理数系教員授業力向上研修会（京都）
2018年7月8日（日） 京都テルサ

身近な事象や現象に注目して探究する「課題研究」の取り組み

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広島大学

SSH事業と課題研究

平成15年度から指定を受け、継続的に研究開発に取り組んでいる。
平成30年度から新たに第4期目の指定を受けている。

【第4期研究開発課題】

社会に開かれた科学技術を先導する人材育成の起点となる科学教育カリキュラムの開発

【研究仮説】

教育課程上に学校設定教科「SAGAs（探す）」を設置し、「課題研究」を中核とした科学教育カリキュラムを開発、実施することによって、科学的（Scientific）、高度かつ専門的（Academic）、国際的（Global）、主体的・自律的（Autonomous）な素養を備えた「Sagacity（（賢明な判断が下せる）洞察力，深い知性，先見の明）」を形成し、社会に開かれた科学技術（未来社会の創造に向けた科学技術イノベーション）を先導する人材を育成・輩出することができる。

SSH事業と課題研究

【研究開発の目的】

社会的変化が人間の予測を超えて加速度的に進展する大変革時代に、「社会に開かれた科学技術（未来社会の創造に向けた科学技術イノベーション）」を先導する人材を育成、輩出するために、その基盤となる能力「Sagacity」を形成する学校設定教科・科目を教育課程上に設置し、「課題研究」を中核とした科学教育カリキュラムを開発する。

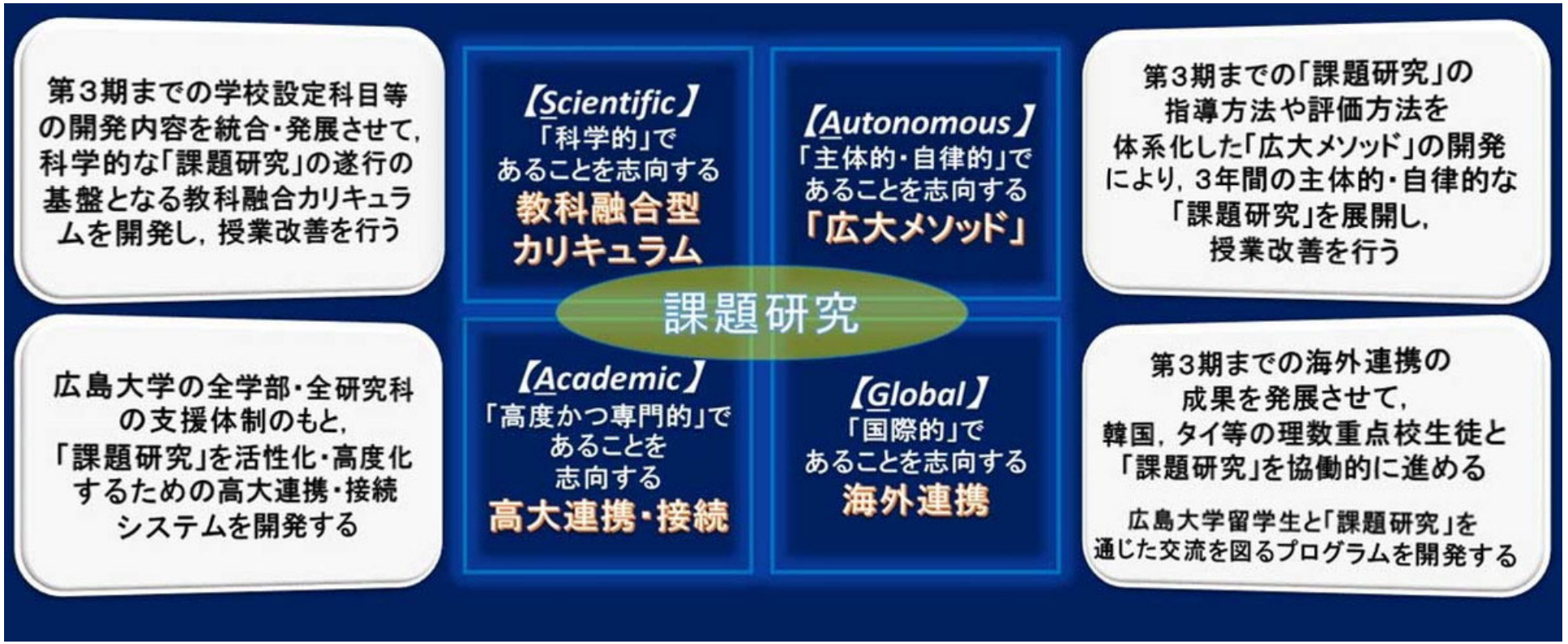
SSH事業と課題研究

【研究開発概念図】

SSH事業と課題研究

広島大学

【研究開発の内容】



SSH事業と課題研究

【学校設定教科「SAGAs（探す）」】

第2学年より普、通科5クラスのうち、1クラスをAS（Advanced Science）コース、4クラスをGS（General Science）コースとする。

新・学校設定教科「SAGAs（探す）」　第2学年より，普通科5クラスのうち，1クラスをASコース，4クラスをGSコースとする

	AS（Advanced Science）コース	GS（General Science）コース	SSHの4つの柱
3年	AS科学探究Ⅱ（1単位）	GS総合科学探究Ⅱ（1単位）	Scientific Autonomous S A Global Academic G A
2年	AS科学探究Ⅰ（2単位）	GS総合科学探究Ⅰ（2単位）	
	AS統計科学（1単位）	GS社会と統計（1単位）	Scientific Autonomous S A
	ASサイエンス・コミュニケーション（1単位）	GSクリティカル・コミュニケーション（1単位）	Scientific Global Autonomous S G A
1年	総合科学（2単位）		Scientific Academic Autonomous S A A

現高3生の課題研究テーマ

広島大学

分野	テーマ
物理	「マイクロバブルの効率的発生」 「心柱を科学する」
化学	「泡と洗浄能力の関係」 「アルギン酸樹脂の性質向上」 「シリカゲルの吸着性能について」
生物	「ゼブラフィッシュの嫌悪記憶とその解消について」 「身近なコケを用いた金属イオンの回収」
地学	「広島花崗岩中に見られる包有岩の形状と形成過程」
数学	「蚊柱の数理的モデリング」 「n stroke times～奇点と筆数の関係～」 「コインの行方」

Moss Recovering Metal Ions

Hiroshima University High School　Ann Hirota, Chiho Fujiwara, Haruka Muraoka, and Takako Kawamoto

Ⅰ　Early study (Nomura et al., 2014) : *Funaria hygrometrica can recover some metal ions such as lead ions.*

Ⅱ　Purpose : To prove that familiar kinds of moss (protonemata) which live in our school have the capability for recovering metal ions, and to apply to the technology of purifying polluted water.

Ⅲ　Methods :

(1)Identification
① Divided our school site into 43 parts
② Observed and identified the moss
→ 40 kinds of mosses and 4 kinds of hepatics

(2)Cultivation
・20 ℃and 24 hours light
・Agar culture medium ➡ 100 –fold dilution MS medium
・Liquid culture medium➡ 10 –fold dilution MS medium

(3)Experiments
① Put protonemata into $Cu(NO_3)_2$ aq ($5 \cdot 10^{-5}$ mol/L), then stirred it.
After that, measure the amount of substance of Cu^{2+} by titration with EDTA ($5 \cdot 10^{-5}$ mol/L).
② Conducted T-test ($p = 0.05$) on the difference in the amount of substance of Cu^{2+} between stock solution and solution after this experiment (Recovered quantity) by using Microsoft Excel.

Fig1. The protonemata of *Pogonatum neesii*

Ⅳ　Results and Discussion :

Preliminary Experiment 1
・Time : 2 minutes and every 1 minute, Fresh Weight : 1.000 g
Moss : *Funaria hygrometrica*

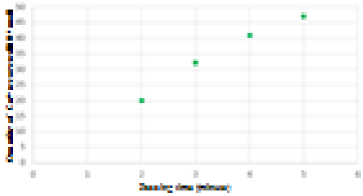


Fig2. Total quantity of Cu^{2+} recovered by *Funaria hygrometrica*

Statistically significant differences were observed between stock solution and each solution after this preliminary experiment.

The longer time is, the more recovered quantity increase.

Preliminary Experiment 2
・Time : 3 minutes, Fresh Weight : 0.015 g Moss : *Funaria hygrometrica*
・Time : 9 minutes, Fresh Weight : 0.016 g Moss : *Funaria hygrometrica*
・Time : 27 minutes, Fresh Weight : 0.011 g Moss : *Funaria hygrometrica*

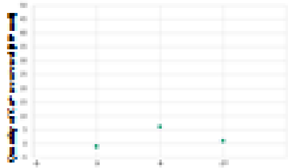


Fig3. Quantity of Cu^{2+} recovered by *Funaria hygrometrica*

Statistically significant differences were observed between stock solution and 9, 27 min solution after this preliminary experiment.

The weight of protonemata relates to recovered quantity.

Experiment 1 and 2 ; Time : 20 minutes, Dry weight : 0.002 g

Experiment 1　・Moss : *Pogonatum neesii*

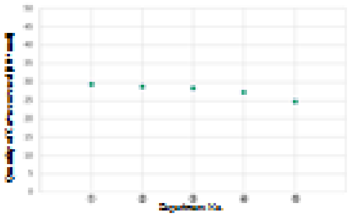


Fig4. Quantity of Cu^{2+} recovered by *Pogonatum neesii*

Statistically significant differences were observed between stock solution and each solution after this experiment.

