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Biological Resource

Inquiry into the Onion

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In Japan, inquiry activities have been introduced into science subjects for upper secondary schools since 1994. Through these inquiry activities students are expected to address issues actively, think deeply by themselves, and feel pleasure in solving problems. However, so far, these activities have not been implemented widely. In the present paper, an example of inquiry activities which relates to the morphology and growth of the onion bulb is proposed. The process of the activity is as follows: First, the teacher gives the students a question, "Which part of the onion do you eat: root, stem, leaf, flower or fruit?" Most of the students may not give the correct answer. Teachers can use the gap between the students' answers and the correct answer to foster students' curiosity. This part is easy and inexpensive, and it can be carried out within one school hour. The next part is also inexpensive, but more challenging. The teacher gives the students another question, "How does the onion bulb get bigger?" To figure out their answers and verify them, students are asked to carry out a series of group activities: making a hypothesis which is an answer to the question, designing an experiment, carrying out the experiment and collecting data, analyzing and discussing the results, and finally deciding whether the hypothesis is acceptable. Then, each student is asked to write a report or give a presentation. Through these activities, students' abilities of logical thinking, decision-making, and expression can be cultivated.

Keywords: active learning, inquiry activity, morphology, onion bulb, plant growth, secondary school biology,

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INTRODUCTION

In Japan, inquiry activities have been introduced into science subjects for upper secondary schools since 1994 when the official school curriculum, the Course of Study (CS), revised by the Ministry of Education, Japan (MOE, presently Ministry of Education, Culture, Sports, Science and Technology, Japan: MEXT) was enforced. Since then, examples of inquiry activities, which are the result of the efforts of highly motivated biology teachers and researchers, have been provided in biology textbooks. In the textbooks that followed each CS which was revised in and after 1989 (MOE, 1989, 1999; MEXT, 2009), each chapter includes at least one inquiry activity. However, there are quite a few teachers who feel that most of these inquiry activities are time-consuming and/or high cost. Thus, these inquiry activities have not been implemented widely.

In the newly revised CS, which was announced in 2018 and will be enforced from the 2022 school year, active learning, *i.e.*, student-centered instruction, is emphasized (Nakamichi and Katayama 2018). Under the revised

CS, science teachers are asked to allow students to learn through inquiry activities much more than at the present time. Students are asked to study through a process of inquiry activities, *i.e.*, to have a question, to decide the key issue, to make a hypothesis, to design a research plan, to carry out experiments, to analyze and discuss the experimental results, to make a decision whether the hypothesis is acceptable, and to write a report to be submitted to the teacher or to be presented in the class.

Here, the author would like to provide an example of inquiry activities which is easily carried out in any upper secondary school.

INQUIRY INTO THE ONION

1. Which part of the onion do you eat?

The first part of this inquiry activity is composed of the teacher's question and an observation activity by students. The time required for this part is one school hour. At first, the teacher gives the students a question, "Which part of the onion do you eat: root, stem, leaf, flower or fruit?" Students are requested to give their answers with reasons.

The author gave this question to the seventh grade (lower secondary school) and the tenth grade (upper secondary school) students and university students. As shown in Figure 1, most of the students thought they eat the stem or root of the onion.

In Table 1 the major reasons they gave are listed. Some students who answered "root" might have been misled by the Japanese term "kyukon" for bulb ("kyu" means round-shaped and "kon" means root). After examining these reasons together, students observed the morphology of the onion bulb to confirm which answer is correct. The gap between student answers and the correct answer may foster student interests.

How can the teacher lead the students to the correct answer? One possible way to proceed is

