AI is excellent at gathering and organizing information into a single answer, saving the user time and effort. This is, however, where the devil lies. **Comparing different sources** allows users to evaluate the quality of information and provides opportunities to identify biases and fallacies. Actually, everyone did compare different sources before the AI age, but many have stopped doing so with the advent of the AI age. You should be alarmed by this trend. You might sometimes be better served by "older" measures such as search engines or printed books in obtaining reliable information and establishing your own understanding.

[Comprehension Check]
What are possible risks in using artificial intelligence in your research?

[Practice]
Ask different generative AI services for advice on your research and compare their outputs.

Day 32 Utilizing AI Tools (2) Ethics and Foundations

[Lecture]

Throughout history, profound scientific discoveries have resulted from intense debates rather than isolated inquiry. Debating includes "questioning," which is essential for pursuit of the truth. In this respect, modern Artificial Intelligence can serve as a powerful **"Thinking Partner"** by engaging you in an **exploratory dialogue**. This differs from a simple search engine; it can simulate peer reviews or act as a "devil's advocate" to challenge your logic. However, since AI is a Large Language Model (LLM) that predicts patterns rather than a fact database, your collaboration must be built on a foundation of strict **Research Ethics**.

1. Protecting Intellectual Property (IP) and Privacy

In the scientific community, your original ideas—your hypotheses, your unique experimental designs, and your preliminary data—are your **Intellectual Property (IP)**. You must protect them. AI platforms, in its default settings, may use the data you input to train their future models. If you paste your unique research ideas into a standard AI without protection, your ideas could effectively enter the "public domain," used by the AI to answer other users' questions.

- **The Opt-out Requirement**: To be a professional researcher, you must master your tools. Before starting any research session, you must enable the **"opt-out" setting** or use "Temporary Chat" modes. This ensures your data is not used for machine learning.
- **Privacy of Subjects**: Protecting human subjects is a pillar of ethics. Never input personal data (names, addresses, or photos) of participants in your experiments. Once data enters an AI model, it is part of a "black box" that is nearly impossible to erase.

2. The Truth vs. Probability: Handling "Hallucinations"

Generative AI does not "know" the truth; it understands the *probability* of words. This leads to a phenomenon called **"Hallucination."** AI can generate perfectly written sentences that cite academic papers that do not exist or describe scientific laws that are completely false.

- **Accountability**: In science, the author of the report holds the **Accountability**. You cannot say, "The AI told me so" if your data is wrong. You have a professional duty to **fact-check** every claim made by AI by verifying it against reliable primary sources like textbooks and peer-reviewed journals.

3. Bias, Human Values, and Copyright

AI reflects the data on the internet that was used to train it. This means it carries all the human prejudices found online. It does not understand "values" or the ethical weight of a statement.

- **Bias**: AI responses may contain **inappropriate or discriminatory** perspectives. It may not respect the cultural values of specific regions or groups.
- **Copyright and Plagiarism**: AI-generated text may unintentionally mimic existing copyrighted works. Simply "copying and pasting" AI output is a form of plagiarism and may lead to **Copyright Infringement**. Your research must remain *your* work. You can use AI to spark ideas, but you must write the final presentation in your own voice.

[Comprehension Check]
1. Why is the "opt-out" setting crucial for a researcher who has a brand-new idea?

2. What should you do if an AI provides a very convincing citation for a scientific paper?

3. Explain the term "Accountability" in the context of using AI for research.

4. Why is "copying and pasting" AI-generated text considered a risk to academic integrity?

[Practice]
1) List any personally identifiable or sensitive information that you must NOT input into the AI. If your research is purely scientific and contains no private data, note "None."

2. AI can reflect prejudices in its training data. Consider your research field. What kind of scientific or technical bias might an AI have?

Day 33　Utilizing AI Tools (3) Pre-editing and Post-editing

[Lecture]

Although the writer of an academic article can be helped by generative AI practically in every phase of writing from searching for information to finalizing the draft for publishing, this course focuses on the language processing aspect in light of its purpose.

The need for human intervention

As discussed in the last section, the principle of human-in-the-loop (HITL) is something you should remember when using AI.　An example of HITL realization is "**pre-editing**" and "**post-editing**."

Here, we will discuss situations in which writers ask AI for assistance in improving the language of their writing, including machine translation.　In this context, pre-editing means modifying your text before you ask the AI to translate it.

Suppose your first language is Japanese.　Since Japanese is linguistically distant from English, even the latest AI platforms can produce mistaken or poor translations.　For example, the following Japanese was translated as below by DeepL.

> ①爬虫類の視力についてはいろいろなことがわかってきたけれども，視力が悪いどころか、人間には見えない紫外線まで識別できる優れた色覚を持っており、動体視力も非常に高く、②視覚だけに頼るのではなく、赤外線（熱）を感知するピット器官や、匂いを感じ取るヤコブソン器官など、他の鋭い感覚と組み合わせることで、周囲の状況を多角的に把握しているとされる。
>
> ①*While much has been learned about reptilian vision, it is far from poor. They possess excellent color vision capable of distinguishing ultraviolet light invisible to humans, and their motion perception is exceptionally keen.* ②*Rather than relying solely on sight, they combine it with other acute senses—such as the pit organ for detecting infrared (heat) and the Jacobson's organ for detecting odors—to comprehensively assess their surroundings.*

In ①, "けれども" is translated into "While," but this is not correct because the "けれども" in this context does not mean contradiction or contrast, but it introduces a topic.　② is not necessarily mistaken, but the logical connection from the previous sentence is ambiguous.　This is because the original Japanese is ambiguous on this point, which is reflected on the English translation.

The biggest problem here is that the Japanese text put to machine translation is too long and too ambiguous.　To obtain a better translation, the Japanese text must be pre-edited to be more "English-like," and thus more "ready to be machine-translated."　An example would be:

> 近年，爬虫類の視力については多くのことが明らかになってきた。爬虫類の中には，人間は知覚できない紫外線を識別できるほど色覚に優れていたり，動体視力が高いものがいる。しかも，視覚に加えて，赤外線（熱）を感知するピット器官や匂いを感知するヤコブソン器官などを持つ種もいて，複数の感覚を組み合わせることで周囲の状況を把握している。

In recent years, much has been revealed about reptilian vision. Some reptiles possess exceptional color vision, capable of distinguishing ultraviolet light imperceptible to humans, while others exhibit superior motion perception. Furthermore, beyond vision, certain species possess specialized organs such as infrared (heat)-sensing pit organs and odor-detecting Jacobson's organs. By combining these multiple senses, they comprehend their surroundings.

This version produced a much clearer translation. This is how pre-editing works.

Post-editing, on the other hand, is editing the translated text so that it fits for the purpose of communication. For example, in the second translation above, you might find the word "imperceptible" too difficult for your reader. In that case, you may rewrite the sentence as "*They can even see the ultraviolet light, which humans cannot see.*"

In other cases, you might want to change the translation into an oral presentation script. The translation is in the written style, and you might ask generative AI to change it to a more colloquial style. For example, Google Gemini generated the following text:

In recent years, we've learned a great deal about how reptiles actually see the world.

First of all, their vision is far more advanced than many people realize. For instance, some reptiles possess extraordinary color vision—they can even distinguish ultraviolet light, which is completely invisible to us humans. Others have incredibly high visual acuity when it comes to detecting movement.

But what's even more fascinating is that they don't just rely on their eyes. Certain species are equipped with specialized sensors, such as 'pit organs' for sensing infrared heat and the 'Jacobson's organ' for detecting chemical scents.

By integrating all of these different senses, reptiles are able to build a highly accurate and sophisticated map of their surroundings.

You must always remember that the responsibility for the final text is on the human author, even when they have sought assistance from AI. Some experts advise that **the writer should use only expressions that they can read aloud smoothly**, which means they are within their English ability. In other words, you must judge what suggestion you take from your AI assistant and what not.

[Comprehension Check]
Explain the two ways to obtain appropriate results from machine translation.

[Practice]
Pre-edit a Japanese text about your research so that it is fit for machine translation.

Day 34 Utilizing AI Tools (4) Directing Your Co-pilot

[Lecture]

In the modern research environment, you must be the **Director** while AI acts as your **Co-pilot**. Although AI can handle complex technical tasks, the final decisions on logic and safety belong solely to you. Simply asking AI to "write everything" causes you to lose control over your research. To maintain your scientific "**voice**," you must lead the AI through a structured process, ensuring it supports your ideas rather than replacing them.

Step 1: Establishing the Mission (Role Setting)

A common mistake is to provide data to an AI without any context. To get professional feedback, you must first define the **"Mission."** Before sharing your research details, give the AI a specific **Persona**. For example, telling the AI to "Act as a Scientific Advisor specializing in Marine Biology" narrows its focus. This ensures that the suggestions it provides are grounded in academic logic and professional standards rather than generic internet conversation.

Step 2: Feeding the "Research DNA"

AI can only provide high-quality output if the input you provide is clear and structured. Professional researchers use a framework called **"Research DNA."** Think of this as the essential blueprint of your project. It consists of the following elements:

- **Background**: What is the "known world"? What does the audience already understand?
- **Conflict (Research Question)**: What is the "mystery"? What gap in knowledge are you trying to fill? A strong conflict effectively contradicts what is commonly known.
- **Hypothesis**: What is your team's **informed guess** to solve that mystery? (This is a logical prediction based on your initial observations).
- **Method**: How exactly are you testing this guess?
- **(Expected) Result**: What do you (expect to) find, and why does it matter?