***Pogonatum neesii* have Cu^{2+} capability for recovery.**

Experiment 2　・Moss : *Atrichum undulatum*

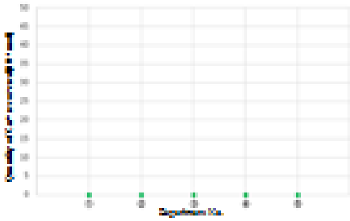


Fig5. Quantity of Cu^{2+} recovered by *Atrichum undulatum*

Statistically significant differences were not observed between stock solution and each solution after this experiment.

***Atrichum undulatum* don't have Cu^{2+} capability for recovery.**

Ⅴ　Conclusions :
① We succeeded in culturing 10 kinds of protonemata. *Pogonatum neesii* and *Atrichum undulatum* are suitable for cultivation.
② *Pogonatum neesii* and *Funaria hygrometrica* have Cu^{2+} capability for recovery, but *Atrichum undulatum* don't have it.

Ⅵ　Prospects :
① Search whether other species of moss have Cu^{2+} capability for recovery.
② Establish the method of titration Pb^{2+} to search about Pb^{2+} capability for recovery.
③ Find the most efficient combination of moss and metal ions that show capability for recovery from the results of experiments.
④ Observe the moss which recovered metal ions by electron microscope, and search the system of recovering them.

Ⅶ　References :

・Nomura Toshihisa et al. (2014), [illegible] Vol.22, No.2, p.126.
・[illegible] et al. (1987), [illegible]
・Nomura Toshihisa et al. (2011), [illegible]

Can we remove trauma from zebrafish ?

Hiroshima University High School　3rd Grade
ITO Haruki INOUE Maho , KAWAHARA Akari KURISU Shota SHODA Miyu HORIGUCHI Yusuke

PURPOSE

To find out what builds trauma in zebrafish, and how to get rid of it.

HYPOTHESIS

i. We can form trauma in zebrafish by giving them electric shock.
ii. We can remove the trauma by exposing the zebrafish to components of smell.

METHOD

- Main experiment
- Control experiment Ⅰ
- Control experiment Ⅱ

Figure1.Model of experimental water tank

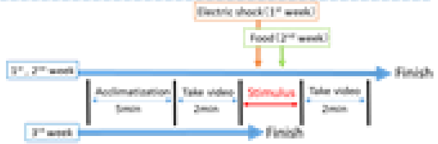


Figure2.Sequence of experiment

1st week 【5days】
・Give electric shock
・The control experiment Ⅱ electric shock

2nd week 【5days】
・Give components of smell
・The control experiment Ⅲ components of smell

3rd week 【5days】
・Observe without any manipulation

CONCLUSION

- We can instill trauma into zebrafish by electric shock.
- Components of smell may have a potential to promote the removal of trauma.

RESULTS

Table 1.Frequencies of zebrafish passing between copperplates in main experiment

	1	2	3	4	5	6	7	8	9	Ave.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Table 2.Frequencies of zebrafish passing between copperplates in control experimentⅠ

	1	2	3	4	5	6	7	8	9	Ave.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3.Frequencies of zebrafish passing between copperplates in control experimentⅡ

	1	2	3	4	5	6	7	8	9	Ave.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

※These tables show the frequencies of zebrafish passing between the copper plates in each week of the experiment.

Figure3.Changes in frequency

DISCUSSION

(1) Day1 1st week and Day2 2nd week
In main experiment
・・・A statistically significant difference ($p < 0.05$)
In control experiment Ⅰ
・・・No statistically significant difference ($p > 0.05$)

(2) (Day1 3rd week - Day1 1st week) in main experiment and in control experiment Ⅱ
・・・A statistically significant difference ($p < 0.05$)

- By giving electric shock, the number of passage decreased.
- The number of passage increased both in main experiment and control experiment Ⅱ .

PROSPECTS

Now , we are doing a new improved experiment.

<Improvements>

Before	After
Direct current	Alternating current
Battery	Power supply
Copperplate	Stainlessplate

Figure4.An apparatus of the new experiment

Analyze not only 5th day's video but also all day's video.
➡ Verify whether components of smell have a potential to promote the removal of trauma or not.

REFERENCES

- Yoshida, Masayuki "Measuring fear and anxiety in fish", Comparative physiology and biochemistry Vol. 28, 4, (2011) 217-225.
- Yoshihara, Yoshihiro,「匂いと行動、その関係をつなぐ」("Link between smell and motion"), RIKEN NEWS, 393, (2014).
- Hashimoto, Tsuruo, "An Experiment on the Performance of an Electric Fish Screen", Bulletin of the Japanese Society of Scientific Fisher's Vol.19, 1, (1953-1954), 23-30.

※These experiments were conducted following Hiroshima University Animal Experiment Guidelines.

The shape of inclusion in Hiroshima granite

Hiroshima University High School
Oda Kohei　Katayama Taro　Yamashita Shuhei

Abstract　The purpose of this study is to reveal the formation process of dark inclusions. Dark inclusions, which are contained in granites, are classified as a sort of xenolith. According to the research in Motoujina, they seemed to be ellipsoid. And the data on their numerical flatness shows that it falls within a certain value range. Judging from both mathematical inspection and the value, the shapes of dark inclusions are almost determined.

Background

(1) Hiroshima granite: Distributed in the south of Chugoku mountainous district, especially around Hiroshima city[1)]

(2) Dark Inclusion(DI):　・Mafic (including Mg and Fe)
・Dark mineral　・Seen in the granites　・Smaller grain[2)]
→ Its origin … **Not well known**

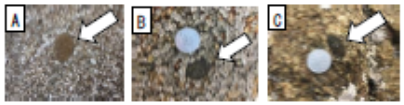


Fig.1 Dark Inclusions (The arrow points to DI.)

(3) Previous study:
・Tainosho(1984)[3)] … Conducting chemical analysis to reveal what chemicals compose DI
・Oshima et al.,(2016)[4)] … Finding DI in Ninoshima, Hiroshima, but its origin not solved

Purpose To Reveal how DI was formed
Hypothesis Shape: Ellipsoid

Fig.2 Location of Motoujina

Field Study In order to make clear the shape of DI
・Place: Motoujina …Tied island connecting to Hiroshima
Exposed Hiroshima granite, and rich in DI
・Way: Look for DI in outcrop → calculate flatness value
Result Histogram of Flatness Value (Fig.4)

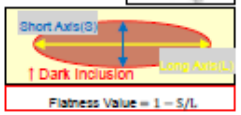
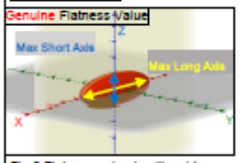


Fig.3 Flatness Value (Schema)

Consideration



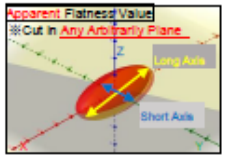


Fig.6 Flatness value in ellipsoid

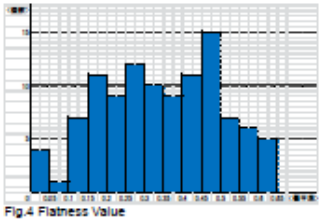


Fig.4 Flatness Value

Conclusion Shape of DI approaches to ellipsoid.

Prospect We are going to focus on the relation between DI and magma
・Conducting model experiment to examine direction of DI in magma
・Investigating geological features of Motoujina in detail, and comparing the distribution of DI

Reference

1) 猪木幸男ほか(1987)，日本の地質 7 中国地方，共立出版　2) 横本正樹ほか(2012)，フィールドジオロジー8 火成作用，共立出版
3) 田結庄良昭(1984)，「茨木複合花崗岩体の暗色包有物」，岩石鉱物鉱床学会誌
4) 大島時雄ほか(2016)，「広島市似島に分布する広島花崗岩類の形成プロセスの解明」課題研究論文集 11，広島大学附属高等学校
5) 渡村権(1989)，日曜の地学 7 広島の地質をめぐって 増補版，築地書館

Where does a dropped coin go?

Hiroshima University High School
TAKASHIMA Akihiro, SASAKI Kokoro, SUGIYAMA Hironobu

Abstract

We have been studying about where a dropped coin goes. The method was that we changed the situation how to drop a coin, and then we dropped a coin 400 times in each situation and took data. We found two things. One is that a dropped coin is more likely to go in the direction which is vertical to the face of a coin. The other is that when we drop a coin from a vertical position, it is more likely to stop at two points, but when we drop it from a horizontal position, the result varied as the height changed.

