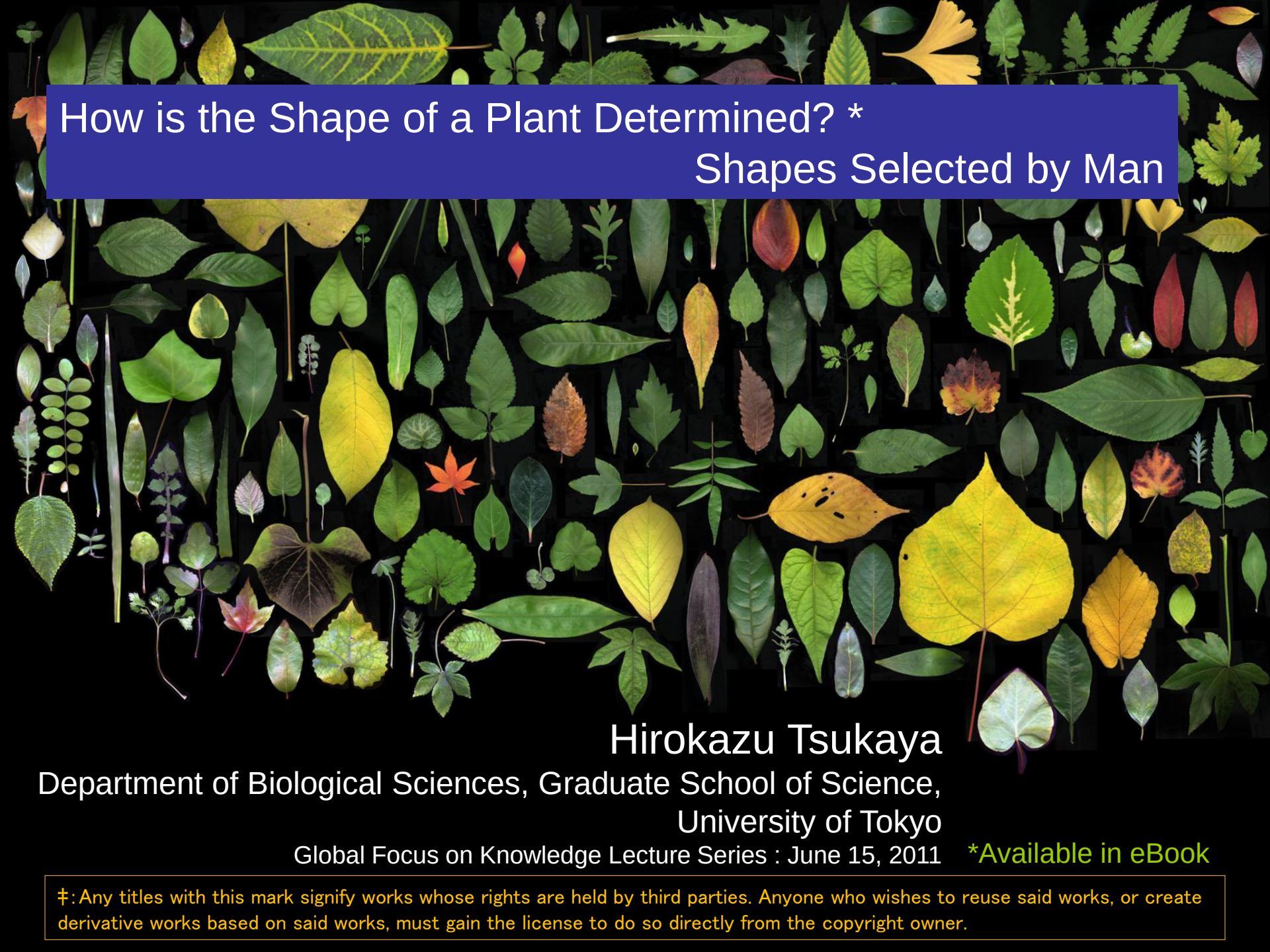

How is the Shape of a Plant Determined? *
Shapes Selected by Man

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Global Focus on Knowledge Lecture Series : June 15, 2011

*Available in eBook

The idea of “Natural Selection” constitutes the foundation of Darwin’s theory of evolution. The outcomes of artificial modification and artificial selection serve as pointers for this idea.

Today, let’s look at the process of artificial selection.

Before we begin, do you recognize this plant? I'm sure you do.

Bloem: 6—herfst. Wit scherm met aan elk schermpje driebladige, naar één kant hangende omwindseltjes, geen omwindsel. Vruchtjes eivormig (3 c vergr., 3 b bloem). V Kl.

Deze **vergiftige** plant kan licht verwisseld worden met de gewone **Pieterselie**, *Petroselínum satívum* (fig. 79), maar deze moesplant heeft een omwindsel en **geen omwindseltjes**.