Step 3: The DNA Interview

Instead of asking for a presentation draft immediately, you should use the **"DNA Interview"** technique. This is a highly effective way to use AI as a thinking partner. After providing your Research DNA, give the AI the following command: *"Ask us 3 to 5 clarifying questions to find any logical holes or missing details in our research DNA before we proceed."* When you answer these questions, you are forced to think more deeply about your project. This interaction transforms the AI from a mere "writing machine" into a powerful "logic-testing machine," helping you strengthen your story before you present it to others.

Step 4: Stress Testing and the HITL Principle

Even after the AI helps you build a draft, you must apply the **Human-in-the-Loop (HITL)** principle. This means you critically evaluate every suggestion and make the final choice.

- **Conflict Check**: Ask the AI if the gap between "the known world" and "your mystery" is sharp enough to interest the audience.
- **Audience Stress Test**: Ask the AI to act as a "tough reviewer" to identify the three weakest points in your logic.

- **Simplification**: Ask the AI to explain your complex topic for a non-expert audience using a simple analogy.

Ultimately, you are the Director. The AI provides the raw material, but you are the one who decides which words represent your research. The final accountability for the logic and the presentation belongs to you.

[Comprehension Check]
1) Why is it important to provide a "Mission Statement" and a "Persona" before sharing your research data?

2) List the five components of "Research DNA" and explain the role of "Conflict."

3) How does the "DNA Interview" technique improve the quality of your research?

4) What is the purpose of an "Audience Stress Test" and how does it help a researcher?

[Practice]
1) If you could hire one world-class expert to review your research in class, what specific role would you choose?

2) Based on your current progress, which part of your Research DNA do you think AI will find "mysterious" or "logically holed"?

☐ Background ☐ Conflict ☐ Hypothesis ☐ Method ☐ Result

Day 35 Utilizing AI Tools (5) Triangulation of Different Tools

Blending Human and Artificial Intelligence

Artificial intelligence has revolutionized the way we approach scientific communication. For non-native English speakers, AI-driven linguistic support has already become a foundational tool for engaging with the international research community. Indeed, learning to navigate these services is now an essential skill for anyone in scientific inquiry.

This does not mean, however, that artificial intelligence is always superior to human intelligence. Rather, you should view AI as a supplementary intelligence. For linguistic support, traditional resources—such as dictionaries, corpora, and search engines—remain indispensable. Dictionaries are the refined products of human expertise; because they are compiled by experts, the knowledge they provide is exceptionally reliable.

Similarly, linguistic corpora (databases designed for specific research purposes) are also products of **human intelligence**. While they exist on digital platforms, their construction requires specialized human knowledge to ensure they provide a reliable foundation for appropriate language use.

Machine translation platforms like DeepL and Google Translate, or editing tools like DeepL Write and Grammarly, occupy a middle ground. Unlike fully autonomous generative AI, these tools often provide multiple suggestions, allowing the user to choose the candidate that best fits the context. This creates a collaborative "**semi-artificial intelligence**" where human judgment and machine processing interact to produce the best results.

Finally, there is Generative AI. While it can produce output almost autonomously, you still maintain control through the prompts you provide.

In writing a research paper or a presentation script, you are most effective when you strategically combine these different layers of intelligence. "**Triangulation**" is originally a surveying term used to determine a precise location by measuring it from different points. In the context of writing, it means looking at the same linguistic problem from multiple perspectives to gain a clearer, "three-dimensional" understanding of the correct expression. By triangulating your results - checking an AI's output against a dictionary and verifying it within a corpus - you ensure that your language is not only fluent but also accurate and appropriate for the scientific community.

[Comprehension Check]
Explain what “triangulation” means in the context of scientific writing.

[Practice]
Write a (part of) report on your research by triangulating different tools.

Part 6

Supplements

1. Research Question and Research Paper

A research question is what drives a research project forward. The researcher plans and conducts their research in order to answer the research question. The answer they found is reported in a research paper. A research paper, therefore, provides the pair of the research question and the answer to it. All the other elements, previous studies or the materials and methods, are chosen to answer the research question, and they are provided on the paper for the reader to understand and evaluate the answer. There is a straight line from the research question to the answer on the research paper… at least apparently.

The actual development of a research project is not so straightforward for many high school scientists. They set their research question at the beginning of their projects. However, soon they learn they cannot retain it when previous studies have already answered it almost perfectly or when it is found to be unpursuable by ordinary high school students due to its complexity. Even in the middle of their research process, they might find the research question unproductive when they actually conduct surveys and experiments. In any of these cases, they have no choice but to change their research question to a "better" one.

These "twists and turns" are very common to high school science projects, so changing research questions is not regarded a failure. Rather, a research question should be seen as something that "develops." Pursuing a better research question is in itself part of scientific inquiry, especially for young researchers.

The problem is whether they should be honest about these non-straightforward processes when they write a research paper. The answer is "No" in many cases, but sometimes it may be "Yes." To discuss this, we need to understand there are two aspects to the dual purpose of a research paper.

A research paper is to report on the findings of a study. In this sense, a research paper is product-oriented. However, in order to verify the product, or for the reader to understand it, the paper must explain how the findings are made. In this sense, a research paper is process-oriented, too. These two aspects, being both product-oriented and process-oriented, lead to the contradicting answers.

When the focus is on the product, the winding process should be removed from sight because the research questions in their older versions hardly contribute to understanding. When the focus is on the process, on the other hand, the older versions have their own places to claim in the paper. They must be shared with the reader so that future researchers can plan their studies in more sophisticated ways.

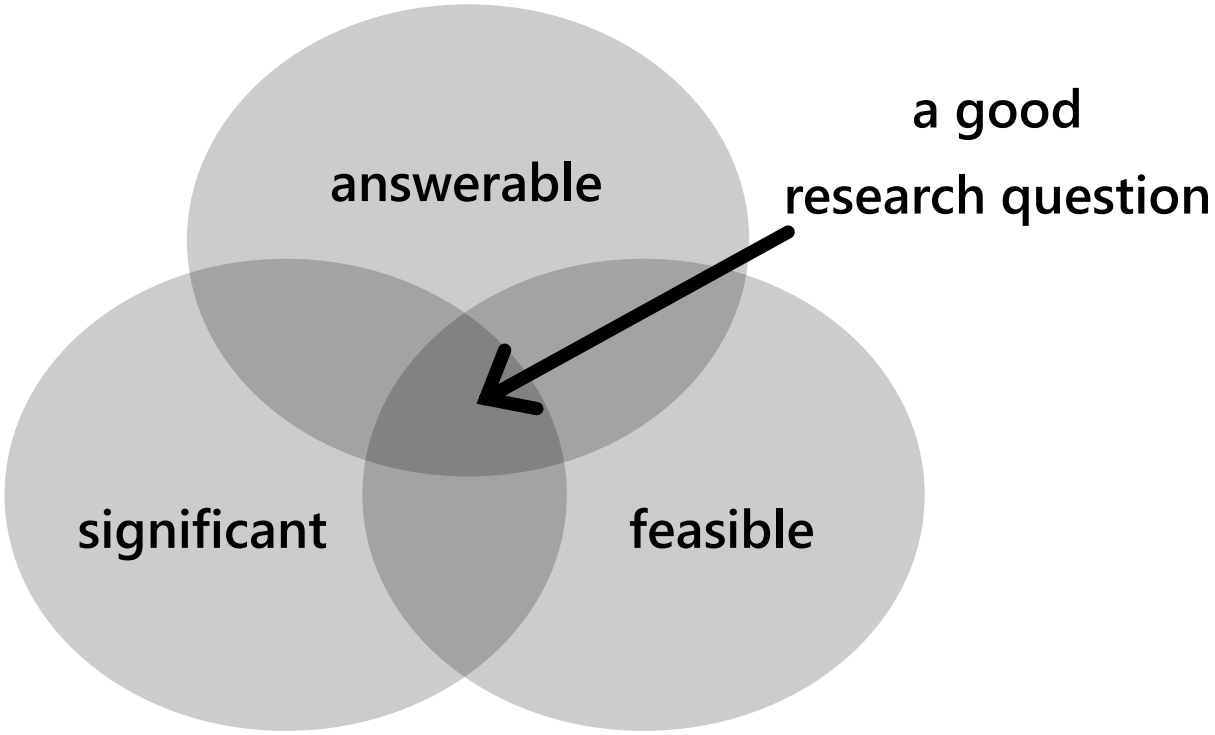
In many cases, at least where high school scientists write, the papers are expected to be product-oriented, so their stories should be straightforward. This is the reason for "No"

above.　However, there are some cases where process-oriented reports are welcome, which is the reason for the reserved “Yes.”