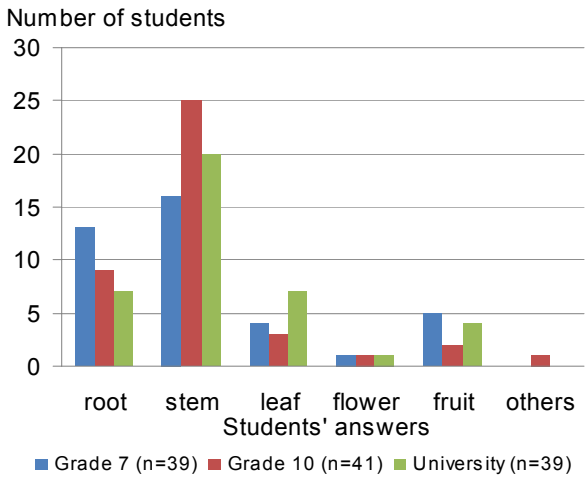

Figure 1: Results of student answers

Table 1: Major reasons of student judgements

Answer	Reasons
Root	➢ I have an image that onion bulb is under the ground and the plant part under the ground is root. ➢ There are green leaves and stems above the bulb. ➢ Onion bulbs resemble tulip bulbs and the Japanese term for bulb is "kyukon."
Stem	➢ The onion bulb is between the roots and leaves. ➢ It is above the root. ➢ There are leaves above it and roots below it. ➢ I learnt it when I was an elementary school child.
Leaf	➢ When we peel the onion bulb, the peeled part looks like a leaf. ➢ It seems to have leaves overlapping. ➢ It has the stem and the root at the bottom. ➢ I heard the onion bulb was composed of many leaves.
Flower	➢ The onion bulb has roots under it, so I think it will be a flower. ➢ It looks like a flower. ➢ Because it is multi-layered.
Fruit	➢ I guess the answer from its round shape. ➢ It has stems and leaves above, roots below, and no flower. Maybe, we eat the fruit. ➢ Because we eat it after peeling. ➢ We eat fruits. ➢ It is the result of elimination.

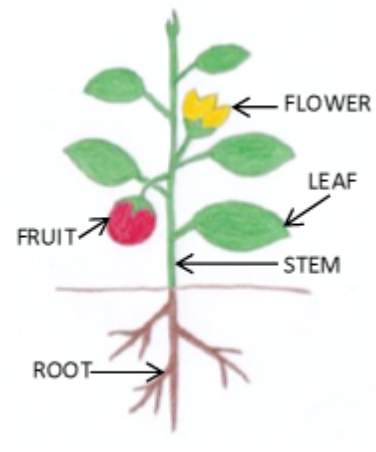

Figure 2: Basic morphology of a plant

Figure 3: Growing onions with onion heads

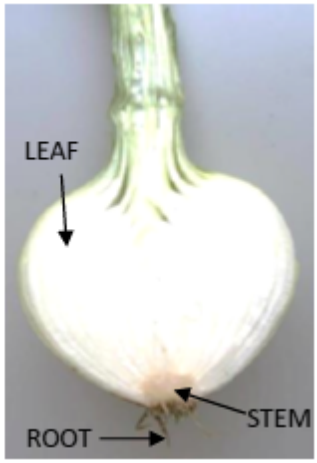

Figure 4: Longitudinal section of an onion bulb

as follows:

At first, let students recall the basic morphology of the plant, *i.e.*, roots, leaves and flowers (fruits) attach to the stem (Figure 2). Then, show a photograph of growing onions in a field (Figure 3), because most students have no experience of seeing onions grow. The teacher can point out that the onion head is a cluster of onion flowers. Figure 4 shows a longitudinal section of the onion bulb. Students can easily identify the roots in the figure. By careful observation, they can recognize that there is the stem above the roots. Since the edible part of the onion is the part attached to the stem, it can be understood that they are scale leaves. The morphology of the onion bulb can also be compared to cabbage or lettuce. The similarity of the morphology between the onion bulb and cabbage can be confirmed by cutting them in half longitudinally.

2. How does the onion bulb get bigger?

The second part of this inquiry activity is more challenging and needs two or three school hours. The teacher asks the students "How does the onion bulb get bigger?"

At first, students are asked to confirm the changes in the diameters of different parts (upper, middle and lower) of the onion bulb during its growth by using such pictures as shown in Figure 5.

Then, students need to continue the process of inquiry, which is composed of several sub-processes: making a hypothesis, designing an experiment or an observation activity, carrying out the experiment or making observations and collecting data, analyzing the results, and having a discussion on whether the hypothesis is acceptable. Students need logical thinking to analyze the data. It also requires the ability to make a decision on whether the hypothesis is supported by the results.