Motive

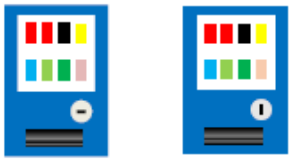


Fig.1 Two types of vending machine

Purpose

・find where a dropped coin is more likely to stop

Method

1. Draw a large ellipse
2. Move shrunk ellipse on the x-y plane
3. Find the central point of the ellipse in which it has the most number of points
4. Change the area of ellipse and repeat 2 and 3

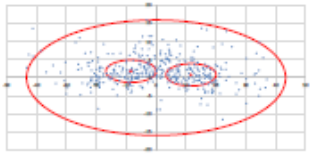


Fig.2 From a vertical position, 0.5 m

Result

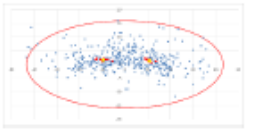


Fig.3-1 From a vertical position, 0.5 m

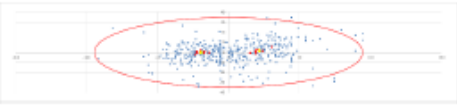


Fig.3-2 From a vertical position, 1.0 m

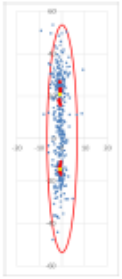


Fig.4-1 From a horizontal position, 0.5 m

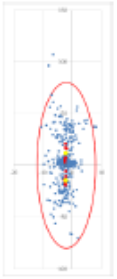


Fig.4-2 From a horizontal position, 1.0 m

Consideration

・form an ellipse
・vertical → two points
・horizontal
→ vary with height

Prospect

・quantify
・horizontal →
the relationship between the number of rotations and the height

Mathematical Analysis of Novels

Hiroshima University High School Second Grade Mathematical research team
Chiharu Kagemoto Nana Tanaka Ayano Fukamizu Natsuki Miyake

▽Motive

We thought that more novels which are easy to read are written recently than early 20th century. Then in this study we will research about characteristics of easy-to-read novels by some mathematical approaches.

▽Heads

- •Ratio of Appearance of Hiragana
- •Ratio of Appearance of Conversation
- •Average Between Punctuation Marks
- •Average Letters of Conversation
- •Average Letters of Paragraph
- •Length of Sentences
- •Letters Between Kanji

▽Objects of Analysis

	Title	Author	Genre
Present Novels	[illegible]	[illegible]	Third person
	[illegible]	[illegible]	
	[illegible]	[illegible]	
	[illegible]	[illegible]	First person
	[illegible]	[illegible]	
Modern Novels	[illegible]	[illegible]	Third person
	[illegible]	[illegible]	First person
	[illegible]	[illegible]	

▽How to Analysis

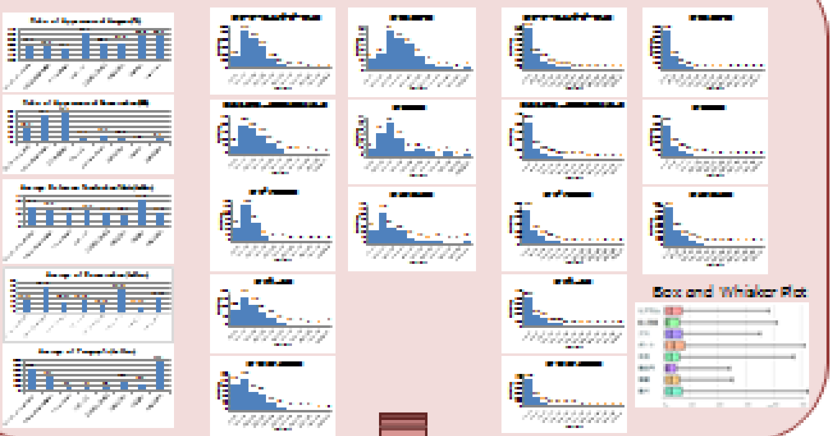
- Digitize these novels
- Count with seven points above

Make some questionnaires by the conclusion of counting
Count the answers of questionnaires and analyze the conclusion by each points

In reality, which is 「easier to read」, recently novels or early 20th century's novels?

▽Result

Length of sentences(Letters) Letters Between Kanji(Letters)



▽Consideration

[illegible]

▽On Questionnaires

[illegible]

▽Prospect

[illegible]

Analysis of Novels Using Statistics

Hiroshima University High School Second Grade Mathematical research team
Chiharu Kagemoto Nana Tanaka Ayano Fukamizu Natsuki Miyake

▽Motive

Akutagawa Ryunosuke Prize and Naoki Sanjugo Prize are ones of the most famous novel prizes in Japan.

It is said there are some differences between these, but those differences are so ambiguous that there have been some discussion about them.

We will examine novels which won these prizes to define the characteristics through mathematical approaches.

▽Hypothesis

- •Ratio of appearance of hiragana
  Akutagawa's standard deviation> Naoki's
- •Ratio of appearance of conversation
  Naoki's average> Akutagawa's
- •Average between punctuation marks
  It reflects author's characteristics clearly
- •Average letters of conversation
  Naoki's average> Akutagawa's
- •Length of sentences
  Naoki's average> Akutagawa's
- •Average letters between kanji
  Akutagawa's standard deviation>Naoki's
- •Amount of blanks per page
  Akutagawa's standard deviation>Naoki's

▽Objects of Analysis

	Title	Author	Winning Year
Akutagawa Prize	①Nonki megane	Kazuo Ozaki	1937
	②Shinobukawa	Tetsurou Miura	1960
	③Sutiru-raifu	Natsuki Ikezawa	1987
	④Kuma no shikiishi	Toshiyuki Horie	2000
Naoki Prize	⑤Jinsei no aho	Takatarou Kigi	1936
	⑥Sakuran	Shotarou Ikenami	1960
	⑦Soul Music Lovers Only	Eimi Yamada	1987
	⑧Niji no tani no gogatsu	Yoichi Funado	2000

We use about 20,000 letters from each books.
※If the books originally have less than 20,000 letters, we use the whole text.

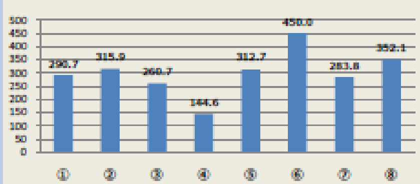
▽Consideration

●Ratio of appearance of conversation
Naoki's standard deviation > Akutagawa's

●Average between punctuation marks
Akutagawa's average
&
Akutagawa's standard deviation
>the other

※Data of ⑥『Sakuran』 are excluded because they are outlier.

Amount of blanks per page (Letters)



●Length of sentences
・Akutagawa's average > Naoki's
・Naoki's standard deviation > Akutagawa's
※Data of ④『Kuma no shikiishi』 are excluded because they are outlier.

●Average letters between kanji
Average & standard deviation
→No differences(≒the other)
Average of largest number
&
Standard deviation of largest number
→Akutagawa's > Naoki's
＝Akutagawa's books tend to use hiragana, not kanji for nouns and adjectives

●Amount of blanks per page
・Naoki's average > Akutagawa's
・Akutagawa's standard deviation > Naoki's
=Naoki's books have shorter paragraph.

▽Conclusion

Six items are characterized by the differences of each prize: ratio of appearance of hiragana, Ratio of appearance of conversation, average between punctuation marks, length of sentences, average letters between kanji, and amount of blanks per page.

Akutagawa Prize
Tend not to use period; longer sentences; Tend to use Hiragana for noun and adjective intentionally

Naoki Prize
Various styles in conversation; shorter paragraphs

For Better Meringue, How to Whip Egg White

Yuri Amakawa

Tomoka Nogami

Sora Hirokane

Hazuki Miyake

Ryo Yamasaki

What is Meringue?

Meringue

- Cake
- Cookie

Making good meringue is... Difficult!

It takes a long TIME...

It returns to liquid...

?

1. Salt

2. Sugar

3. Citric acid

4. Soda

If you want to know the answer...

Please come to our poster!!

For Better Meringue, How to Whip an Egg White

Hiroshima University High School Science Club 2nd grade

Yuri Amakawa Tomoka Nogami Sora Hirokane Hazuki Miyake Ryo Yamasaki

Purpose of the Study

①To clarify how conditions affect the quality of meringue and the cause of the change

②To discover the best way to whip egg white for better meringue

Quality → Foaming Property / Stability

Condition

・Cold or Frozen ・New or Old

・Additive(Salt/Sugar/Citric Acid/Soda/None)

Figure1 Egg white after whipping

Conclusion

1. Add a little ACID, such as citric acid and lemon juice for well-foaming meringue
2. Add NOTHING for stable meringue
3. DO NOT add ELECTROLYTE like salt

Pre-Experiment

○Foaming Property

Whip egg white for 90 sec and measure the volume of the meringue.

<Result & Consideration>

①The best : Citric acid → Effect caused by pH

②Cold ＞ Frozen

○Stability

Measure the amount of liquid separated from meringue 1 hour later.