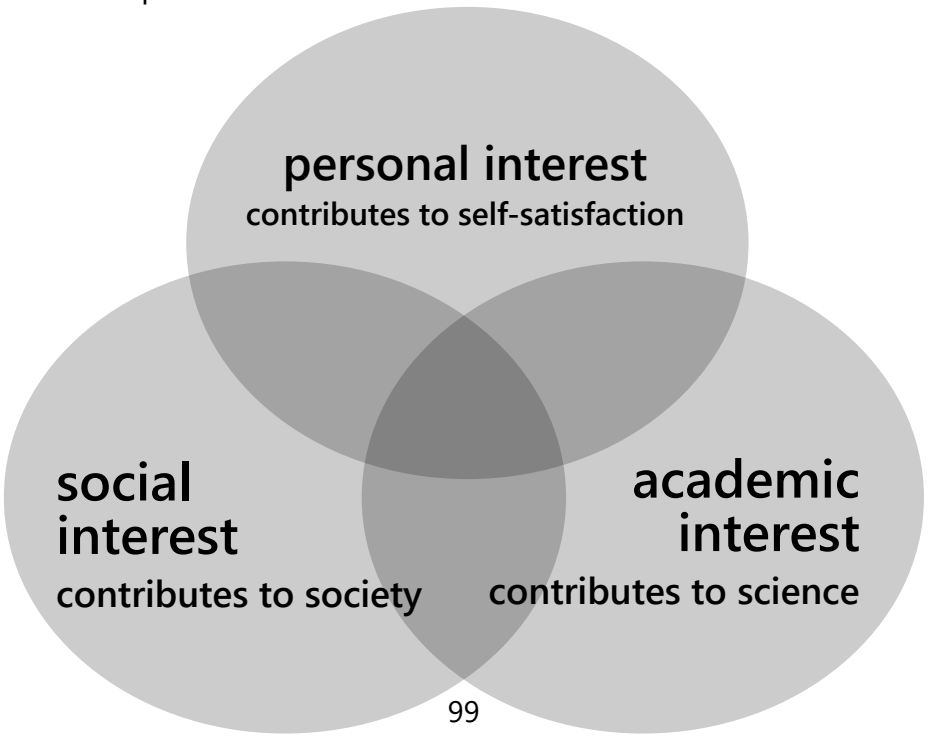
According to Sato(2024)*, there are some conditions for developing a good research question.

*佐藤郁哉. 2024.『リサーチ・クエスチョンとは何か?』. 筑摩書房.

The figures are recreated and the terms are translated into English by the authors of this textbook.



The motivation for setting a research question can come from three areas.　These areas may or may not overlap each other, and the more areas overlap, the better sources they are for finding a research question.



2. Logic and Reasoning

Three types of logic

Induction

I see cats on my way to school. One chilly morning I saw a cat sitting in a sunny spot. It looked relaxed and perhaps dozing. When I turned the corner, I saw another cat sitting in a sunny spot. It looked happy too. The next morning, when it was even chillier, I saw more cats sitting in sunny places. Cats like to be in sunny places for warmth.

Deduction

Cats like to be in sunny places for warmth. So, it would be better to prepare a sunny and warm spot in our living room for our cat Mike.

Abduction［Retroduction / Hypothesis Formation］

One fall morning, as I entered the warehouse, I saw something moving quickly and going somewhere. I couldn't see exactly what it was. But the place where it first was was lit by the sunlight coming through the high window. It must have been the wild cat I often see around my house, for cats like to be in sunny places for warmth.

Syllogism

Conclusion: *Socrates will die.*
↑
Minor Premise: *Socrates is a human being.*
↑
Major Premise: *All human beings will die.*

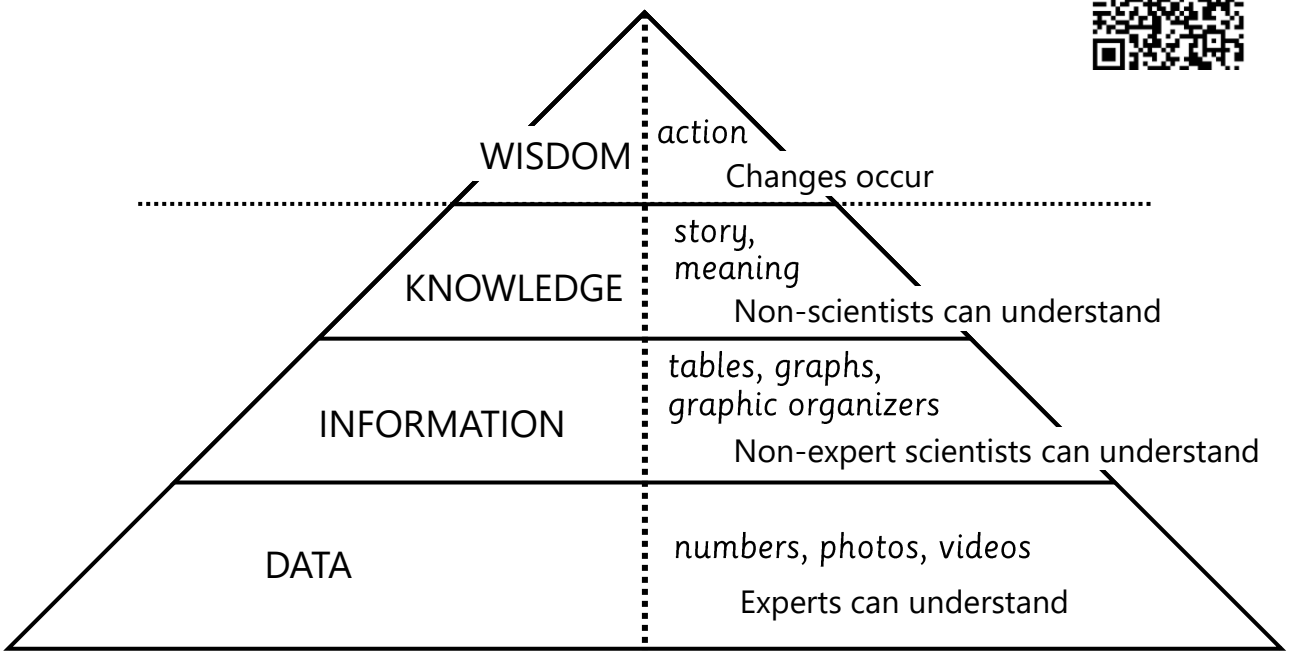
Conclusion	**Socrates**	→	**will die**
Minor Premise	Socrates	a human being	
Major Premise		human beings	will die

The Toulmin Model

Claim: *You have no class today.*
↑
Data: *Today is Sunday.*
↑
Warrant: *You have no class on Sundays.*

Data	Today is Sunday.	→	Claim	**You have no class today.**
		↑		
		Warrant	You have no class on Sundays.	

3. The DIKW Pyramid



You must consider who your audience is to control what you should provide at the presentation. If your audience is a group of experts on the exact topic of your research, "**Data**" may suffice. Looking at the raw data, the numbers obtained from the surveys, or photos and videos taken during the experiments, allows the audience to interpret it on their own, and discussions will be sparked automatically.

On the other hand, if the audience is a group of scientists who do not necessarily own specialized knowledge of your topic, you must "summarize" the data into more accessible forms, typically tables, graphs, charts, and simplified images or graphic organizers. This is "**Information**." Information can be described as "data + scientific significance/meaning." High school scientists should be able to provide Information at academic conferences.

When you speak to non-scientists who do not share basic understanding of scientific methodology, you must further summarize Information to shape it into a story that is grounded on their everyday experience. This is "**Knowledge**." Knowledge can be described as "Information + everyday meaning/significance." It enables non-science people to look at the world from a new perspective. This is perhaps the highest achievement for high school scientists. They should try to provide Knowledge when they speak to high school or junior high school students.

The ultimate level is "**Wisdom**." It changes many people's perspectives and eventually the society/world. This is, of course, rare to be achieved. However, it is possible for high school scientists to dream it.

4. Expressions for Oral Presentation

Introduction

We are interested in…
The purpose of this presentation is…
Today, the topic of our presentation is…
We will divide the discussion into three parts. First,… Second,… Finally,…
Let us begin our talk by giving you an explanation of…
To start with, we will provide background information on…
We would like to comment on the problem of…
We would like to briefly mention (that)…
There are two points we would like to make.
We'll show you the data later.
How can we explain…? / Is there a link between…? / Is there a solution to…?
Next, we will demonstrate…
After that, we will take a look at…
We'll give you more information about this in the next section.
Generally speaking,…

Body

So far, we have reviewed….
Let us now turn to…
Let's move on to the next point.
This leads us to another question of…
To illustrate this point, let's consider…
This apparatus consists of…
We'd like to define the term X. X refers to… / X can be defined as…
We'd like to show you the experimental set-up we used.
These results show…
On the one hand, I would say…, but on the other hand,…
In spite of…, we should remember…
Despite the fact that…
Although… we still think… because…
What do these results tell us about…?
What can we conclude from these results?
What do we mean by X?
First of all,… / To begin with,…
In addition,… / Moreover…
It seems to us… / We have to say…
As far as we are concerned…
To put it simply…

Conclusion

In conclusion, we have made the following points. Number one… Number two…
In closing, we'd like to mention that….
In conclusion, we would like to say…
We'd like to go over our major findings.
We'd like to summarize the main findings of this study.
The main findings of this study are as follows.
As you can see, there are three main points.
In this study, we found that…
Our future work will be to…
We plan to look at…
The next stage in this research is to…
Our future goal is to…
That's we all have to say. Thank you for your attention.
That concludes our presentation. Thank you.
That covers everything we want to say. Thank you.
On the whole, …

Q&A (disagreeing)

I agree in principle, but…
You have a point there, but…
I can see your point of view, but…
I see what you mean, but…
That may be true, but…
I agree with you on the whole, but…
I respect your opinion, but…

but…+
it could also be said that…
we should still think… because…
that is only one of the many contributing factors
that is much too simplified.
our data tell us the opposite

I'm afraid…

Q&A (unable to answer directly)

At present we don't have enough data to answer that question, but generally speaking…
I'm afraid we can't give you a definite answer, but my speculation is that…
I'm sorry, but that is outside the area of this study.
I'm sorry, but we did not look at that point.
I'm afraid that requires careful discussion.
We do not have enough time to discuss it now. Could we talk later?