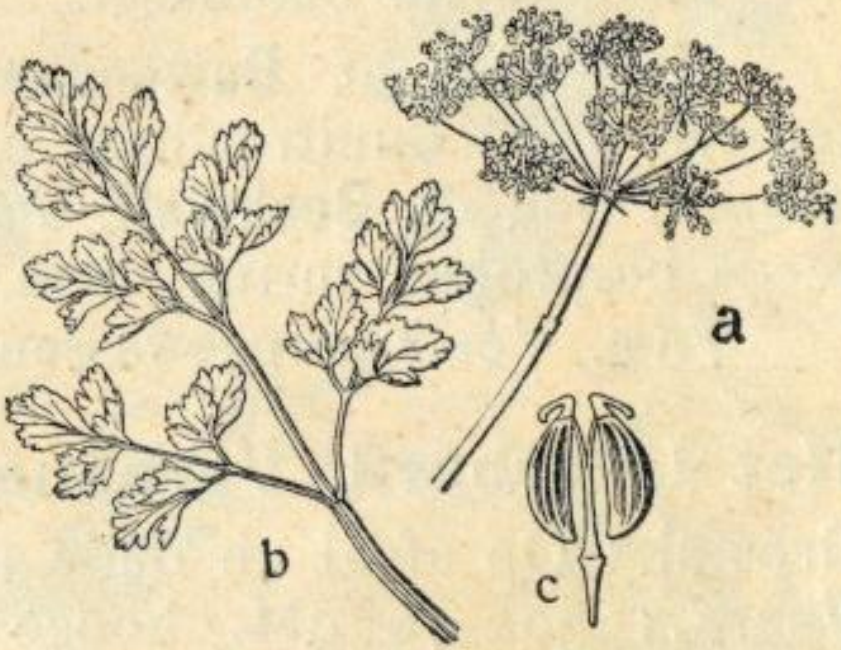

Fig. 79.

Fam. Schermgewassen. *Umbellíferae.*

‡ Buekers, P.G. 1956, Plantenboek, Zutphen: W.J. Thieme, p.103.

Incidentally,

Just last week I received an e-mail.

And the e-mail read,

“My name is XX. I am currently producing a TV program titled ‘XX Earth XX’ for XX television group. Please forgive this unexpected e-mail.

We plan to feature Mt. XX in our program and are now conducting research on the natural conditions at Mt. XX.
We’d like to ask Professor Tsukaya about flower petals and leaves: to be specific, how is the number of leaves determined?”

Incidentally,

What did he mean – “how is the number of leaves determined”?

So I picked up the telephone to find out.

“Good morning. Are you asking how the number of leaves is determined? To be honest, I’d say that the number of leaves is not specifically determined in any plant.”

After listening I understood that they wanted to know “why there are three parts in a clover leaf.” Hmm, the number of “leaflets”…?

“Well, I don’t think there is any particular reason, that is, it just happened to have three leaflets; it just happened to work out without difficulty, and there was no other form that worked better. Since there was no competition, it simply ended up having three leaflets, and remains so to this day.”

As you can see, television programs tend to rely on the concept of natural selection, or the “significance” of life forms, to explain the raison d’être of natural life forms.

Anyway, let's get back to this plant.

JULI. OP AFVAL EN RUIGTEN. 103

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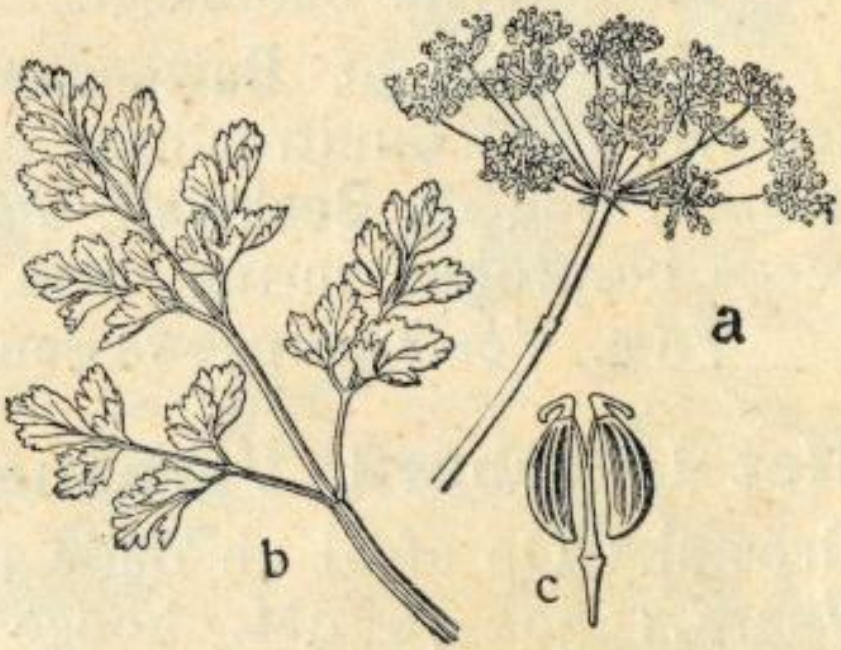

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Answer

Several years ago I had the following conversation regarding this particular plant.

One day, while working at the National Institute for Basic Biology in Okazaki, I received a phone call from a state-run broadcasting station, whose name I won't mention.

"Hello, we're going to talk about parsley in a program called XXX."

"Uh…OK."

"So, could you tell us why parsley leaves are shaped the way they are?"

