Reading Guide for Henri Poincaré, *Science and Method*

Read: Chapters 1 (The Selection of Facts) and 3 (Mathematical Discovery).

Core question:
What guides scientists?

Introduction:

→ Brief introduction to the author
→ About *Science and Method*
→ Main ideas set out in Chapter 1
    # Selection of facts is necessary because of infinite facts
    # Simple facts as a way to general laws
    # Sense of beauty
→ Main ideas set out in Chapter 3
    # Importance of intuition in mathematical discovery
    # The conscious ego and the subliminal ego
→ Apply to our lives
    # What are our beliefs based on?
    # My own definition of beauty?

Jules Henri Poincaré (1854–1912), a French mathematician and theoretical physicist, was a dominant figure in the world of science and is often described as a polymath who made many fundamental and remarkable contributions to mathematics and theoretical physics. In his 30's, he began to investigate the three-body problem, a typical example of which is the three-body celestial system formed by the sun, the moon and the earth. This study led to the discovery of chaotic systems and laid the foundation of modern chaos theory. Poincaré wrote over 400 science books and articles, including those written for the general public such as *La Science et l'Hypothèse* (*Science and Hypothesis*), *La Valeur de la Science* (*The Value of Science*) and *Science et Mèthode* (*Science and Method*), which were published in 1902, 1905 and 1908, respectively.

The core text comes from Poincaré's *Science and Method*. In this book, the author reviewed the methodology of scientific investigations and also the psychology involved in scientific discoveries with examples drawn from theoretical physics, mathematics and the author's personal reflection on the basic scientific activities of experimentation, fact selection and human reasoning.

Chapter 1 begins with the assertion that selection of facts is necessary for scientific discovery because of the scientist's incapability in handling infinitely many facts. The author then suggested that simple facts or recurring facts should be relied

on as the very first step on the way to general laws. He further added that humans have a sense of beauty. Because of this sense, we prefer simple facts. With this sense, humans have the intuition into the harmony of the universe.

In Chapter 3, Poincaré explored the nature and the psychology of mathematical discovery. He observed that people had various degrees of mathematical intuition, only those with strong intuition could be discoverers. From a personal account of his work on Fuchsian functions, the author proposed the existence of two egos, a conscious one and a subliminal one, which has aesthetic sensibility to think and select fruitful combinations of ideas.

Most of us are not doing scientific research, but the questions raised in these two chapters are still worth our further reflection. Everyone has his beliefs, but what facts are these beliefs based on? Different people have different definitions of beauty, how about yours? What kind of beauty deserves your whole life of seeking?

Suggested outline of the text:

Chapter 1

Paragraphs 1-3: The necessity of selection of facts and its criteria.
Paragraphs 4-5: Scientists believe a hierarchy of facts which guides selection.
Paragraphs 6-9: Simple facts.
    6-7: Recurring facts as a way to general laws.
    8-9: Simple facts as examples of recurring facts
    10: Where to the find simple fact?
Paragraphs 11-12: Resemblance and difference.
Paragraphs 13-14: Concluding remarks for the first part.
Paragraphs 15-17: Intellectual beauty, the search for it as a guideline of selection.
Paragraphs 18-21: Why do beautiful things also give us practical advantages?

Chapter 3

Paragraphs 1: Introduction: Mathematics as a way to understand human mind.
Paragraphs 2-9: A good memory is valuable.
    2-5: Ask why some people do not understand mathematics and make error.
    6-7: Because of forgetting.
    8-9 It is good for a mathematician to have a good memory.
Paragraphs 10-12: Different people have different degrees of mathematical intuition.
Paragraphs 13-17: Mathematical discoveries are selections that lead to fruitful combinations of facts.
Paragraphs 18-25: The mind of a mathematician during discovery, the author’s

personal experience as an example.

Paragraphs 26-28: Two remarks on the existence of an unconscious work and the condition of fruitfulness.

Paragraphs 29-38: The existence of a subliminal ego.

29: Proposal of the existence of a subliminal ego.

30-31: Hypothesis 1: The possibility of its being superior to the conscious ego.

32-38: Hypothesis 2: It has the aesthetic sensibility to select fruitful combinations of ideas.

Paragraphs 39-47: A pictorial description of how the two egos work.

Study Questions

(Answers can be found at the end of this section.)

(Chap. 1, Para.1-5: Selection of facts)

1. Why is the selection of facts necessary?

(a) There is no way to deal with infinite number of facts.
(b) All facts are different.
(c) We have to select the facts which fit in our theory.
(d) We have to separate facts from non-facts in nature.

2. In Para. 5, the last sentence reads “One has only to open one’s eyes to see that the triumphs of industry, which have enriched so many practical men, would never have seen the light if only these practical men had existed, and if they had not been preceded by disinterested fools who died poor, who never thought of the useful, and yet had a guide that was not their own caprice.” Who are those “disinterested fools who died poor”?

(a) Poincaré. (b) Industrialist. (c) Scientists. (d) Businessmen.

(Chap. 1, Para.6-10: Simple facts)

3. The author mentions the “fools” again in Para. 6. Do they refer to the scientists?

(a) Yes. (b) No.

4: The author puts two kinds of guidance in contrast. What are they?