5. Expressions for Describing Graphs

(1) Different information types

Table
This table summarizes the results of...
As shown in this table, the values indicate...
If you look at the second column, you will see...
The data presented here compares [X] and [Y]...
According to this table, the highest figure was recorded in...
These rows represent the different variables we tested...

Bar graph
This bar graph illustrates the difference between...
The vertical axis represents [quantity], while the horizontal axis shows...
As the graph shows, [Category A] is significantly higher than [Category B].
The bars indicate a clear ranking of...
You can see a sharp contrast between these two groups...
This chart shows how the various categories compare in terms of...

Pie chart
This pie chart displays the distribution of...
As you can see, [Category X] accounts for the largest portion of the total.
This segment represents approximately 30 percent of the whole.
The chart is divided into five main sectors...
The smallest slice indicates that...
This gives us a clear picture of the breakdown of...

Line graph
This line graph shows the trend of [X] over time.
The line indicates a steady increase in...
As you can see, there was a sharp drop in [Year].
The values fluctuated during the first half of the study...
The trend line suggests a gradual recovery in...
We can see a peak reached in the month of...

Scatter diagram
This scatter diagram plots the relationship between [X] and [Y].
Each dot represents a single data point from our sample.
The distribution of the points suggests a positive correlation.
As you can see, the points are tightly clustered around the line.
There appears to be no significant correlation between these variables.
This outlier over here indicates an unusual result that...

Radar chart

This radar chart compares the performance across several dimensions.
The shape of the web indicates that we are strongest in [Category].
Each axis represents a different metric, such as…
As the chart expands outward, it shows an improvement in…
The overlap between these two shapes shows the similarities in…
This visual allows us to see the overall balance of…

(2) Describing trends

Upward Trends

There was a significant increase in…
The figures rose steadily over the period.
The numbers reached a peak in [Year].
The value soared to its highest level yet.
We noticed a gradual upward trend in…

Downward Trends

The results showed a sharp decline in…
The numbers dropped significantly after the second trial.
The values plummeted to a record low.
There was a slight dip in the middle of the experiment.
The downward trend suggests that…

Stability and No Change

The figures remained stable throughout the study.
The values leveled off after an initial increase.
There was no significant change in the data.
The trend stayed relatively flat over the six-month period.
The results fluctuated slightly but remained within the expected range.

Speed and Degree of Change

The numbers increased dramatically in a short time.
There was a marginal improvement in the results.
The change was sudden and unexpected.
We observed a steady and consistent growth.
The values shifted rapidly between [X] and [Y].

6. Nouns for Science

(1) 数字 number

(2) 整数 integer

(3) 偶数 even number

(4) 奇数 odd number / uneven number

(5) 小数 decimal / decimal fraction

(6) 小数点 decimal point

(7) 小数第 I 位 the first decimal place

(8) 分数 fraction

(9) 分子 numerator

(10) 分母 denominator

(11) 3等分（する） trisection (trisect)

(12) 式（数式・公式） formula / numerical expression

(13) 平均 average

(14) 合計 total / sum

(15) 7 以上（以下） seven or more (less)

(16) 四捨五入（する） round(ing) off

(17) 切り上げ（捨て）（る） round(ing) up (down)

(18) 2乗（する） square

(19) 3乗（する） cube

(20) 10^{13} ten to the (power of) thirteen / ten to the thirteenth power

(21) 乗数 multiplicator / multiplier

(22) 絶対値 absolute value

(23) 単位 unit

(24) 重さ weight

(25) 長さ length

(26) 割合 proportion

(27) 比 ratio

(28) 速さ speed / velocity

(29) 目盛り scale

(30) 比例 proportion

(31) 反比例 inverse proportion

(32) 図形 figure

(33) 円 circle

(34) 正方形 square

(35) 長方形 rectangle

(36) 三角形 triangle

(37) 正三角形 equilateral triangle / regular triangle

(38) 直角三角形 right triangle

(39) 二等辺三角形 isosceles triangle

(40) ひし形 rhombus

(41) 平行四辺形 parallelogram

(42) 台形 trapezoid

(43) 五角形 pentagon

(44) 六角形 hexagon

(45) 八角形 octagon

(46) 角度 angle

(47) 頂点 apex / vertex

(48) 直角 right angle

(49) 直線 straight line

(50) 曲線 curved line / curve

(51) 対角線 diagonal line

(52) 底辺 base

(53) 高さ height

(54) 半径 radius

(55) 直径 diameter

(56) 円の中心 center

(57) 円周 circumference

(58) 円周率 pi

(59) 平行（であること） parallel(ism)

(60) 線（点）対称 line [point] symmetry

(61) 垂直（であること） perpendicular(ity)

(62) 直方体 cuboid / rectangular parallelepiped

(63) 立方体 cube

(64) 三角柱 triangular prism / triangular pole

(65) 四角柱 quadrangular prism/ square pole

(66) 円柱 cylinder

(67) 面積 area

(68) 体積 volume

(69) 平方センチメートル square centimeter

(70) 立方センチメートル cubic centimeter

(71) 原子 atom

(72) 分子 molecule

(73) 酸素 oxygen

(74) 水素 hydrogen

(75) 炭素 carbon

(76) 窒素 nitrogen

(77) リン phosphorus

(78) 硫黄 sulfur

(79) 塩素 chlorine

(80) 銅 copper

(81) 質量 mass

(82) 物質 matter / substance

(83) 物体 body

(84) 化学反応 chemical reaction

(85) 運動エネルギー kinetic energy

(86) 位置エネルギー potential energy

(87) 弾性エネルギー elastic energy

(88) 熱エネルギー thermal energy

(89) 放射線 radiation

(90) 同位体 isotope

(91) 慣性の法則 inertial law / law of inertia

(92) 摩擦 friction

(93) 遠心力 centrifugal force

(94) 重力 gravity

(95) 磁力 magnetic force

(96) 電磁波 electromagnetic wave

(97) 周期表 periodic table

(98) 陽子 positron

(99) 電子 electron

(100) 中性子 neutron

(111) 試験管 test tube

(112) 試験管立て test tube stand

(113) 試験管ばさみ test tube clamp

(114) ビーカー beaker

(115) 三角フラスコ Erlenmeyer flask

(114) 丸底フラスコ round-bottomed flask

(116) シャーレ・ペトリ皿 petri dish

(117) メスシリンダー measuring cylinder / graduated cylinder

(118) ピペット pipette

(119) ビュレット burette

(120) スポイト dropper

(120) 漏斗 funnel

(121) 薬包紙 weighing paper

(122) 薬さじ medicine spoon

(122) 濾紙（ろし） filter paper

(123) 坩堝（るつぼ） crucible / melting pot

(124) 乳鉢 mortar

(125) 乳棒 pestle / muddler

(126) デシケーター desiccator

(127) スターラー stirrer

(128) カバーガラス cover slip / cover glass

(129) スライドガラス glass slide

(129) 安全メガネ safety goggles

(130) ピンセット tweezers

(131) 鉗子 forceps / scissor pliers

(132) アルコールランプ alcohol lamp

(133) ガスバーナー gas burner

(134) （算術）平均 mean

(135) 中央値 median

(136) 最頻値 mode

(137) 度数分布 frequency distributions

(138) 累積度数 cumulative frequency

(139) 標準偏差 standard deviation

(140) 分散 variance

(141) 連続変数 continuous variable(s)

(142) 離散変数 discrete variable(s)

(143) 母集団 population(s)

(144) 統計調査 statistical survey

(145) 全数調査 census

(146) 標本 sample

(147) 階層化無作為抽出 stratified random sampling

(148) 偏り（のある） bias(ed)

(149) アンケート questionnaire

(150) 正／負の相関 positive/negative correlation

(151) 正規分布 normal distribution(s)

(152) 数列 (number) sequence / progression

(153) 初項 the first term

(154) 第 *n* 項 the *n*th term

(155) 有酸素運動 aerobic exercise

(156) 抗生物質 antibiotic

(157) アポトーシス apoptosis

(158) 自閉症 autism

(159) 双極性障害 bipolar disorder

(160) 発がん性物質 carcinogen

(161) 悪寒 chill

(162) 葉緑体 chloroplast

(163) 染色体 chromosome

(164) 合併症 complication

(165) 濃度 concentration

(166) 伝染病 contagious disease

(167) 歯科 dentistry

(168) 糖尿病 diabetes

(169) 飛沫 droplet

(170) 胎芽・胚 embryo

(171) 酵素 enzyme

(172) 胎児 fetus / foetus

(173) 繊維 fiber

(174) ゲノム genome

(175) ブドウ糖 glucose

(176) 培養液 growth medium

(177) 海馬 hippocampus

(178) 免疫 immunity

(178) 体外受精 in vitro fertilization (IVF)