"What do you mean by 'why'?"

"Well, there must be some advantage to being shaped the way they are."

As you can see, television programs tend to rely excessively on the concept of natural selection, or the "significance" of life forms, to explain the raison d'être of natural life forms.

I'm sure you see the answer: "There is no advantage. Man just happened to find and select a mutant plant."

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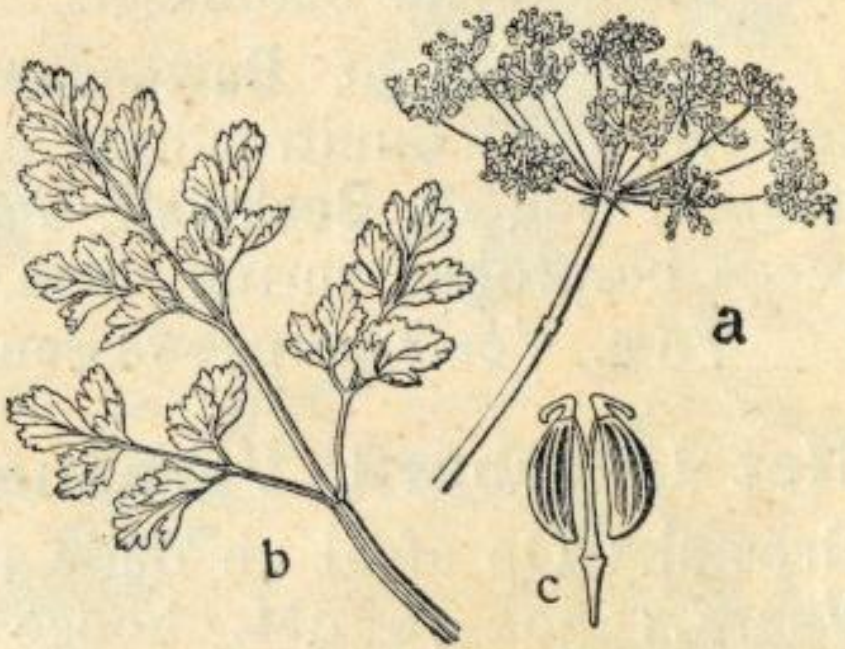