(a) Guidance by pure intelligence and guidance by law.
(b) Guidance by instinct and guidance by law.
(c) Guidance by pure intelligence and guidance by reason.
(d) Guidance by instinct and guidance by reason.

5. In Para. 6, the author says "… each one of our thoughts must be useful in as many circumstances as possible." What does "useful" mean?
(a) Generating practical value.
(b) Being applicable in many different situations.
(c) Being accepted by the general public as a theory.
(d) Being regarded as good by the general public.

6. The author explains that we can find recurring facts because we are lucky to live in a world of not too many varieties. According to the author, what will be the consequences if there are too many varieties?
I No two pebbles will be alike.
II There will be no science.
III There will be only individuals but no species.
(a) I and II only. (b) II and III only. (c) I, and III only. (d) I, II, and III.

7. The author points out two kinds of simplicity: the first kind is real simplicity, and the second kind is the result of thorough mixing of elements. Which of the options below belongs to the second kind?
(a) A mercury droplet. (b) The helium gas inside a balloon.
(c) An air bubble. (d) A piece of gold.

8. According to Poincaré, what are biologists' simple facts?
(a) DNA. (b) Cells. (c) Organisms. (d) Species.

(Chap. 1, Para.11-12: Resemblance and difference)
9. Refer to Chapter 1 of Watson's text (DNA). In Para. 26, Watson talks about the red-eyed fruit flies and white-eyed ones. How would Poincaré describe the white-eyed ones?
I. They are the most striking.
II. They are the most instructive.
III. They teach us nothing new.
(a) I only. (b) II only. (c) I and II only. (d) I, II and III.

10. Why will scientists eventually cease to look for resemblances?
(a) Resemblances teach us nothing new.
(b) Resemblances have no practical value.
(c) The scientists will eventually exhaust all the resemblances.
(d) Resemblances are too striking.

(Chap. 1, Para.18-21: Why do beautiful things give us practical advantages?)
11. The first sentence of Para. 19 reads "Whence comes this concordance?" What does the author ask?
(a) Why is the beautiful not useful?
(b) Why do both the architect and the layman admire architecture?
(c) Why do we have both selection of facts and natural selection?
(d) Why is the beautiful also useful?

12. The author suggests two answers to the question "Whence comes this concordance?" One is that the beautiful is best adapted to our intelligence. The other is related to ___

(a) the similarity between the Greek concept of beauty and the barbarians' concept of beauty.
(b) the intellectual beauty of the Greeks and the sensible beauty of the barbarians.
(c) the practical Greek idea of sensible beauty.
(d) the less practical barbarians' concept of intellectual beauty.

(Chap. 3, Para.1-25: about mathematical discoveries)

13. What does the author want to study in the investigation of the genesis of mathematical discovery?

(a) How mathematics relates to the world.
(b) The relationship between logic and mathematics.
(c) The human mind.
(d) The relationship between mathematics and physics.

14. In Para. 3, what astonished the author?

I. Some people do not understand mathematics.
II. Some people make mistakes in doing mathematics.
III. Some people do not like mathematics.

(a) I only. (b) III only. (c) I and II only. (d) I, II and III.

15. What quality of a whist player (and also a chess player) does the author pay attention to?

(a) Good at geometry. (b) Good at calculation.
(c) Having a good memory. (d) Familiar with the rules of card games.

16. The author mentions three different kinds of people in Para 12. Indicate them by writing 1 (who appears first in the passage), 2, and 3 (who appears last) in the appropriate boxes:

Memory & attention / Intuition	Weak / ordinary	Strong
Weak / ordinary		
Strong		

17. The author says that some combinations are fruitless while some are fruitful. Among the fruitful ones, some are the most fruitful. What properties do the most fruitful ones have?

I. Rare.
II. Revealing unexpected relations.
III. Formed of elements from widely separated domains.

(a) I and II only. (b) I and III only. (c) II and III only. (d) I, II and III.

(Chap. 3, Para.26-28: remarks on the existence of an unconscious work and the condition of fruitfulness)

18. The author makes two remarks in Para. 26-28. What is the first remark?

(a) Conscious work does exist.
(b) Unconscious work does exist.
(c) It is important to take a rest.
(d) Conscious work is always fruitless.

True or False

19. The second remark is that the unconscious work will be fruitful as long as it is followed by conscious work.

(Chap. 3, Para.29-38: The existence of a subliminal ego)

	First statement	**Second statement**	
A	True	True	The 2nd statement is a correct explanation of the 1st statement.
B	True	True	The 2nd statement is NOT a correct explanation of the 1st statement.
C	True	False	
D	False	True	

20. The subliminal ego has nothing to do with mathematical discovery.	Mathematical discovery is not simply a mechanical work.

True or False

21. The author would accept that the subliminal ego is superior to the conscious ego.

22. The author hypothesized that one can never be a real discoverer if he does not have the aesthetic sensibility to (sieve / construct) fruitful combinations of ideas.

Answers:

1.a	6.d	11.d	16. (upper row) 1, 2; (lower row) 3, 3	21.F
2.c	7.c	12.b	17.d	22. sieve
3.a	8.b	13.c	18.b	
4.d	9.c	14.c	19.F	
5.b	10.a	15.c	20.d	

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