(179) 感染 infection

(180) 炎症 inflammation

(181) 注入・注射 injection

(182) 白血病 leukemia / leukaemia

(183) リンパ腺 lymph gland

(184) ミトコンドリア mitochondrion (-dria)

(185) 突然変異 mutation

(186) 壊死・ネクローシス necrosis

(187) ニューロン neuron

(188) 肥満 obesity

(189) 卵子 ovum / egg

(190) 病原体 pathogen

(191) 痘疹 pock

(192) 膿 pus

(193) 検疫・隔離 quarantine

(194) 呼吸 respiration

(195) かさぶた scab

(196) 精子（精液） sperm (semen)

(197) 脳卒中 stroke

(198) 甲状腺 thyroid

(199) 毒素 toxin

(200) 腫瘍 tumor

7. Verbs for Science

(1) absorb **absorb** carbohydrate 炭水化物を吸収する

(2) accelerate **accelerate** a particle to light speed 粒子を光速まで加速する

(3) accumulate Greenhouse gases **accumulate** in the atmosphere.
温室効果ガスが大気中に蓄積する

(4) actuate The lever will **actuate** the pump. このレバーがポンプを作動させる。

(5) adapt **adapt** to the climate change 気候変動に適応する

(6) add **add** the compound to the solution その化合物をその溶液に加える

(7) adjust **adjust** the concentration of the solution その溶液の濃度を調整する

(8) adsorb control rods **adsorb** atomic particles 制御棒は原子の粒子を吸着する

(9) alternate **alternate** walking and running ウォーキングとランニングを交互に行う

(10) amount The total loss **amounted to** about 35% 総減少量は約 35%に達した

(11) analyze **analyze** the relationship その関係性を分析する

(12) apply **apply** a force perpendicular to… …に垂直な力を加える

(13) assemble **assemble** the apparatus その装置を組み立てる

(14) assess **assess** the intensity その強度を評価する

(15) assimilate **assimilate** carbon dioxide 二酸化炭素を吸収する

(16) attract Unlike charges **attract**. 異なる電荷はひきつけあう。

(17) behave Solids and liquids **behave** differently. 固体と液体のふるまいは違う。

(18) bend **bend** metal using heat 熱を加えて金属を曲げる

(19) bind Molecules **bind** together. 分子どうしが結合する。

(20) calculate **calculate** the circumference 円周を計算する

(21) cause Heating ice will **cause** it to melt. 氷を熱すれば溶ける。

(22) capture **capture** CO_2 二酸化炭素を回収する（捉える）

(23) charge **charge** a battery　バッテリーを充電する

(24) classify **classify** whales as mammals　クジラを哺乳類に分類する

(25) code **code** a computer program　コンピュータ・プログラムを書く

(26) coexist Humans and animals **coexist**　人間と動物が共存する。

(27) coincide Sneezing and blinking **coincide**.　くしゃみとまばたきが同時に起こる。

(28) combine **combine** hydrogen with oxygen　水素と酸素を結合させる

(29) communicate The disease is **communicated** by fleas. その病気はノミによって伝染する。

(30) compare **compare** your results　結果を比較する

(31) compensate **compensate** for the effect of gravity 重力の影響を補正（相殺）する

(32) comply **comply** with safety regulations　安全規定を順守する

(33) compose Water is **composed** of hydrogen and oxygen.
水は水素と酸素からできている。

(34) compress **compress** files　ファイルを圧縮する

(35) conceive Sleep deprivation can decrease the possibility to **conceive**.
睡眠不足は妊娠の可能性を下げうる。

(36) concentrate The lenses **concentrate** sunlight.　そのレンズは日光を集める。

(37) condense Water vapor **condenses** into tiny drops.
水蒸気が凝結して小さな水滴になる。

(38) condition **condition** rats to press the button
ラットをボタンを押すように条件付けする

(39) conduct **conduct** an experiment　実験を行う

(40) confirm Further tests will **confirm** the identity of the gas.
さらに試験をすれば気体の正体がわかる。

(41) conserve These collisions **conserve** momentum.
これらの衝突は運動量を保存する。

(42) consist The experiment **consists** of three stages.
その実験は3つの段階から成っている。

(43) constitute Lime and sand **constitute** mortar.　モルタルは石灰と砂でできている。

(44) construct **construct** a hypothesis　仮説を立てる

(45) consume **consume** a lot of energy エネルギーを大量に消費する

(46) contain　Cigarette smoke **contains** carbon monoxide.
たばこの煙には一酸化炭素が含まれている。

(47) contrive　We will **contrive** a way to measure the gas.
その気体を測定する方法を工夫（考案）する。

(48) control　**control** other variables　他の要因を統制する

(49) convert　**convert** inches into centimeters　インチをセンチメートルに換算する

(50) correlate　The temperature **correlated** with the production rate.
温度と産出速度に相関があった。

(51) correspond　The results **corresponded** with our hypothesis.
その結果は我々の仮説と一致していた。

(52) corrode　Acid rain **corrodes** buildings.　酸性雨は建物を腐食させる。

(53) culture　**culture** the infected cells　感染した細胞を培養する

(54) decode　**decode** the message　そのメッセージを解読する

(55) define　**define** categories clearly　カテゴリー（範疇・分類）を明確に定義する

(56) demonstrate　**demonstrate** that the hypothesis is correct
その仮説が正しいことを証明する

(57) depend　The value of *y* depends on *x*.　*y* の値は *x* に従属する。

(58) derive　**derive** from fossil fuels　化石燃料に由来する（から作られる）

(59) describe　**describe** the procedure clearly　その手順を明確に説明する

(60) detect　**detect** contaminants　汚染物質を検知する

(61) deteriorate　Hearing **deteriorates** with age.　聴力は加齢とともに落ちる。

(62) determine　**determine** the cause　原因を突き止める

(63) develop　**develop** a cat phobia　猫恐怖症になる

(64) differ　the results **differ**　結果が異なる

(65) dilute　**dilute** the solution　その溶液を希釈する

(66) discharge　The human body **discharges** waste.　人体は老廃物を排出する。

(67) discover　**discover** the relationship　関係性を発見する

(68) disinfect　**disinfect** water with ultraviolet light [UV rays]　水を紫外線で殺菌する

(69) display　**display** your findings　分かったことがらを示す

(70) disregard　For this calculation, we **disregarded** air resistance.
この計算では，空気抵抗は無視した。

(71) dissolve　**dissolve** in acid　酸に溶ける

(72) distinguish　Indicators help **distinguish** acids from bases.
指示薬は酸と塩基を区別するのに役立つ。

(73) distort　**distort** the image　画像をゆがめる

(74) distribute　The samples **distributed** evenly.　標本（サンプル）は均等に分布していた。

(75) diversify　**diversify** your experiment locations
実験場所に変化をもたせる（多様化する）

(76) document　Its negative influence is well **documented**.
その負の影響は十分に立証されている。

(77) drain　**drain** water from the container　容器から水を排出する

(78) drive　The machine is **driven** by water power.　その機械は水力で動く。

(79) elevate　**elevate** the body temperature　体温を上昇させる

(80) ease　**ease** muscle tension　筋肉の緊張をやわらげる

(81) emerge　New properties **emerge** at the quantum level.
量子レベルでは，新しい特性が現れる（創発する）。

(82) emit　**emit** greenhouse gases　温室効果ガスを排出する　／
light-**emitting** diode = LED

(83) employ　**employ** a new method in the experiment　実験で新しい方法を用いる

(84) engage　The two gears **engaged**.　その2つの歯車がかみ合った。

(85) engineer　genetically **engineered** bacteria　遺伝子組み換え細菌

(86) ensure　This bolt will **ensure** a tight seal.　このボルトが密閉性を確実にする。

(87) equal　Two to the power of five **equals** 32.　2の5乗は32。

(88) establish　We must establish a control group.
対照群（統制群）を設定しなければならない。

(89) evaporate　Heat **evaporates** water.　熱は水を蒸発させる。

(90) evolve　Small dinosaurs **evolved** into birds.　小型の恐竜が鳥類に進化した。

(91) exceed　Pollutants **exceed** safety standards.　汚染物質が安全基準を超過する。

(92) exert　Magnets **exert** a force on iron. 磁石は鉄に力を及ぼす。

(93) exhale　**exhale** carbon monoxide 一酸化炭素を吐き出す

(94) exhibit　**exhibit** initial symptoms of a hear attack　心臓発作の初期症状を示す

(95) expand　The universe is **expanding**.　宇宙は膨張している。

(96) experience　The solution may **experience** a color change.
溶液の色に変化が生じることがある。

(97) experiment　**experiment** on human subjects　人間を被験者として実験する

(98) explode　The chemicals exploded.　化学薬品が爆発した。

(99) explore　**explore** for methane hydrate　メタンハイドレートの採掘調査をする

(100) expose　be **exposed** to heat and acid 熱と酸にさらされる

(101) express　**express** the relationship in an equation　その関係性を数式で表す

(102) extend　**extend** downward　下方に向かって伸びる

(103) extract　**extract** DNA from a cell　細胞からDNAを抽出する

(104) facilitate　**facilitate** a chemical reaction　化学反応を促進する

(105) fashion　**fashion** the apparatus from plastic bottles ペットボトルでその装置を作る

(106) flow　Heat will **flow** from hot to cold. 熱は高温から低温へと移動する。

(107) form　Crystals **form** under high pressure. 結晶は高圧化で生成する。

(108) freeze　The system **froze**.　システムがフリーズした

(109) function　**function** in a similar way　同じように機能する

(110) furnish　the apparatus was **furnished** with a battery charger
その装置には充電器が付いていた