<Result & Consideration>

Separated Liquid Citric acid ＞ Salt ＞ Soda ＞ Sugar ≒ None

⇩ Little separated liquid＝Good Stability

Stability None ≒ Sugar＞ Soda ＞ Salt ＞ Citric acid

→Influence of **Electrolyte**

①pH

②Electrolyte

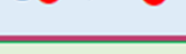
affect Foaming Property and Stability

→Advanced experiment on these conditions

Electrolyte = Ion in egg white

→Measure the amount of ion

Ionic Strength ⇧ = Ion ⇧



Main Experiment

○Foaming Property

Effect of electrolyte and pH on the density of whipped egg white

pH4 → Smaller density

Figure2 pH and density

More salt → Larger density

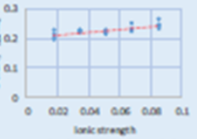


Figure3 Ionic strength and density

○Stability

Measure the amount of liquid separated from meringue 1 hour later

Smaller pH → More liquid

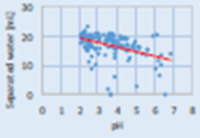


Figure4 pH and liquid

More salt → More liquid

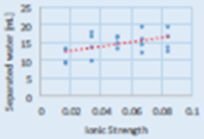


Figure5 Ionic strength and liquid

Consideration

①Foaming Property

・Ionic Strength⇧ → Foaming Property⇩(density⇧)

(Correlation Coefficient・・・0.39)

・Around ~~pH4~~ → Foaming Property **MAX**

↳ Isoelectric Point of Ovalbumin

②Stability

・Ionic Strength ⇧ → Stability ⇩

(Correlation Coefficient・・・0.47)

・pH ⇩ → Stability ⇩

(Correlation Coefficient・・・-0.61)