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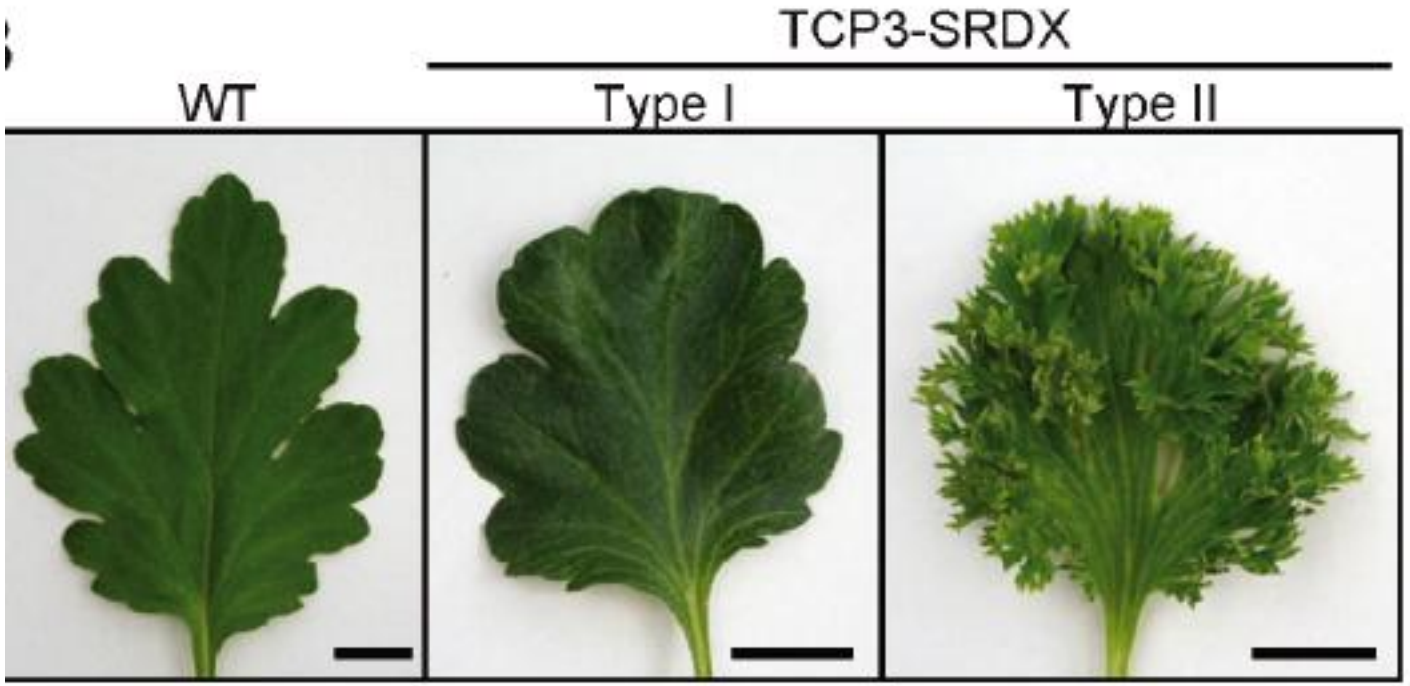
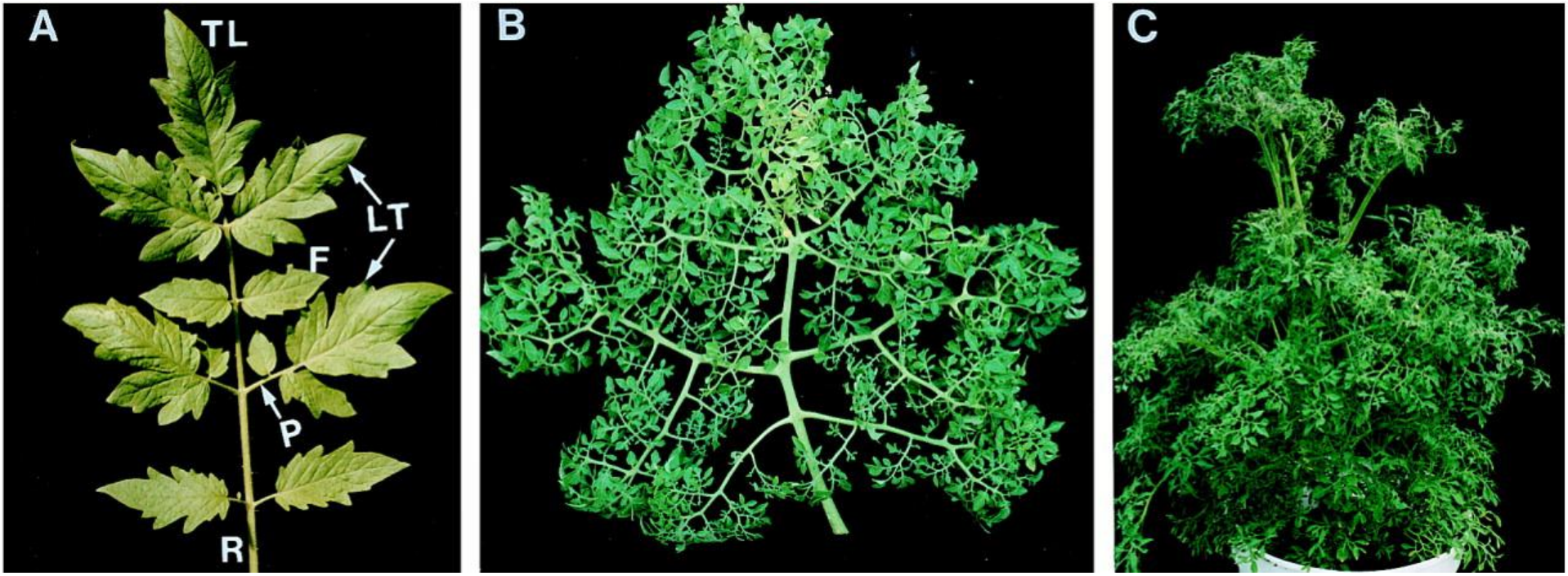
How do such mechanisms work?
1: By impairing the functions of the TCP genes in chrysanthemums, the edges of the leaves are reported to grow curly, like parsley.



‡ Narumi et al.(2011) Arabidopsis chimeric TCP3 repressor produces novel floral traits inTorenia fournieri and Chrysanthemum morifolium, *Plant Biotechnology*, 28(2):131-140 p.137 Fig.4(B)

How do such mechanisms work?
2: An over-expression of Class 1 homeobox genes in tomatoes is reported to transform compound leaves into fractal structures.