(111) heat　**heat** the solution to 80℃　その溶液を 80℃まで熱する

(112) generate　**generate** electricity for commercial use 商業用に発電する

(113) identify　**identify** the extracts　その抽出物が何であるかを突き止める（同定する）

(114) illustrate **illustrate** the importance of balance in the ecosystem
生態系のバランスの重要さを示す

(115) improve **improve** energy efficiency　エネルギー効率を高める

(116) include **include** the data in our analysis そのデータを分析に含める

(117) indicate The test results **indicated** a substantial change
大きな変化があったことを示す検査結果だった。

(118) induce A current was **induced** in the coil.　コイルの中に電流が誘導された。

(119) influence The stimulus **influenced** the rats' behavior.
その刺激がラットの行動に影響を与えた。

(120) inhale **inhale** oxygen and exhale carbon dioxide
酸素を吸入して二酸化炭素を排出する

(121) inhibit **inhibit** an allergic reaction　アレルギー反応を抑制する

(122) integrate **integrate** visual and auditory information
視覚情報と聴覚情報を統合する

(123) interfere **interfere** with enzymes　酵素を阻害する

(124) invent **invent** a device　装置を開発する

(125) investigate **investigate** the relationship between study hours and test scores
学習時間とテストの点数の関係を調べる

(126) load **load** the spring to measure its displacement
ばねに負荷をかけて,その変位を測定する。

(127) locate **locate** the cause of the problem 問題の原因をつきとめる

(128) magnify **magnify** the image by 250%　画像を 250%に拡大する

(129) maintain **maintain** a constant density　一定の密度を保つ

(130) measure **measure** the speed　速さを計測する

(131) melt Ice **melts** into water.　氷が溶けて水になる。

(132) mitigate **mitigate** air pollution 大気汚染を緩和する

(133) mix mix the resin and hardener thoroughly
樹脂と硬化剤を十分に撹拌する

(134) modify genetically **modified** crops　遺伝子組み換え作物

(135) monitor **monitor** the electric(al) charge of the blades　羽根の電荷を観察する

(136) number **number** each cell from 1 to 15　それぞれのセルに1～15の数字を振る

(137) neutralize　**neutralize** alkali [acid]　アルカリ［酸］を中和する

(138) observe　**observe** the phenomenon　その現象を観察する

(139) obtain　**obtain** energy from food　食物からエネルギーを得る

(140) operate　The device **operates** on battery power.
その装置はバッテリー電源で作動する。

(141) plot　**plot** temperature on the y-axis　温度をY軸に取る（置く・描く）

(142) position　Global **Positioning** System (GPS)　全地球測位システム

(143) power　**power** the motor　モーターに電力を供給する

(144) precipitate　**precipitate** in the solution　溶液中で沈殿する

(145) present　These molecules present a stable structure.
これらの分子は安定した構造を呈する。

(146) progress　The reactions **progress** over time.　反応は時間経過とともに進行する。

(147) protect　**protect** the surface from drying　表面を感想から守る

(148) provide　**provide** the cell with energy　細胞にエネルギーを供給する

(149) range　**range** in height from 10cm to 120cm
高さが 10cm（のもの）から 120cm（のもの）まである

(150) react　A noble gas rarely **reacts** with other elements.
貴（希）ガスは他の元素と反応することがほとんどない。

(151) reduce　**reduce** nitrates to nitrites　硝酸塩を亜硝酸塩に還元する

(152) refer　**Refer** to Table 2 for details.　詳細については表2を参照のこと。

(153) refine　**refine** crude oil　原油を精製する

(154) reflect　The sunlight **reflected** off the white sand.　日光が白い砂に反射した。

(155) regulate　**regulate** body temperature　体温を調節する

(156) release　**release** heat into the atmosphere　熱を大気中に放出する

(157) remove　Filters **remove** impurities.　フィルターが不純物を除去する。

(158) renew　The tropical rainforest cannot **renew** itself.　その熱帯雨林は再生しない。

(159) repel　**repel** dirt　泥をはじく

(160) replenish　**replenish** lost water　失われた水分を補給する

(161) resist　**resist** corrosion　腐食に耐える

(162) resolve　Water is **resolved** into oxygen and hydrogen.
水は酸素と水素に分解される。

(163) respond　**respond** to stimulation　刺激に反応する

(164) rest　let the solution **rest** for ten minutes 溶液を 10 分間静置する

(165) result　**result** in a complication　合併症を引き起こす

(166) retain　This sponge can **retain** a lot of water.
このスポンジは多くの水分を保持する。

(167) retrieve　**retrieve** information from the Internet
インターネットで情報を検索する（取り出す）

(168) reverse　The Earth's magnetic field has **reversed** a number of times.
地球の磁場は何度も反転している。

(169) revise　**revise** downward　下方修正する

(170) rotate　The wheels **rotate** on an axle. その車輪は車軸を中心に回転する。

(171) seal　a lead-**sealed** container　鉛の密閉容器

(172) sense　**sense** the change in the Earth's magnetic field
地球の磁場の変化を感知する

(173) serve　**serve** as a catalyst　触媒として働く

(174) settle　let the sediment **settle** at the bottom 沈殿物を底に沈殿させる

(175) signal　**signal** the end of processing　処理の終了を知らせる

(176) simplify　**simplify** the design　設計を単純化する

(177) sit　let the beaker **sit** overnight ビーカーを一晩静置する

(178) smooth　use sandpaper to **smooth** the surface
サンドペーパーを使って表面を滑らかにする

(179) specify　**specify** all the factors　すべての要因を特定する

(180) start　The temperature **starts** to rise. 温度が上昇し始める。

(181) steady　**steady** the panel　パネルを固定する

(182) steam　**steam** the cloth to remove stains　蒸気を布に当ててしみを取る

(183) stimulate　**stimulate** an immune response　免疫反応を促す

(184) strain　**strain** the soup　スープを漉す

(185) stream　The liquid **streamed** down.　その液体が流れ落ちた。

(186) structure　a **structured** interview　構造化面接法（事前に決めた質問に沿って行う面接）

(187) substantiate　These findings **substantiate** the original theory.
これらの知見は元の理論を裏付ける。

(188) substitute　You can **substitute** copper for silver.　銅で銀を代用できる。

(189) survey　**survey** global environmental changes　地球環境の変動を調査する

(190) suspend　**suspend** further testing　さらなる実験を中止（一時中断）する

(191) synthesize　**synthesize** glucose from amino acids　アミノ酸からグルコースを合成する

(192) transfer　**transfer** between hemispheres　脳半球（右脳と左脳）の間で伝達する

(193) transform　**transform** a table into a graph　表をグラフに変換する

(194) travel　Sound **travels** faster in water than in air.
音は空気中よりも水中の方が速く伝わる。

(195) treat　Plants can help **treat** wastewater.　植物は排水を処理するのに役立つ。

(196) utilize　**utilize** deep-sea resources　深海の資源を活用する

(197) vary　**vary** according to conditions　条件によって変わる（変動する）

(198) verify　**verify** password　パスワードを照合する

(199) wane　The magnetic field began to **wane** as the distance increased.
距離が離れるにつれて磁場が弱まり始めた。

(200) yield　**yield** a by-product　副産物を生む

Part 7

Worksheets

Research Proposal

Group Number : A_____

Group Members : _____

_____

Title of the Research Project : _____

1. Why is the study needed?

1.1. What is known about the topic of study?

1.2. What is not known about the topic of study?

1.3. What should be known about the topic of study? Why?

2. What are you going to do?

2.1. What do you want to find out / make clear?

2.2. What can you do with your resources available?

3. What is your study going to be like?

3.1. What is the purpose / goal of your study? What is your hypothesis?

3.2. What method are you going to adopt? / What procedure are you going to follow?

3.3. What results do you expect? What results are desirable in your study?

3.4. What good will your study do?
Why should the nation's precious tax be used on your study?

5Cs	
Steps	Words
Common Ground 相手の知っていること・ 常識・共通理解	○○ってわかりますよね ○○ってあるじゃないですか ○○って聞いたことありませんか
Conflict 相手の知識・理解と 矛盾すること	でも, それでは説明できない現象があるんです ところが, それが当てはまらない場合があるんです しかし, それでは不十分なんです
Concept introduced 矛盾を解消する 新しい考え方・発見	このように考えると説明できるんです これを説明してくれる発見があったんです・実験結果が 得られたんです
Concrete examples 具体例	具体的には, こういうことです たとえば, こんな事例があります
Conclusion and **C**heck 確認	まとめると, こういうことです 今の説明で伝わりましたか？ ご不明な点はありますか？

Main Story	
Steps	Words
Common Ground	
Conflict	
Concept introduced	
Concrete examples	
Conclusion and **C**heck	