Protein attaches with each other → Foaming Property ⇧

References

・小山静郁, 植田志摩子 「卵白の起泡力および安定度について」, 帯広大谷短期大学紀要28, 63-68, 1991

・土井悦四郎 「食品タンパク質の加工特性に関する研究」, 日本食品工業学会誌39(12), 1163-1169, 1992

・中村良,佐藤泰 「鶏卵卵白の泡立ちに関する研究」, 日本農芸化学会誌35(4),385－390, 1961

数理モデリングの例

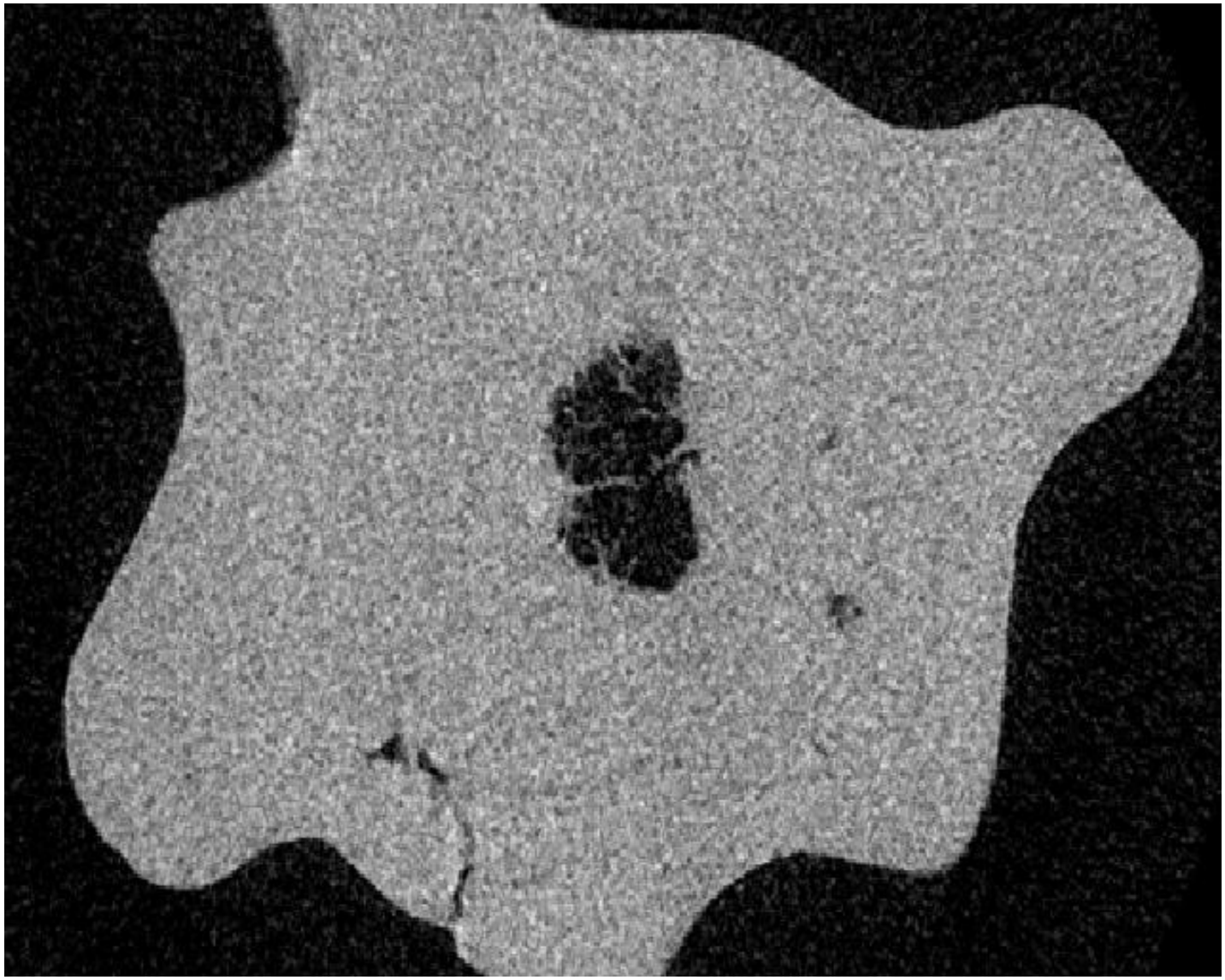
金平糖の数理モデリング

広島大学附属高等学校

井野口光宏　鈴木蓮　北村晃成
川野達也　小方智景　藤岡真由

金平糖の作り方

(金平糖の作り方 エビス堂製菓
http://www.ebisudoseika.co.jp/hpgen/HPB/entries/11.htmlより引用）



↑エックス線CTによる金平糖の断片写真

（宮城新聞　科学ってそもそも何だろう？より引用）

研究目的

- 金平糖の突起部分を角と定め，金平糖が形成されるメカニズムを解明し，それを数理モデルで表す

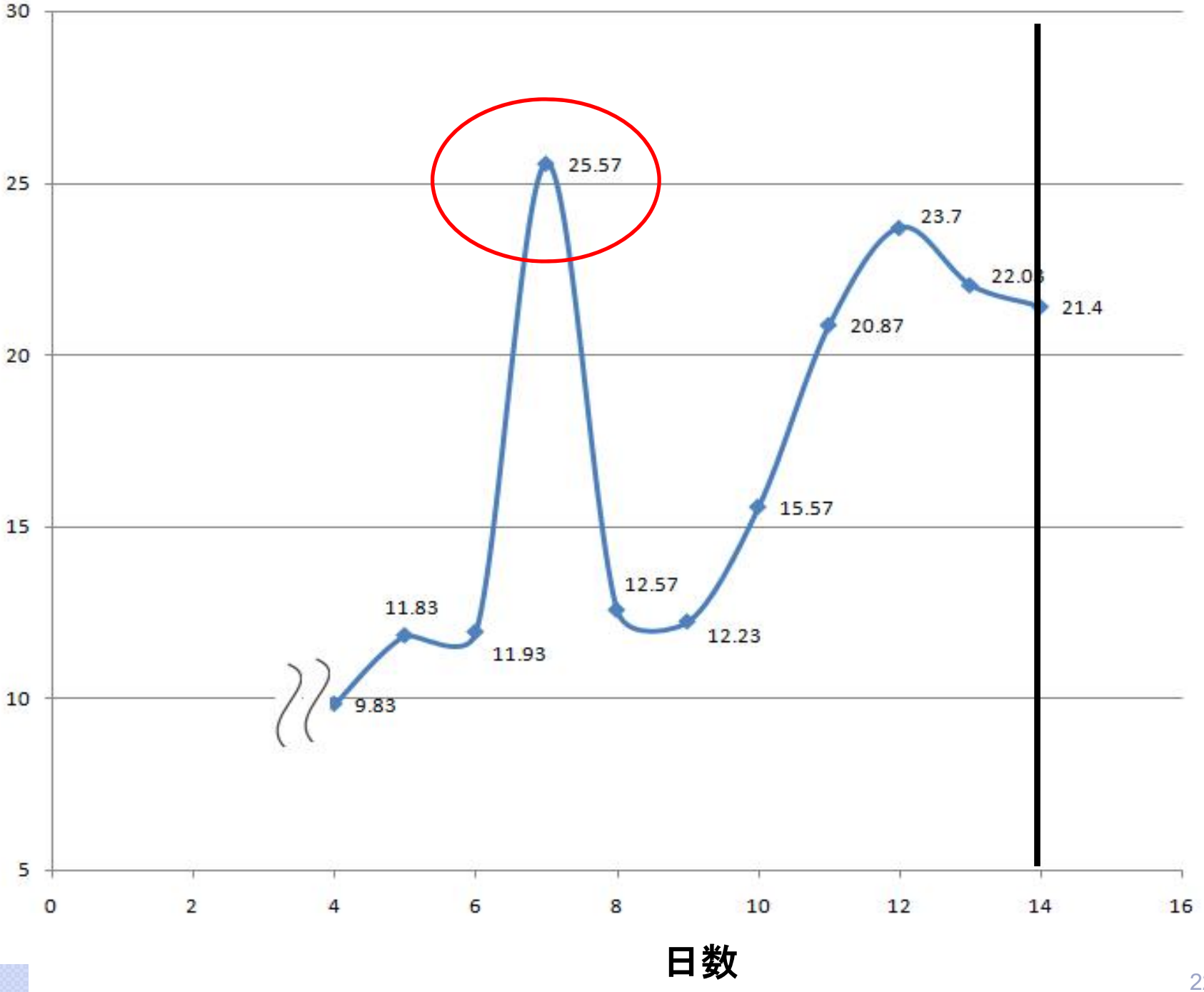
角

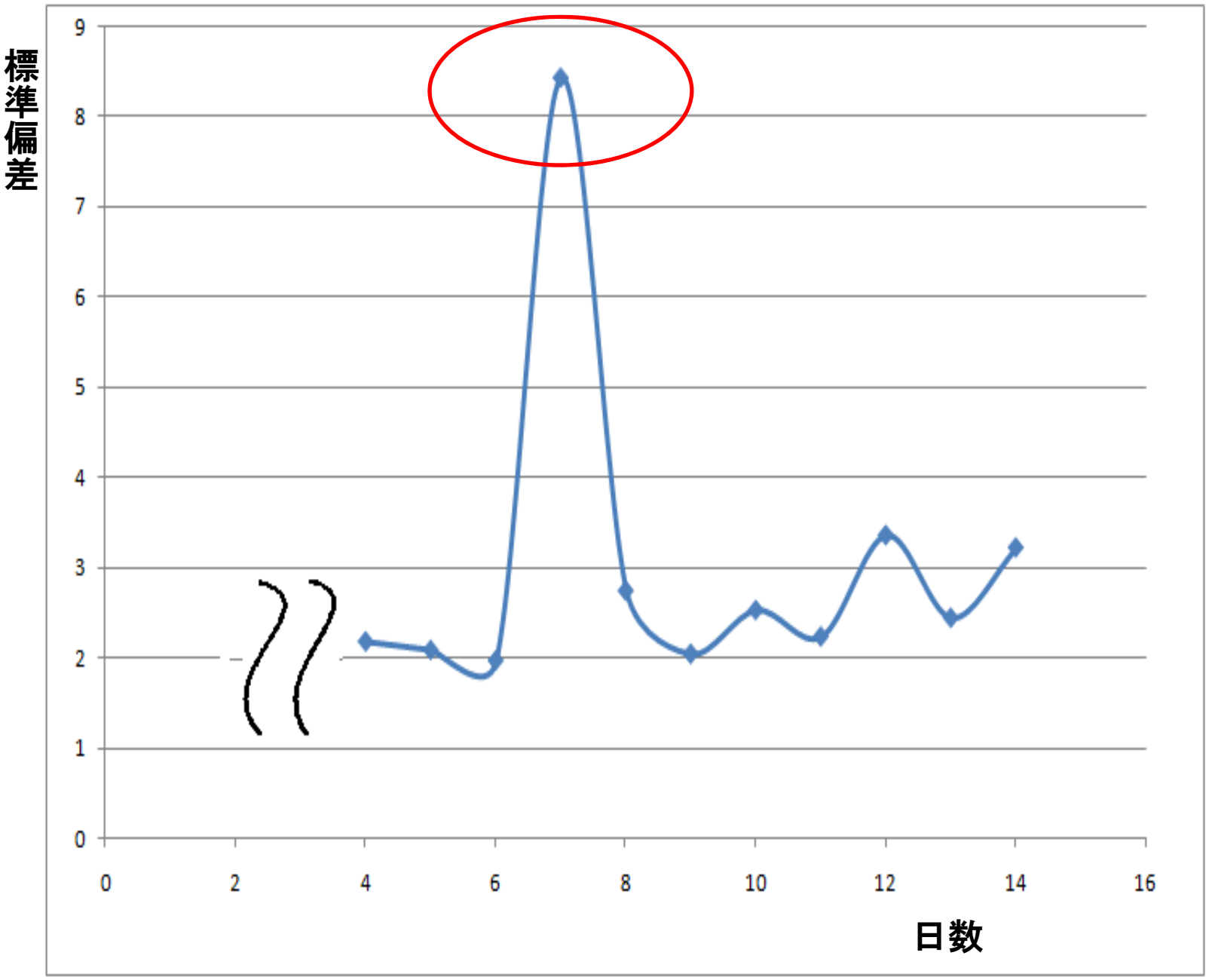
予備実験

1 金平糖を顕微鏡、書画カメラを用いて観察する

2 作り始めからの日数ごとに分け、
角の個数を数えて30個の金平糖の
平均値、標準偏差を算出する

金平糖一つ当たりの角の数




標準偏差
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
16
日数

(A) (B) (C)

(A)ぶつかってくずれた金平糖

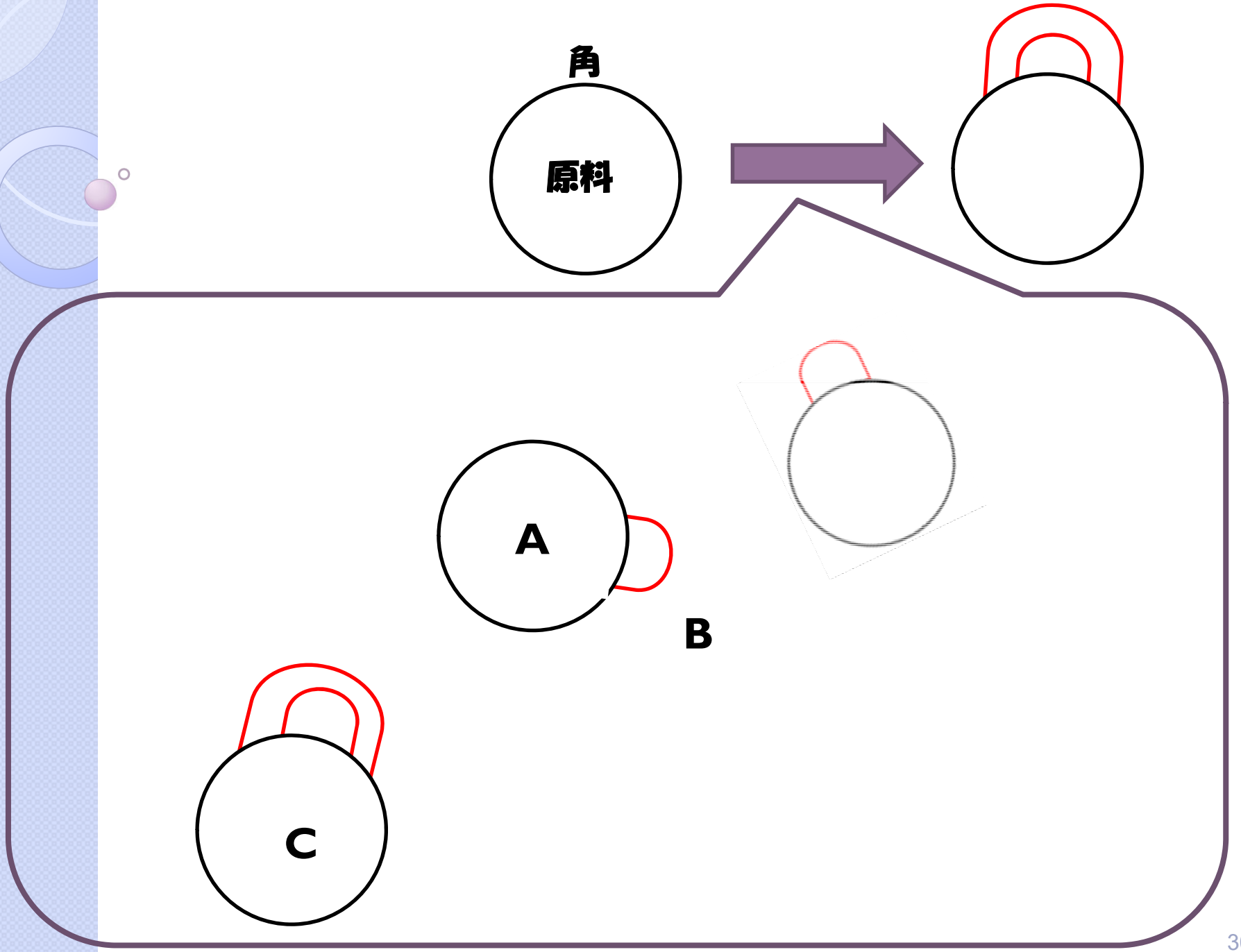
(B)くずれることなく順調に成長した金平糖

(C)ぶつかってくずれた金平糖と結合した金平糖

(A) (B) (C)

<8日目>
くずれることなく順調に成長した金平糖は、ぶつかってくずれた金平糖とくっつき、小さな角どうしが溶けて結合して大きくなる。

7,8日目の考察をふまえると…


角
原料
A
B
C

研究内容

1　金平糖の角のでき方について確率を用いて
自分たちでルールを定める

2　そのルールに従ってExcelで
シミュレーションを行い、
結果をレーダー上にプロットし、
実際の金平糖の断面と比較する

角の形成過程に関する仮説

（早川・酒井，2007より）
・突起の高さが高いほど粒子がつきやすい

（予備実験より）
・隣の地点とある程度の高低差がつくと
角が崩壊する

シミュレーションを行う上での仮定

- 中心となる核、実際の金平糖でいう
  ザラメ糖にあたる部分を円と仮定する

- その円の辺をN等分した点上に
  結晶化した糖蜜、すなわち突起が付く

シミュレーションに用いた数式

$a_n(t)$:時刻ｔ、地点ｎにおける重なった突起の高さ

$$P_n(t)=\frac{a_n(t)}{\sum_{i=1}^{n} a_i(t)}\times k$$

$$a_n(t+1)=\begin{cases} a_n(t)+1 & (P_n(t)>Q_n(t)) \\ a_n(t) & (P_n(t)\leqq Q_n(t)) \end{cases}$$