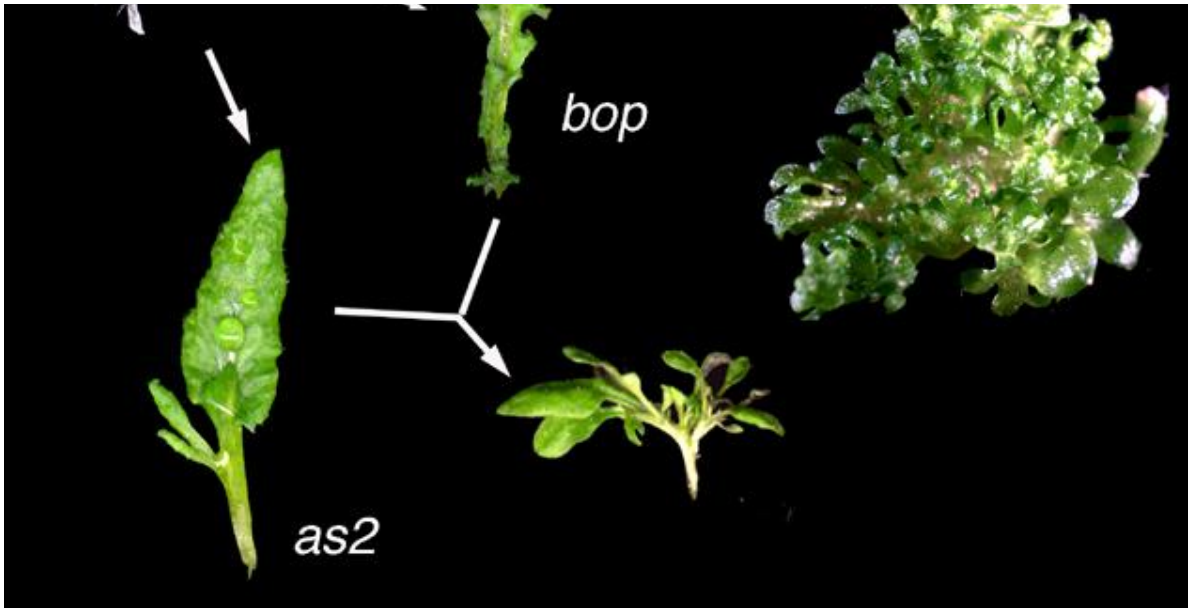


‡ Hareven et al. (1996) Cell 84(5): 735-744, courtesy of Eliezer Lifschits

(Tsukaya, H., "Kawaru Shokubutsugaku (Changing World of Botany)," p. 81, University of Tokyo Press)

3: In *Arabidopsis thaliana*, a plant used for experiments, similar shapes can also be created through genetic alteration in two genes.

Repeated morphogenesis + delayed growth arrest create these figures.



About *Arabidopsis thaliana*, the model plant:

Advantages of using *Arabidopsis thaliana* as a model system:

- The plant itself is small and allows easy homogeneous cultivation indoors.
- Its genome size is very small. (once deemed the smallest)
- Cultivation is easy. It can be grown under indoor fluorescent lighting.
- Its life cycle is short. (about 1.5 months)
- Genetic analysis is easy due to self-fertilization.

As a result:

- Its genome has already been deciphered. (130 million base pairs)
- International cooperation systems are well established. (genetic resource centers, properly maintained websites, annual international conferences)
- Researchers in the field are increasing and research is progressing.

My reply to the earlier mentioned state-run broadcasting station was that most crops or livestock we eat, or plants we admire, are not in their natural form; rather, they are mutants selected by man or the outcomes of repeated selective breeding. My reply seemed to come as a surprise.

Now that we think about it, selective breeding is seldom taught in compulsory education. This seems a bit strange, as it is one of the key ideas that led Darwin to the theory of evolution.

Ordinary roses like these above are actually the result of countless cases of breeding; the yellow hybrid tea rose is one such example.

As species related to the yellow rose already existed in nature, the change in color in this case was probably neutral. Color-variations seen in *Phelotrupes laevistriatus*, for example, may also have been generated from such neutral mutations.

It is true that blue roses are currently created through genetic modification, but these “genetically modified blue roses” are not your ordinary red roses turned blue. Through a long history of breeding, mauve roses are now commonly available, and these genetically modified “blue roses” are created merely by adding a bluish hue through gene transfer to readily-available mauve roses. With its brief history, genetic modification remains no match for the classical method of selective breeding, which has a long history and proven to be quite powerful.

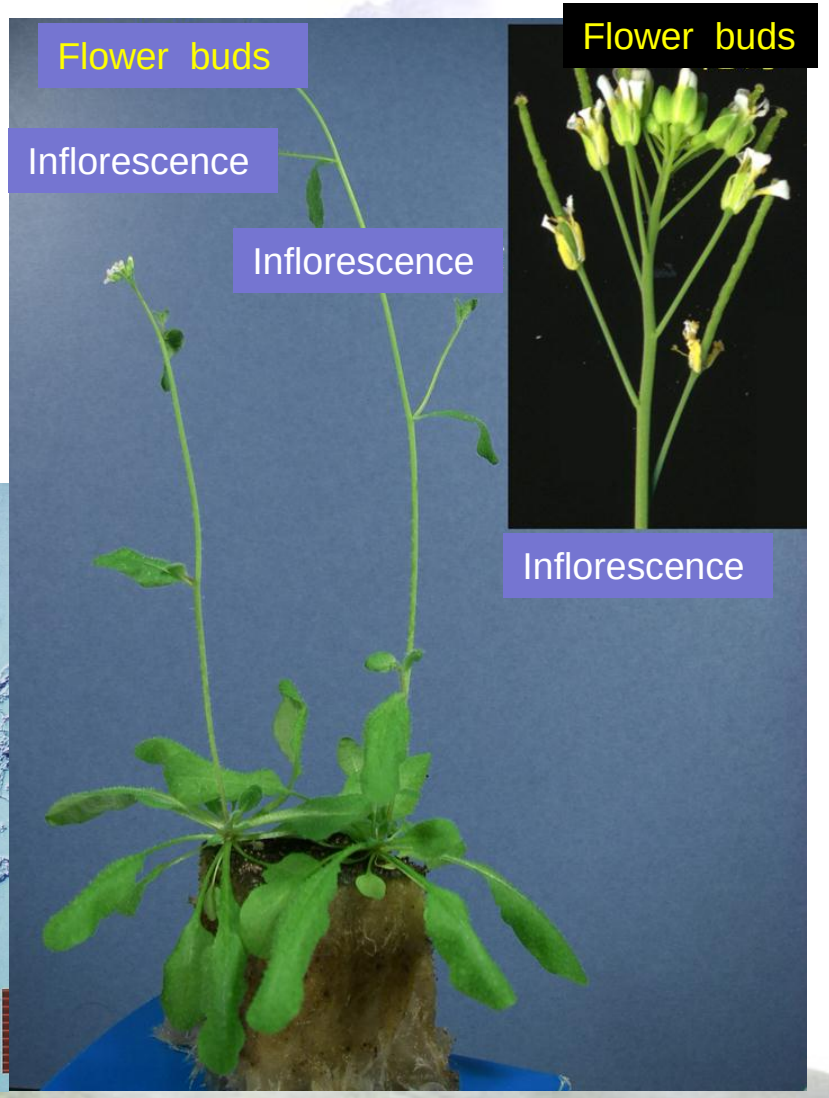
However, these “genetically modified blue carnations” (though they look more purple than blue) have a revolutionary hue unlike any in the history of selective breeding, which accounts for their large demand in the market.