Elevator Pitch Plan

Steps	Words
Introduction	
Body	
Conclusion	

Poster/Slide Plan 1

Poster/Slide Plan 2

TRAC		
Thank		· *Thank you for your question.* · *Thank you for asking that.* · *That is a good question.* · *That's what matters here.* · *That's exactly what I want to make clear.* · *Actually it is a tough question.* · *Actually it is not easy to answer that question.*
Repeat		· *Your question is …, right?* · *You are asking about …, right?* · *What you mean is …. Am I right?* · *Let me rephrase your question like this. "…"* · *Could I say your question is about…?* · *Your point is…*
Answer	**B**asics (Common ground)	· *In principle,….* · *In the first place,…* · *As everyone knows,….* · *The definition of … is … / I define … as … in my study.* · *The reason why I take up this in my study is that….* · *The bottom line of my study is that….* · *From the perspective of…* · *The simple conclusion here is that….* · *What I'd like to make clear here is that….*
	Core (Essence)	· *The most important thing here is….* · *Let me emphasize this.* · *The essence (of the experiment) is that….*
Check		· *This is my answer.* · *Does that answer your question?* · *Am I clear?* · *What do you think?* · *Could I ask what suggestion you have?*

Q&A Plan

Thank		
Repeat		
Answer	**B**asics (Common ground)	
	Core (Essence)	
Check		

Abstract Plan	
Title	
Throughline	
Introduction (Background, Conflict, Purpose)	
Method & Material	
Results	
Discussion & Conclusion	

Ethical AI & Fact-Checking

1. Pre-flight Safety Check

Verify your settings before starting the dialogue.

[ ] I have enabled "Temporary Chat" or the "Opt-out" setting in the AI menu.

[ ] I have removed all personally identifiable or sensitive information from my data.

2. Hunting for Hallucinations (The Accuracy Test)

AI often generates fake but professional-looking citations. Challenge it.

Prompt: "Explain the core scientific principles of [Your Research Topic] and provide 2 specific peer-reviewed journal references (Title, Author, Journal, Year) from the last 5 years."

AI's Response Summary:

The Reality Check (Cross-reference):

Search for the provided titles/authors in Google Scholar or a university database.

[ ] Verified (The source exists and matches)

[ ] Hallucinated (The title/author seems fake or mixed up)

[ ] Partial (The author exists, but they never wrote that specific paper)

3. Stress-Testing for Bias & Regional Gaps

Test if the AI respects your specific local context or if it favors Western/General data.

Prompt: "What are the most common challenges for researchers studying [Your Topic] specifically in Japan? Are there any unique environmental or cultural factors that global AI models might overlook?"

AI's Observations:

Critical Reflection:

Does the AI provide specific local insights, or just generic "global" answers? List one thing the AI missed about your local context.

4. Demonstrating Accountability (Source Validation)

To maintain your accountability, you must bridge the gap between AI and primary sources.

Action: Identify one Primary Source (a textbook, a government database, or a known journal) that you already trust. Compare one claim made by the AI in Section 2 with this source.

- Your Trusted Primary Source: _____
- The AI's Claim: _____
- The Comparison Result:

(Is the AI's terminology, data, or logic consistent with your primary source? Describe the difference or consistency.)

Directing Your Research DNA

Define Your Research DNA

・ Background *What is the established fact or common knowledge?*	
・ Conflict *What is the specific gap or contradiction you found?*	
・ Hypothesis *What is your logical prediction to solve the mystery?*	
・ Method *Briefly, how are you proving your hypothesis?*	
・ (Expected) Result *What do you (expect to) find, and why does it matter?*	

Remember: AI is your co-pilot, but YOU are the Captain. You make the final decision on every word.

Use these prompts to collaborate with AI effectively. Replace the text in [ ] with your own research details.

★ Step 0: Set the Mission (Role Setting)

Prompt❶: "We are a team of researchers specializing in [your field]. I want you to act as our Scientific Advisor. We will provide our research data (DNA)
and your task is to help us build a logical presentation structure and a compelling introduction. If you understand
please reply with: 'Understood. Please provide your research DNA.'"

★ Step 1: Sharpen Your Input (The DNA Interview)

Prompt❷: "Here is our research DNA:

- Background: [Notes]
- Conflict: [Notes]
- Hypothesis: [Notes]
- Method: [Notes]
- Result: [Notes or "Pending"]

Prompt❸"Ask us 3 to 5 clarifying questions to find any logical holes or missing details in our research DNA before we proceed."

★ Step 2: Build the Bridge (Hook & Analogy)

Prompt❹: "Suggest three different 'Hooks' and analogies that connect our research to the audience's daily life. These should be things they already understand or consider common sense.

Requirements:

1. Use analogies or metaphors related to everyday life or social issues.
2. Avoid technical jargon; make the audience feel the topic is relevant to them.
3. Create a natural transition from the general concept to our specific research theme."

☞ Choose the best one from the AI's suggestions. Why does it fit your research?

★ Step 3: Act as the Director (Refinement)

Prompt: Based on our discussion write a draft for our Introduction. [Add your Director's Orders➡ *See "AI Prompt Cheat Sheet" on the next page*].

☞Write down the final version you are happy with. Focus on the flow from Hook to DNA.

★ Step 4: Test the Tension (Conflict Check)

Prompt: "Critically analyze our 'Conflict'. Does it effectively contradict what is commonly known? Is the gap between 'the known world' and 'our mystery' sharp enough?"

- Is the boundary between 'what is known' and 'what is unknown' clear?
- What is the 'cost' of not solving this problem?
- Are there any logical leaps (logical leaps) in our story? Please suggest a more impactful way to frame this Conflict if needed."

☞How did the AI help you make the "Mystery" more exciting or clear?

Step 5: Preparing for the Q&A (Stress Test)

Prompt: "Act as a tough reviewer. Identify the 3 weakest points in our logic and suggest how we can defend them."

☞Fill in the blanks

The Most Critical Weak Point:	
Your Defense Strategy:	

AI Prompt Cheat Sheet

☆Director's Orders (Refinement)

Professionalism	Make it more professional; focus on [Something].
Simplicity	Make it easy to understand for a 14-year-old using a simple analogy.
Reality Check	I don't think this is happening in everyday life, so audiences cannot understand it. Please try another example.
Tone Adjustment	That sounds too formal. Can you make it more conversational and friendly?
Focus Shift	The analogy is good, but my research focuses more on [Specific Point]. Can you adjust the bridge to emphasize that?
Tightening	Great, but it's too long for an opening. Shorten it to two sentences without losing the impact.
Stress Test	Act as a tough reviewer. What are the 3 weakest points in this logic?
Customization	Now, we need to present this to [Specific Audiences]. 1. How should we change our tone and vocabulary for them? 2. What part of our story will they care about the most? 3. Suggest a specific 'Call to Action' for this audience.
Improve Prompt	What information do you need from me to make this draft better?
Methods	Create an analogy to explain our equipment.
Results	Why does this data matter? Explain using the Ladder of Abstraction.
Word Choice	"You used the word '[patterns],' but can you replace it with more descriptive words that fit the '[sheepdog]' example?"

100 Nouns for Science

Generated by Google Gemini and edited by author

【物理】Physics

☐1. 慣性 inertia

☐2. 速さ／速度 speed / velocity

☐3. 等速直線運動 uniform linear motion

☐4. 等加速度直線運動 uniformly accelerated linear motion

☐5. 重力加速度 gravitational acceleration

☐6. 質量と重さ mass / weight

☐7. 力 force

☐8. 作用反作用の法則 law of action and reaction

☐9. 摩擦力 friction / frictional force

☐10. 弾性力／フックの法則 elastic force / Hooke's law

☐11. 浮力／アルキメデスの原理 buoyancy / Archimedes' principle

☐12. 圧力／大気圧 pressure / atmospheric pressure

☐13. 仕事／エネルギー work / energy

☐14. 運動エネルギー kinetic energy

☐15. 位置エネルギー potential energy

☐16. エネルギー保存の法則 law of conservation of energy

☐17. 電力・電力量 electric power / electric energy

☐18. オームの法則 Ohm's law

☐19. 直流／交流 direct current / alternating current

☐20. 磁界／磁力線 magnetic field / magnetic field lines

☐21. 電磁誘導／レンツの法則 electromagnetic induction / Lenz's law

☐22. 光の反射／屈折 reflection / refraction

☐23. 凸レンズ／凹レンズ／焦点距離 convex lens / concave lens / focal length

☐24. 音の性質／振幅／周波数 nature of sound / amplitude / frequency

☐25. 波長 wavelength

【化学】Chemistry

☐26. 原子／分子 atom / molecule

☐27. 元素記号 element symbol

☐28. 化学式 chemical formula

☐29. 化学反応式 (chemical equation)

☐30. 物質の三態／固体／液体／気体 three states of matter / solid / liquid / gas

☐31. 融点／沸点 melting point / boiling point

☐32. 蒸留／ろ過 distillation / filtration

☐33. 密度 density

☐34. 水溶液／溶解度 aqueous solution / solubility

☐35. 飽和水溶液 saturated solution

☐36. 質量パーセント濃度 mass percent concentration

☐37. 酸／アルカリ／塩基 acid / alkali / base

☐38. pH（水素イオン指数） pH

☐39. 中和反応 neutralization reaction

☐40. イオン／陽イオン／陰イオン ion / cation / anion

☐41. 電気分解／陽極／陰極 electrolysis / anode [positive pole] / cathode [negative pole]