$Q_n(t)$: 0～1までを0.01刻みでランダムに1つ発生させた数

A

地点N / 時刻t		A	B	C
t-1		12	16	13
t				
t+1				

t-1のときすべての地点についた粒子の合計が648個だとすると

突起の高さが高いほど新たな粒子がつきやすい

ひとつ前の時間での高さが、粒子のつきやすさに対応する

B

地点N / 時刻t		A	B	C
t-1				
t		$\frac{12}{648}$	$\frac{16}{648}$	$\frac{13}{648}$
t+1				

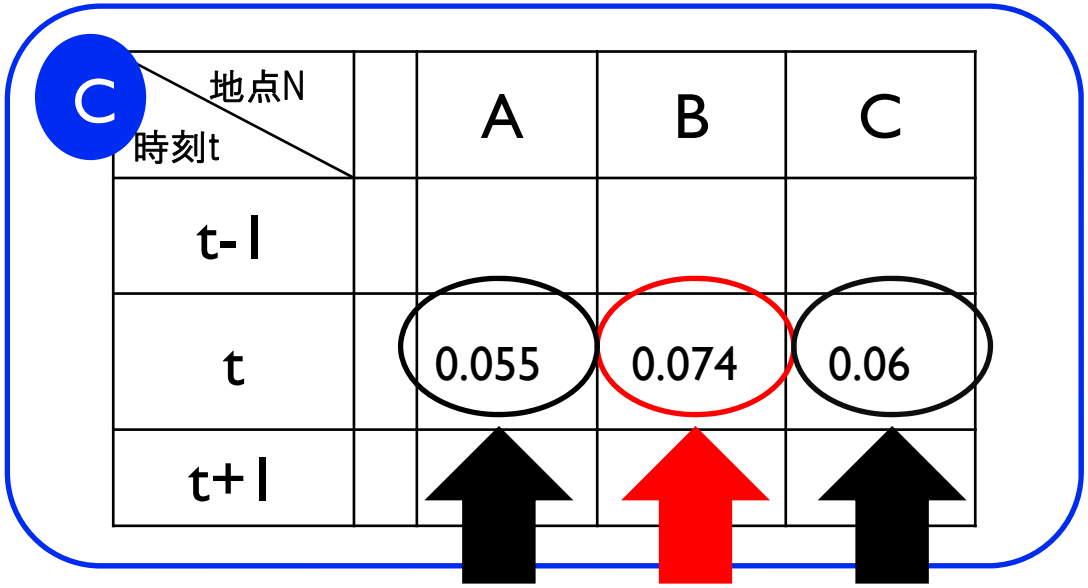
B

地点N / 時刻t		A	B	C
t-1				
t		$\frac{12}{648}$	$\frac{16}{648}$	$\frac{13}{648}$
t+1				

1単位時間に付くと期待できる粒子の数(=k)をかける
この場合はk=3なので

C

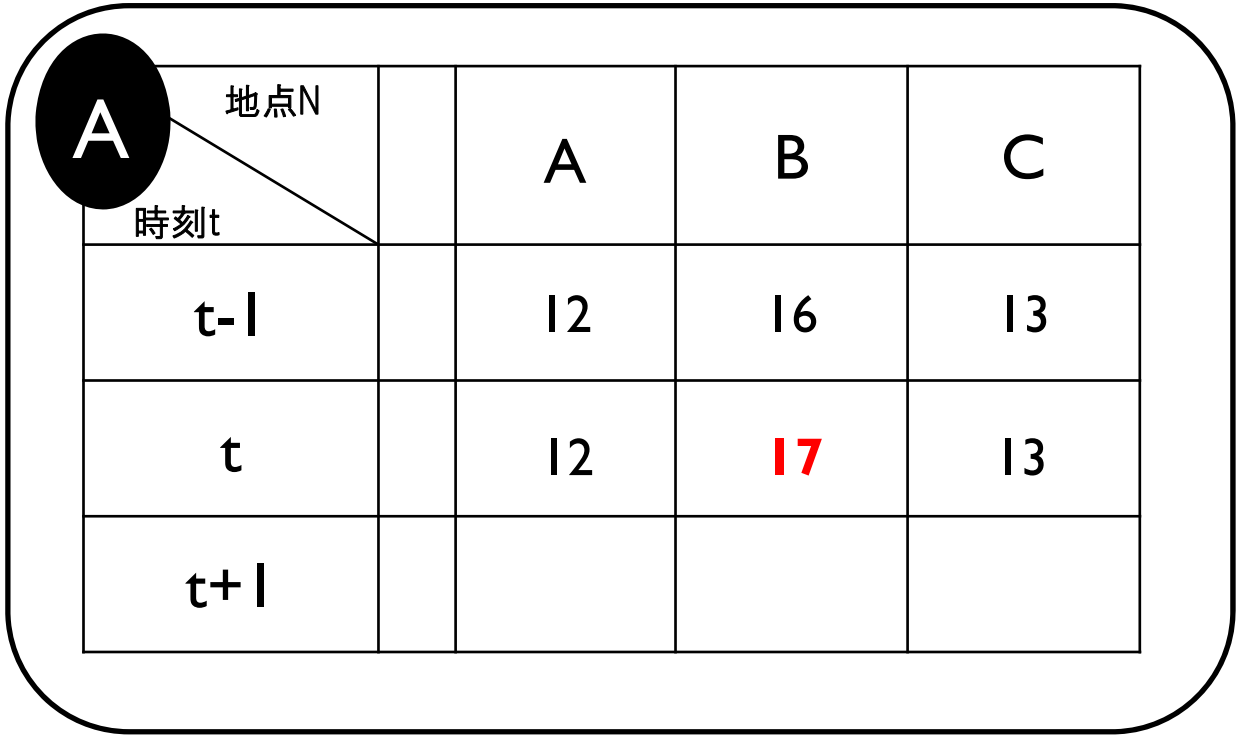
地点N / 時刻t		A	B	C
t-1				
t		$\frac{12\times3}{0.055\ 648}$	$\frac{16\times3}{0.074\ 648}$	$\frac{13\times3}{0.06\ 648}$
t+1				