Now, to the next theme:

Do you know which part of this plant we eat as a vegetable?
= >Q

About the cauliflower:

Normally, when flowers bloom on plants in the Brassicaceae family such as the cauliflower, the inflorescence from which the flower buds sprout forms first.



This is a developmental process that reflects the phase transition of the shoot apical meristem emanating from between the cotyledons.

In other words, it's all about transition – from the vegetative shoot phase (when leaves and stem are formed), the reproductive shoot phase (when branches for flower buds are formed) to the flower buds.

The mechanism:

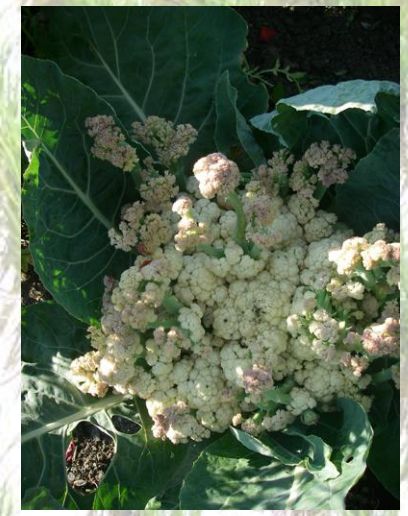
It is known that in order for the reproductive shoot to make its phase transition into flower buds in *Arabidopsis thaliana*, *AP1* and *CAL1* genes are needed. Once the functions of these two genes are impaired, the plant cannot move on from the reproductive shoot phase, thereby repeatedly generating inflorescence and creating a fractal structure.

As a matter of fact, in the cauliflower, inflorescence is formed over inflorescence in the place of flower buds in an endless cycle. Needless to say, the cauliflower is markedly mutant; it is inefficient in producing flower buds, which in turn leads to lower probabilities of leaving offspring in comparison to wild types, and this means it would not be able to continue its existence in the natural world on its own.

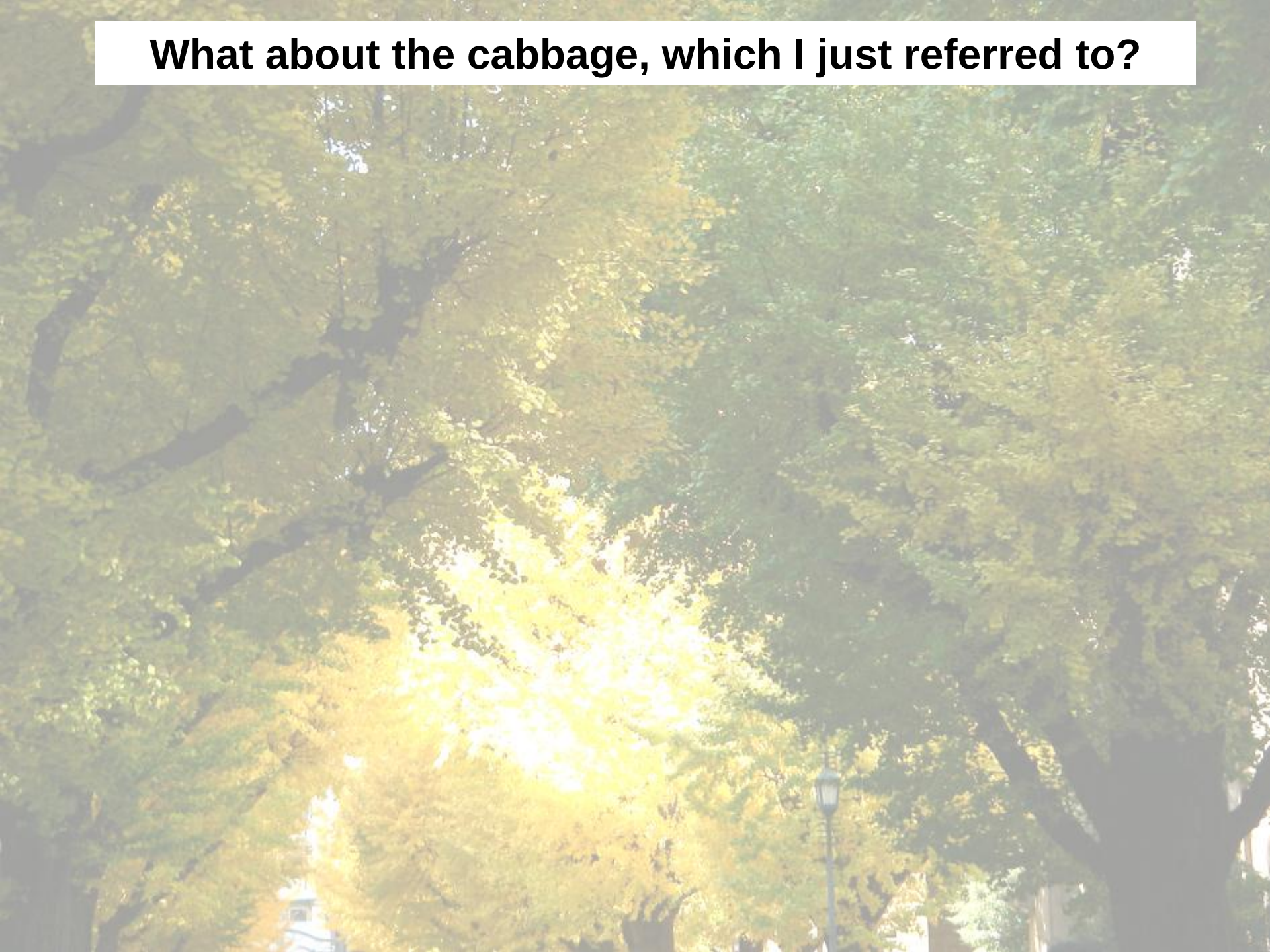
The mechanism:

A different type of edible plant that has no such abnormality is the kale, which belongs to the same species as the cabbage.
Broccoli is a plant with a modest degree of abnormality: you can see the flower buds.
Cauliflower is a plant with the most pronounced abnormality, supposedly the result of conducting selective breeding on broccoli.

In other words, the part of the plant that we eat as cauliflower consists of the inflorescence stem, the inflorescence meristem on top, and the structure partly transformed into flower buds.



What about the cabbage, which I just referred to?



The cabbage is the mutant among all mutants.

This is kale, which is an ancestor of the cabbage. The cabbage is a mutant of kale that was selected for eating.

Do you know this plant?
It's a species related to the cabbage. I'm sure you've eaten it.

The cabbage is the mutant among all mutants.

In addition,
there are
Brussels sprouts…

And new varieties…

Petite Verts

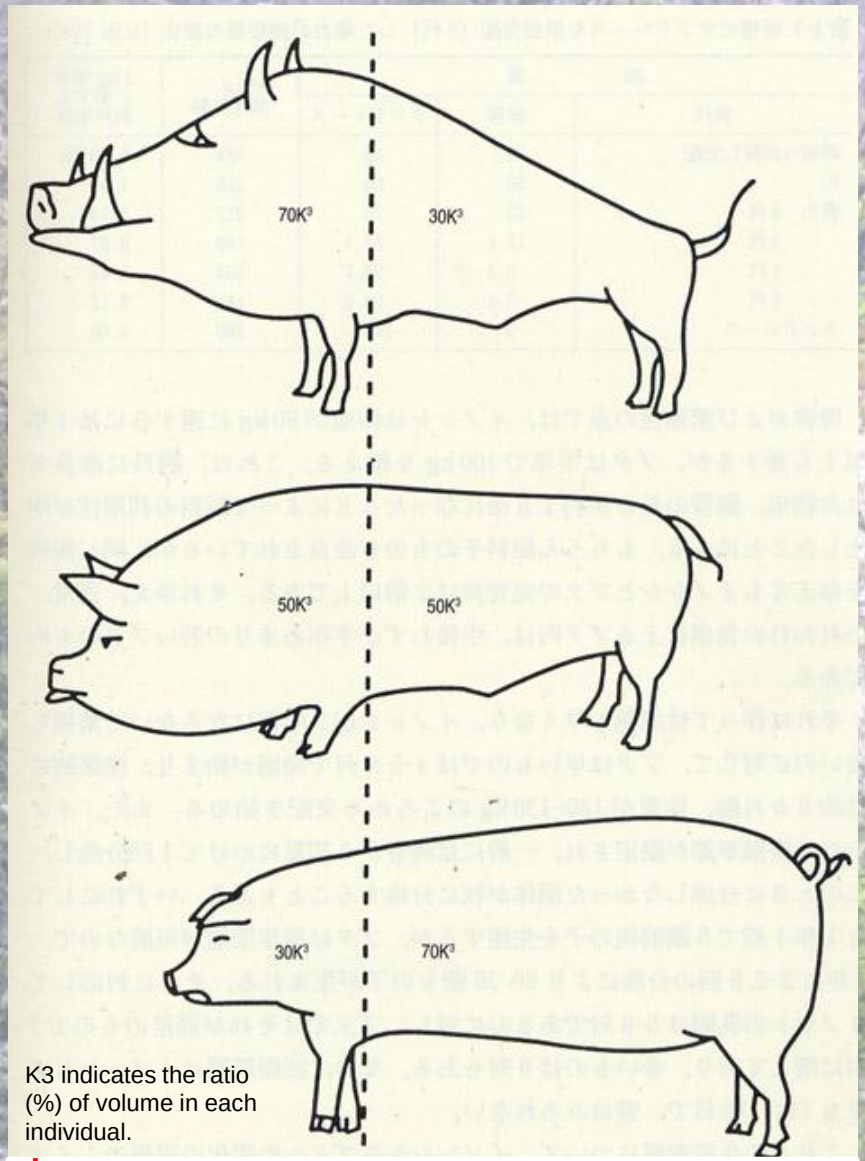
Curly Kale

Flowering Kale

There are many more food plants that are strange mutants, and many mutants among ornamental flowers as well.

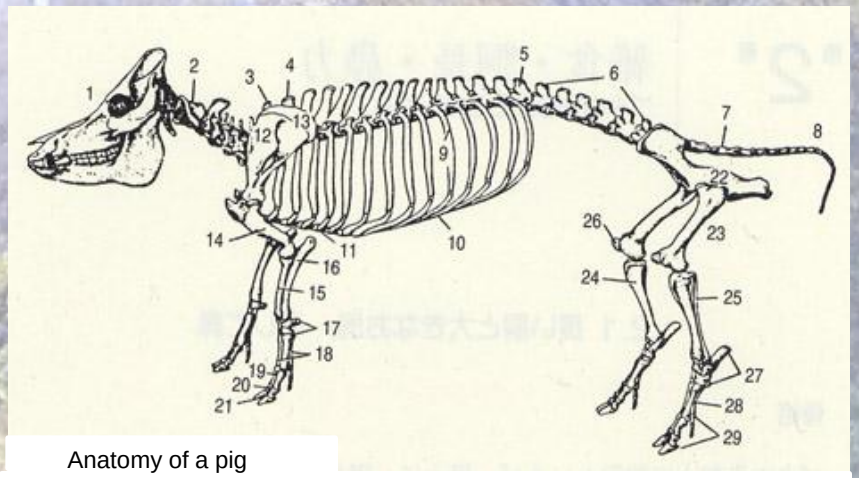
Wait a minute. Perhaps you think, oh, it's only about plants. True, you may not mind seeing mutations in plants, just as you don't feel guilty when you tear a leaf off a plant. Even so, you may hesitate if mutations are seen in animals. Selective breeding has long been conducted in some funny ways, as you can see in the case of goldfish or dogs. And that includes animals that are not pets…

Selective breeding of boars into pigs



K3 indicates the ratio (%) of volume in each individual.

‡ Edited by Yoichi Shoda, "*Hinshukairyo no Sekaishi / Kachiku Hen* (The World History of Selective Breeding / Livestock Edition)," p. 7, Yushokan, 1970



Anatomy of a pig

1: Cranium 2:Atlas 3: 7th cervical vertebra 4: 1st thoracic vertebra 5:14th thoracic vertebra 6:Lumbar vertebra 7:Sacrum 8:Coccyx 9:Rib 10:Costal cartilage 11:Sternum 12:Scapula 13:Scapula cartilage 14:Humerus 15:Radius 16:Ulna 17:Carpal 18:Metacarpal 19:Proximal phalanx 20:Intermediate phalanx 21:Distal phalanx 22:Coxal bone 23:Femur 24:Tibia 25:Fibula 26:Patella 27:Tarsus 28:Metatarsus 29:Pastern