☐42. 酸化／還元 oxidation / reduction

☐43. 有機物／無機物 organic matter / inorganic matter

☐44. プラスチック／ポリマー plastic / polymer

☐45. 金属の性質 properties of metals

☐46. 炎色反応 flame (coloration) test [flame reaction]

☐47. モル／物質量 mole / amount of substance

☐48. アボガドロ定数 Avogadro constant

☐49. 周期表／族／周期 periodic table / group / period

☐50. 質量保存の法則 law of conservation of mass

【生物】Biology

☐51. 細胞／核 cell / nucleus

☐52. 光合成 photosynthesis

☐53. 呼吸 respiration

☐54. 維管束系／木質部／師管部 vascular system / xylem / phloem

☐55. 気孔／蒸散作用 stoma / transpiration

☐56. 消化／吸収 digestion / absorption

☐57. 血液循環／動脈／静脈 blood circulation / artery / vein

☐58. 赤血球／白血球 red blood cell / white blood cell

☐59. 反射 reflex

☐60. 中枢神経系／末梢神経系 central nervous system / peripheral nervous system

☐61. 感覚器官 sensory organ

☐62. 生殖／有性生殖／無性生殖 reproduction / sexual reproduction / asexual reproduction

☐63. 染色体／遺伝子／DNA chromosome / gene / DNA: deoxyribonucleic acid

☐64. メンデルの法則 Mendelian inheritance

☐65. 進化／相同器官 evolution / homologous organ

☐66. 生態系／生産者／消費者／分解者 ecosystem / producer / consumer / decomposer

※菌類／細菌／無脊椎動物 fungi / bacteria / invertebrates = FBI

☐67. 食物連鎖／食物網／捕食者／被食者 food chain / food web / predator / prey

☐68. 環境保全／生物多様性 environmental conservation / biodiversity

☐69. 恒常性（ホメオスタシス） homeostasis

☐70. ホルモン hormone

☐71. 免疫反応／免疫系 immune response / immune system

☐72. 減数分裂 meiosis

☐73. 胚の発生 embryonic development

☐74. 被子植物／裸子植物 angiosperm / gymnosperm

☐75. 双子葉類／単子葉類 dicotyledon / monocotyledon

【地学】Earth Science

☐76. 火山 volcano

☐77. 火成岩／火山岩／深成岩 Igneous rock / volcanic rock / plutonic rock

☐78. 堆積岩 sedimentary rock

☐79. 地層／化石 stratum (-ta) / fossil

☐80. 地震波／P 波／S 波 seismic wave / P-[primary] wave / S-[secondary] wave

☐81. 震源／震央 hypocenter / epicenter

☐82. プレートテクトニクス plate tectonics

☐83. 気象／湿度／気圧 meteorology / humidity [moisture] / atmospheric [air] pressure

☐84. 前線／寒冷前線／温暖前線 front / cold front / warm front

☐85. 飽和水蒸気量／露点 saturated vapor density / dew point

☐86. 高気圧／低気圧

anticyclone [high (atmospheric) pressure] / cyclone [low (atmospheric) pressure]

☐87. 季節風 monsoon [seasonal wind]

☐88. 太陽系／惑星／衛星 solar system / planet / satellite

☐89. 天体の自転／公転 rotation / revolution

☐90. 月／満ち欠け／日食／月食 moon / wax and wane / solar eclipse / lunar eclipse

☐91. 太陽／黒点／コロナ sun / sunspot / corona

☐92. 銀河（星雲）・銀河系（＝天の川銀河） galaxy / the Galaxy [the Milky Way]

☐93. 恒星 fixed star [sun]

☐94. 季節の変化 seasonal changes

☐95. 金星の見え方（相） phases of Venus

☐96. 海流／暖流／寒流 ocean current / warm (ocean) current / cold (ocean) current

☐97. エルニーニョ現象 El Niño

☐98. 温室効果／温室効果ガス greenhouse effect / greenhouse gas

☐99. 地球温暖化 global warming

☐100. 示準化石／示相化石 index fossil / facies fossil

The Periodic Table of Elements

Group / Period	1	2	3	4	5	6	7	8	9
1	1 H 水素 Hydrogen								
2	3 Li リチウム Lithium	4 Be ベリリウム Beryllium							
3	11 Na ナトリウム Sodium	12 Mg マグネシウム Magnesium							
4	19 K カリウム Potassium	20 Ca カルシウム Calcium	21 Sc スカンジウム Scandium	22 Ti チタン Titanium	23 V バナジウム Vanadium	24 Cr クロム Chromium	25 Mn マンガン Manganese	26 Fe 鉄 Iron	27 Co コバルト Cobalt
5	37 Rb ルビジウム Rubidium	38 Sr ストロンチウム Strontium	39 Y イットリウム Yttrium	40 Zr ジルコニウム Zirconium	41 Nb ニオブ Niobium	42 Mo モリブデン Molybdenum	43 Tc テクネチウム Technetium	44 Ru ルテニウム Ruthenium	45 Rh ロジウム Rhodium
6	55 Cs セシウム Cesium	56 Ba バリウム Barium	*Lanthanoid Series*	72 Hf ハフニウム Hafnium	73 Ta タンタル Tantalum	74 W タングステン Tungsten	75 Re レニウム Rhenium	76 Os オスミウム Osmium	77 Ir イリジウム Iridium
7	87 Fr フランシウム Francium	88 Ra ラジウム Radium	*Actinoid Series*	104 Rf ラザホージウム Rutherfordium	105 Db ドブニウム Dubnium	106 Sg シーボーギウム Seaborgium	107 Bh ボーリウム Bohrium	108 Hs ハッシウム Hassium	109 Mt マイトネリウム Meitnerium
			Lanthanoid Series	57 La ランタン Lanthanum	58 Ce セリウム Cerium	59 Pr プラセオジム Praseodymium	60 Nd ネオジム Neodymium	61 Pm プロメチウム Promethium	62 Sm サマリウム Samarium
			Actinoid Series	89 Ac アクチニウム Actinium	90 Th トリウム Thorium	91 Pa プロトアクチニウム Protoactinium	92 U ウラン Uranium	93 Np ネプツニウム Neptunium	94 Pu プルトニウム Plutonium

10	11	12	13	14	15	16	17	18
								2 He ヘリウム Helium
			5 B ホウ素 Boron	6 C 炭素 Carbon	7 N 窒素 Nitrogen	8 O 酸素 Oxygen	9 F フッ素 Fluorine	10 Ne ネオン Neon
			13 Al アルミニウム Aluminum	14 Si ケイ素 Silicon	15 P リン Phosphorus	16 S 硫黄 Sulfur	17 Cl 塩素 Chlorine	18 Ar アルゴン Argon
28 Ni ニッケル Nickel	29 Cu 銅 Copper	30 Zn 亜鉛 Zinc	31 Ga ガリウム Gallium	32 Ge ゲルマニウム Germanium	33 As ヒ素 Arsenic	34 Se セレン Selenium	35 Br 臭素 Bromine	36 Kr クリプトン Krypton
46 Pd パラジウム Palladium	47 Ag 銀 Silver	48 Cd カドミウム Cadmium	49 In インジウム Indium	50 Sn スズ Tin	51 Sb アンチモン Antimony	52 Te テレル Tellurium	53 I ヨウ素 Iodine	54 Xe キセノン Xenon
78 Pt 白金 Platinum	79 Au 金 Gold	80 Hg 水銀 Mercury	81 Tl タリウム Thallium	82 Pb 鉛 Lead	83 Bi ビスマス Bismuth	84 Po ポロニウム Polonium	85 At アスタチン Astatine	86 Rn ラドン Radon
110 Ds ダームスタチウム Darmstadtium	111 Rg レントゲニウム Roentgenium	112 Cn コペルニシウム Copernicium	113 Nh ニホニウム Nihonium	114 Fl フレロビウム Flerovium	115 Mc モスコビウム Moscovium	116 Lv リバモリウム Livermorium	117 Ts テネシン Tennessine	118 Og オガネソン Oganesson

63 Eu ユウロピウム Europium	64 Gd ガドリニウム Gadolinium	65 Tb テルビウム Terbium	66 Dy ジスプロシウム Dysprosium	67 Ho ホルミウム Holmium	68 Er エルビウム Erbium	69 Tm ツリウム Thulium	70 Yb イッテルビウム Ytterbium	71 Lu ルテチウム Lutetium
95 Ac アクチニウム Actinium	96 Cm キュリウム Curium	97 Bk バークリウム Berkelium	98 Cf カリホルニウム Californium	99 Es アインスタイニウム Einsteinium	100 Fm フェルミウム Fermium	101 Md メンデレビウム Mendelevium	102 No ノーベリウム Nobelium	103 Lr ローレンシウム Lawrencium

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※本テキスト作成にあたり原著を参照したが邦訳も出版されているものについては，原著の書誌情報を示したうえで，(　) 内に邦訳の情報を示しました。逆に，邦訳を参照した場合は (　) 内に原著の情報を示しました。両方を参照した場合は，原著を参照した形式にそろえています。

※本テキストはSSH研究開発の成果物です。その性質に鑑み，以下の文献リストには，本テキストの内容に直接的に反映されているものだけでなく，学校設定科目「サイエンス・コミュニケーション」開発の参考にさせていただいたものも含めています。

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