The inquiry activity may be organized in the following manner:

<u>(1) Making a hypothesis</u>

Students are asked to make a hypothesis ex-

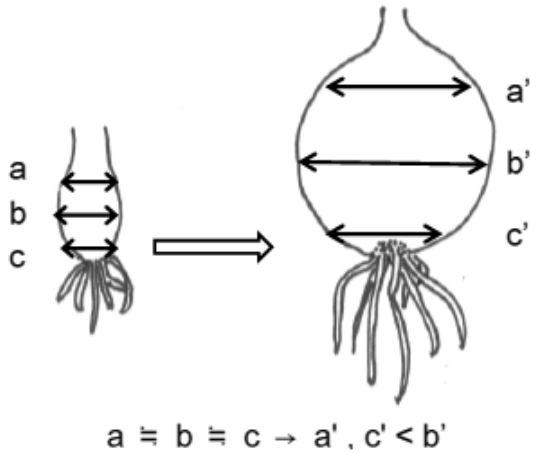

Figure 5: Growth pattern of the onion bulb

plaining the difference in the growth of different parts of the onion bulb. They may make various hypotheses; for example, focus on the size of epidermal cells, or on the number of scale leaves, or on the hypertrophic growth of cells, and so on. I would like to show two simple examples of hypotheses which are related to the cells of scale leaves.

Hypothesis (I): The size of cells changes.

Hypothesis (II): The number of cells changes.

(2) Designing an observation activity

Students are asked to design an observation activity to verify their answers. One approach to prove the hypotheses is to observe cells in different parts of an onion bulb and measure the size of cells in each part.

(3) Making observations and collecting data

(i) After removing the dry brown skin, cut the onion bulb into six or eight wedges.

(ii) Insert three toothpicks deeply into the upper (a), middle (b), and lower (c) areas of a wedge (Figure 6). Then remove the toothpicks. The remaining holes will mark the upper, middle, and lower areas.

(iii) Separate the wedges into three pieces: inner, intermediate, and outer. (Figure 7)

(iv) Take a small epidermal segment of inner (the abaxial) side from the three locations (upper, middle, lower) of each piece.

(v) Put the epidermal segment on a glass slide, add a drop of methylene blue solution, and seal it with a cover slip. Soak up excess solution.

(vi) Observe each specimen by microscope, take photographs, and measure the cell sizes. To find cell size, use a micrometer to measure the length of the long side and the short side of cells (Figure 8).

If a micrometer and a camera for the microscope are not available, students need to design another method of measurement. For example, the number of cells in a standardized area, such as the field of vision of the microscope, can be compared, and the camera function of a smartphone can be substituted for an ordinary camera.

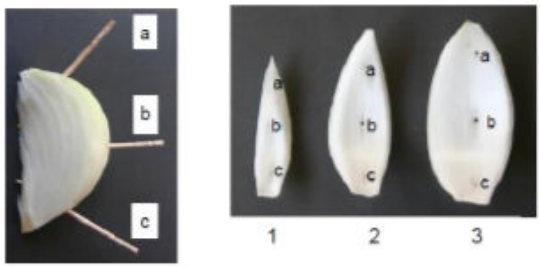

Figure 6 (right): Onion bulb wedge
Figure 7 (left): Scale leaves of onion bulb
1: inner leaf, 2: intermediate leaf, 3: outer leaf.

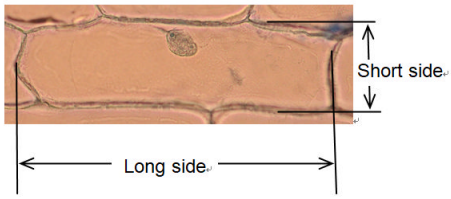

Figure 8: Measurement of the long side and the short side of a cell

(4) Analyzing the results

After collecting the data, students need to compile and tabulate the results of the observations in order to analyze the data. An example of the results that was collected from my own research is shown in Figure 9 and Table 2. In Table 2, each figure in the column of long side and short side is the average length for 10 cells. Cell size could be shown simply as the area of the cross section of each cell which is a product of the length of long side by the length of short side. If possible, it is better to analyze the results statistically. By calculating the standard deviation for each value, it becomes possible for students to consider variations in cell size at each location. Then, they can verify whether the difference of the values is significant.

From the data, one can understand the following:

* The cell size increases at every location from inner to outer.

* Within the same piece, the cell size at the middle

(location b) is the largest.

* At the lower area (location c), cell sizes show the least difference, and the length of the short side is the smallest and almost the same in all pieces.