‡ Yoshitaro Kato, "*Kachiku Hikaku Kaibo Zusetsu Zokaiteiban* (Illustrated Dictionary of Comparative Anatomy of Livestock, Revised Edition, p. 328, Yokendo, 2010

The combined number of thoracic and lumbar vertebrae were increased from 19 to 24. This is the result of selective breeding to increase the portion of spare ribs in each pig.

Now, based on your newly acquired understanding of selective breeding, please feel free to ask questions.

Are you uncomfortable eating genetically modified crops?

Genetically modified crops are also called Franken-crops. The term probably stems from the image that crops genetically modified by man are monsters which shouldn't exist in the natural world. Do you agree?

Are you averse to man creating crops and livestock with forms and qualities that otherwise would not be found in the natural world?

Do you feel uncomfortable eating such crops or livestock?

In any case,

It is a fact that life forms can “evolve” into considerably strange forms and qualities given strong selective pressure.

However, parsley, cabbage, and cauliflower were not purposely made into their current forms. The starting point lies in the fact that certain qualities, which just “happened” to be generated, “happened” to be taken up. Similar cases of mutation may also have arisen for other plants, but as it happened they were not taken up. Biologically speaking, we recognize such happenings as chance. However, the selective pressure that follows is applied in the direction of a certain goal, and its result is viewed as having been necessary.

In the world of nature, is the evolution of form similar to selective breeding? From the standpoint of the neutral theory, some suggest that many instances of evolution in the natural world are actually the result of neutral mutations that just happened to become fixed. In my next lecture, we’ll take a look at the adaptation of plant life forms in the natural world.