この値を比較する！

地点N / 時刻t		A	B	C
t-1				
t		0.24	0.03	0.54
t+1				

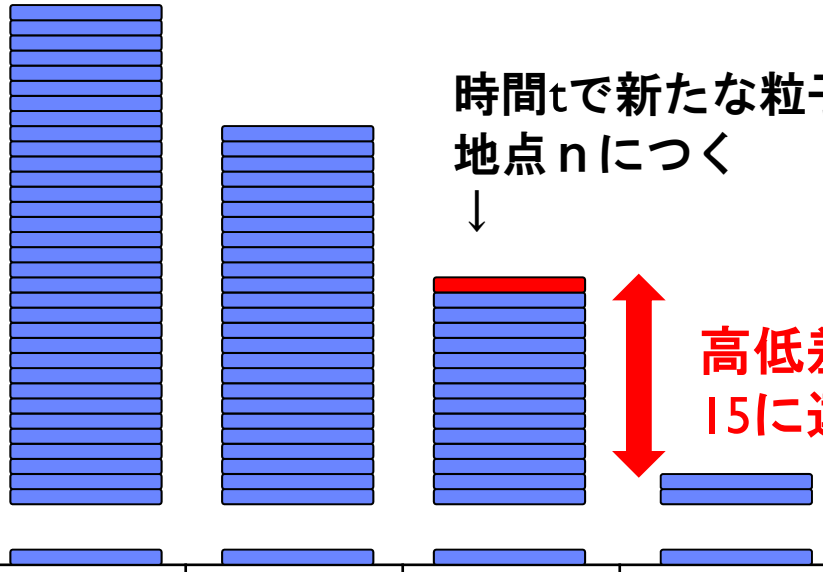
0～1を0.01刻みでランダムに発生させた数


A
地点N
時刻t
A
B
C
t-1
12
16
13
t
12
17
13
t+1

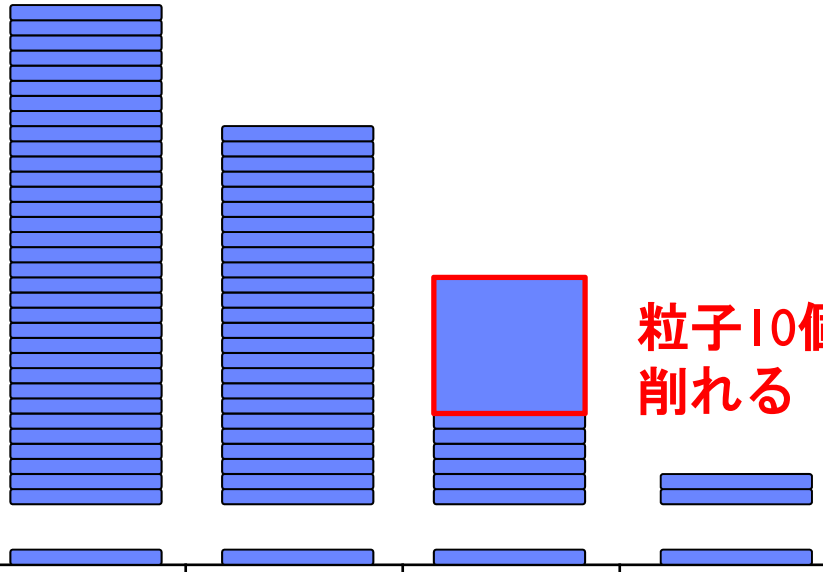
α：突起が崩壊するときの隣点との高低差＝15

β：一回の崩壊で崩れる高さ＝10

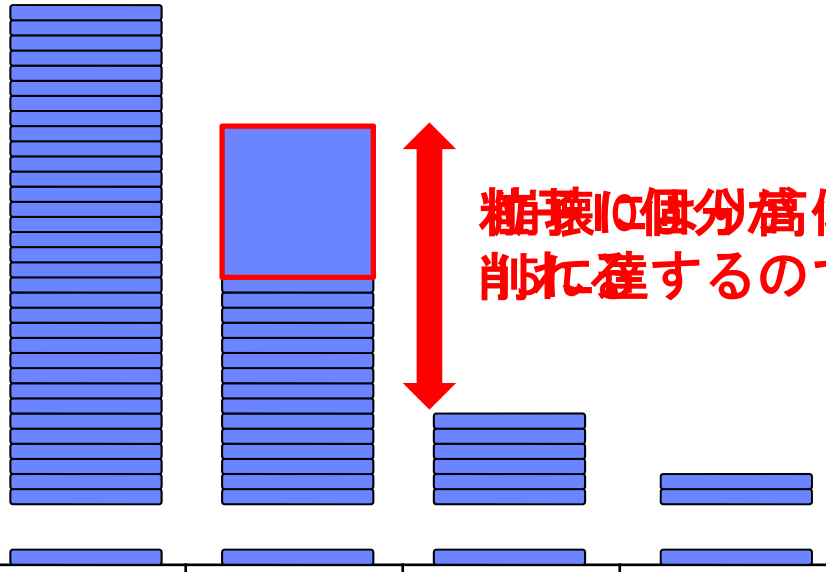
地点N / 時間t	…	A	B	C	D
t-3		49	40	31	17
t-2					
t-1					
t					



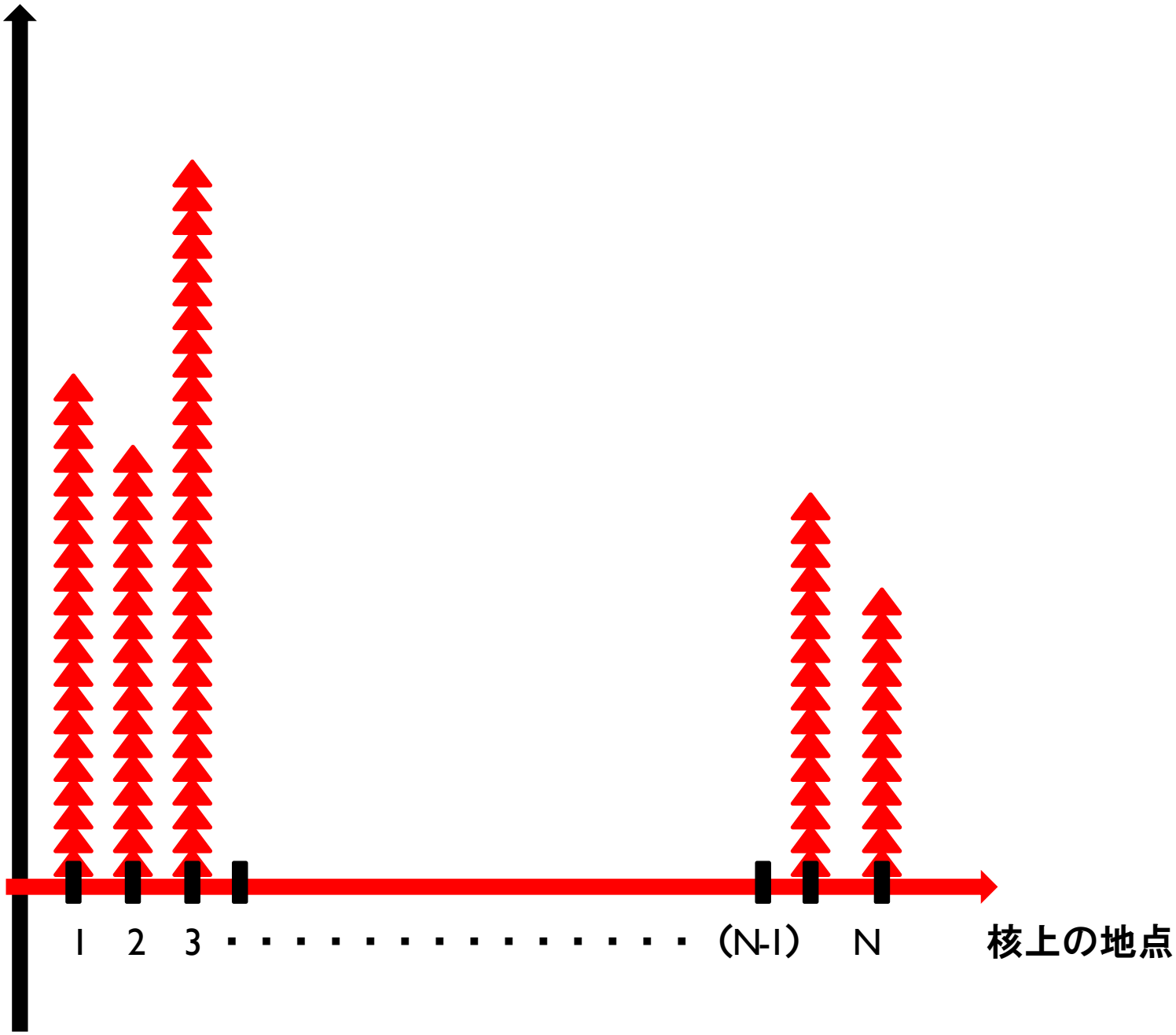
時間t \ 地点N	…	A	B	C	D
t-3		49	40	31	17
t-2		49	40	32	17
t-1					
t					