(5) Having a discussion on whether the hypothesis is acceptable

By the microscopic observation, most students can notice the differences in cell size of different parts of the onion bulb. Then they have a discussion on the hypothesis they choose prior to beginning the observation activity.

From the results, students can come to see that hypothesis (I) is acceptable and hypothesis (II) is not acceptable. This well coincides with the findings of Aoba (1954) who reported that the enlargement of an onion bulb is caused by the increase in both the number of scale leaves and the thickness of each scale leaf. He mentioned that (i) the number of scale leaves increases during the bulb growing period, (ii) the number of scale leaf cells scarcely increases after the scale length comes up about 1 cm, and (iii) the thickness of

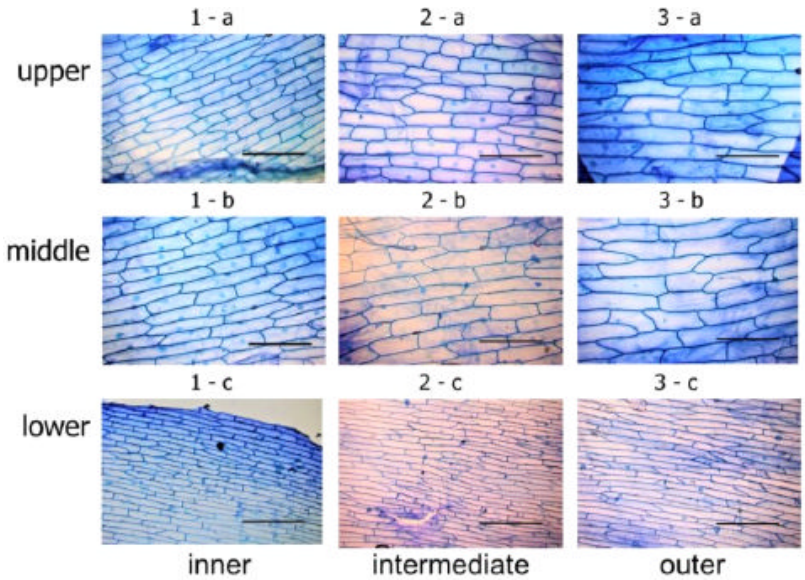

Figure 9: Epidermal tissue of onion scale leaf (Bars = 300 μm)

Table 2: Average of cell sizes at each area

Area of the wedge	Location*	Long side		Short side		Cell size (μm^2/100)
		Length (μm)	SD**	Length (μm)	SD**	
1 Inner	a	336	32.3	61	4.3	206
	b	377	94.8	78	6.7	294
	c	256	49.1	36	6.0	92
2 Intermediate	a	280	29.5	86	6.8	242
	b	382	95.1	93	6.4	354
	c	280	50.9	37	3.4	103
3 Outer	a	421	117.8	96	4.5	406
	b	437	109.9	110	6.6	481
	c	369	50.0	40	2.0	147

* a: upper, b: middle, c: lower
** SD: standard deviation

bulbs is caused solely by the enlargement of cells in scale leaves.

(6) Writing a report

At the end of the activity, each student is asked to write a report or give a report by oral or poster presentation. Students can use ICT to prepare the report so that this process may nurture the ability of expression in the students.

CONCLUDING REMARKS

The latest revision of the CS by the MEXT was carried out with the aim of preparing students for society in the 2030s when they will be adults. In the new era, people will live in an information-based society because of the development of techniques of AI (artificial intelligence), IoT (the internet of things), and so on. They will need to respond to different environments with intellectual flexibility. The teacher-centered teaching style cannot cultivate such abilities. MEXT advocates the importance of proactive, interactive and deep learning for living in the forthcoming society.

The inquiry activities described in this article will be helpful for nurturing the following abilities specified by MEXT.

* Through careful observations of natural phenomena, students will have lots of questions. By having a question which is the first step of scientific inquiry, students can cultivate a proactive attitude.
* Through experiments, students can foster the ability to understand things deeply.
* Through discussion, students can deepen their understanding and develop dialogue skills.

Inquiry activities would be valued more than ever, as these activities can help students develop the skills they must acquire for their future life. Teachers would be expected to introduce many more inquiry activities. I hope that the contents introduced in this article will encourage teachers to incorporate these activities into their lessons.

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