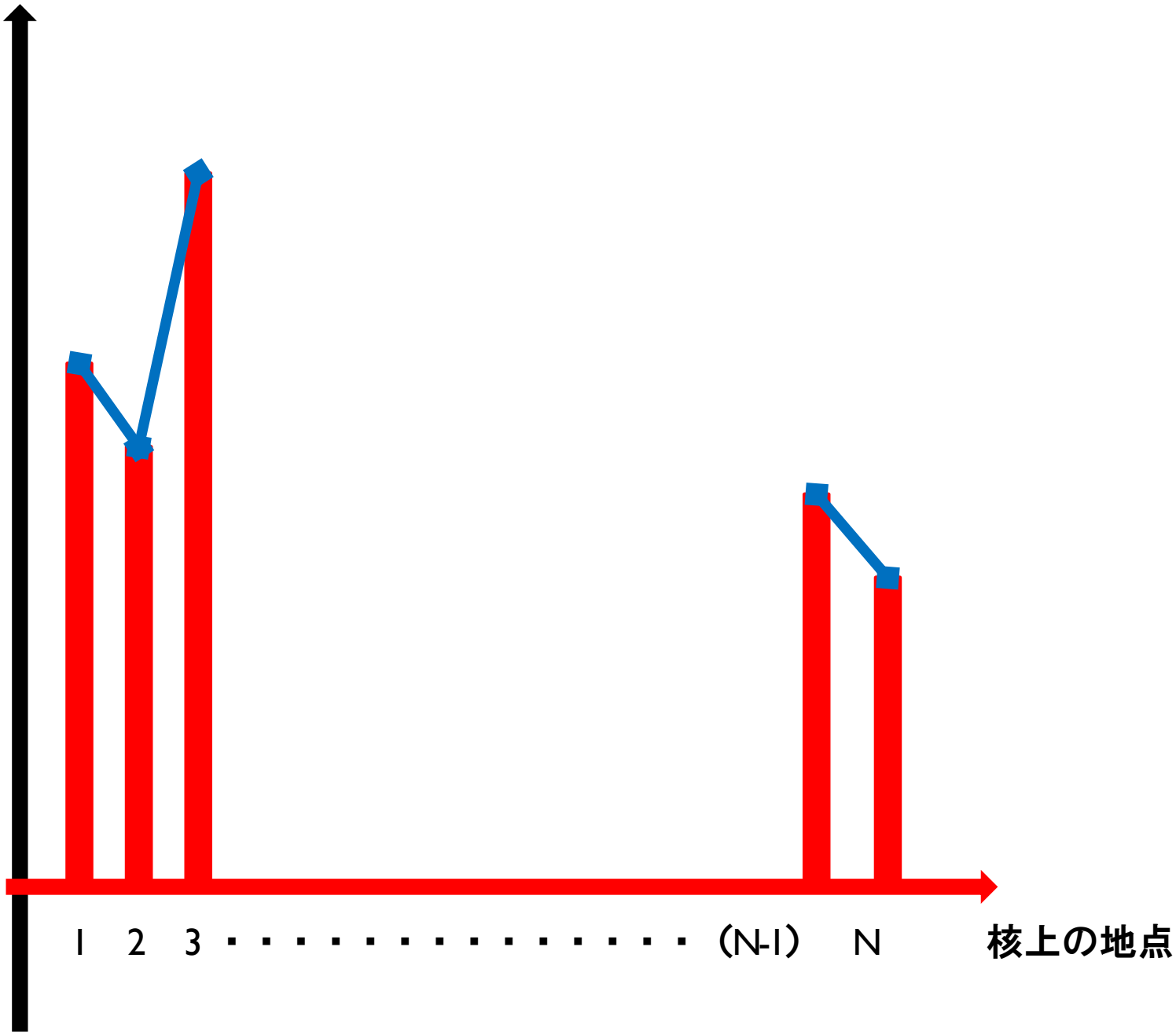


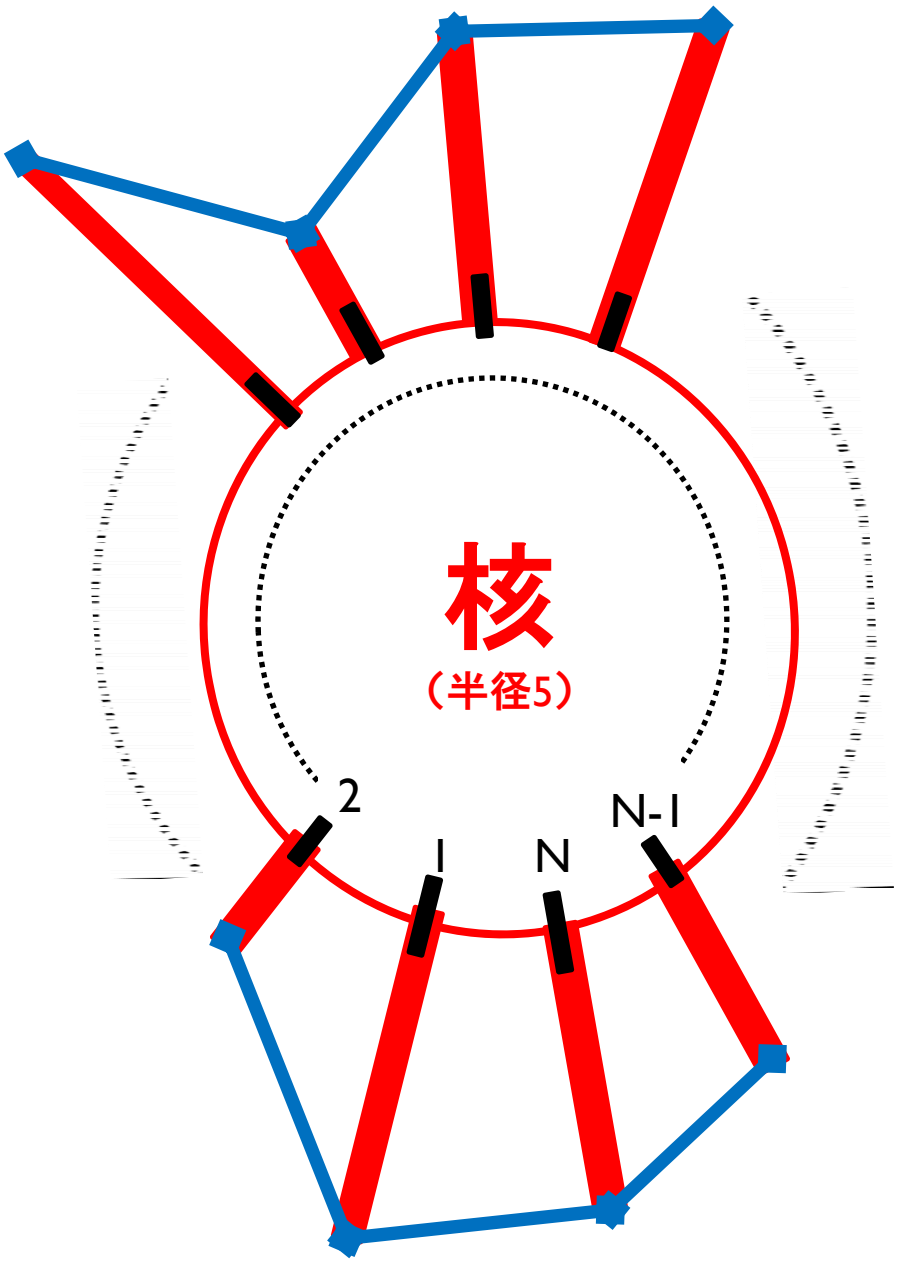
時間t ＼ 地点N	…	A	B	C	D
t-3		49	40	31	17
t-2		49	40	32	17
t-1		49	40	22	17
t					



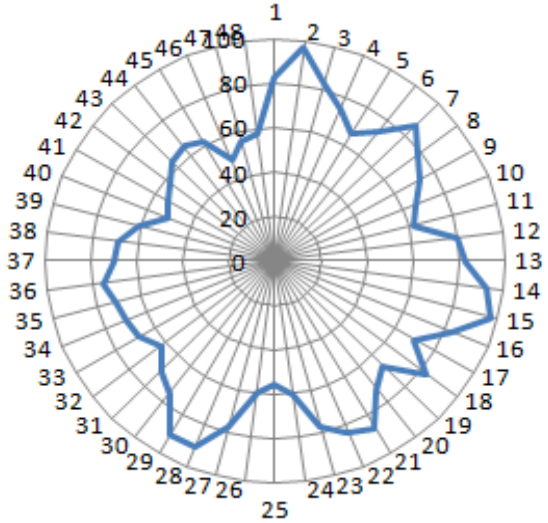
時間t ＼ 地点N	…	A	B	C	D
t-3		49	40	31	17
t-2		49	40	32	17
t-1		49	40	22	17
t		49	30	22	17


突起の高さ
1
2
3
(N-1)
N
核上の地点

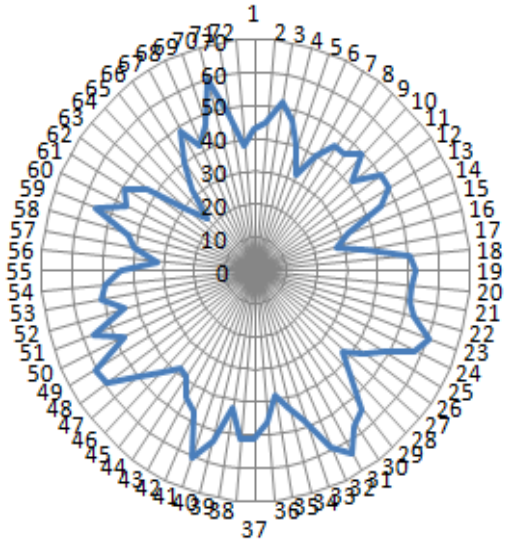

突起の高さ
1 2 3 ・・・・・・・・・・・・・・・・・・・・ (N-1) N
核上の地点


核
（半径5）
2
1
N
N-1

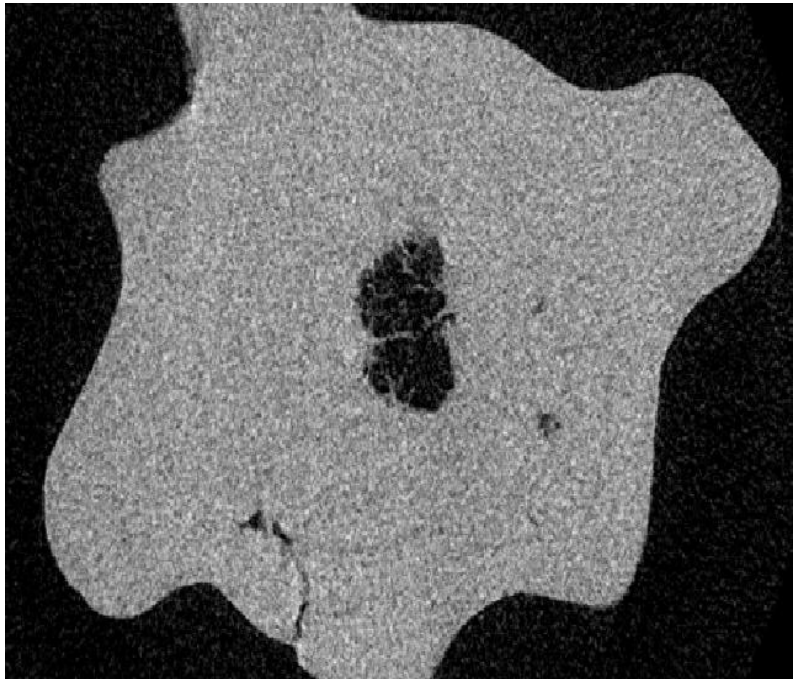
シミュレーションの結果



α=17　β=15　N=48　k=3



α=15　β=10　N=72　k=3



今後の課題

以下の方法を用いることでシミュレーションの結果をより現実に近づけることができると考えている

- 形が近似している、していないを判断する基準を作る
- 完成する時刻 t の値をより厳密に設定する
- 成長するに従い、単位時間あたりにつく粒子の数が増加する条件を組み込む