The truth obtained by reconsidering René Descartes' philosophy from a current perspective

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This is a topic from the field of dentistry. It is taken from a previous post.

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To translate the Japanese version of the article into English, I used the translation apps DeepL and Google Translate.

The truth obtained by reconsidering René Descartes' philosophy from a current perspective

Part I.

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About the Scientific Revolution of the 17th Century in Europe

The Scientific Revolution is given by historians of science to the period in European history when the conceptual, methodological, and institutional foundations of modern science were established. Although historians of science differ as to the exact period, the 17th century is considered to be the center of the scientific revolution, the 16th century the period of preparation in various aspects, and the 18th century the period of consolidation and groundwork.

In recent years, studies of medieval science have revealed that medieval natural philosophy laid the foundation stones for the scientific revolution. Therefore, we can distinguish between the medieval period that laid the foundation stone of the scientific revolution and the period of superstructure construction. The Middle Ages were once thought to be a period of sterility and stagnation for science, but thanks to the many excellent studies written from a continuist perspective, no one now denies the legacy of the medieval thinkers. In particular, we now know that remarkable contributions were made in the Middle Ages in the development of the mathematical sciences of astronomy, cosmology, optics, and kinematics, as well as in the development of ideas of natural laws and experimental methods.

Galilei's integration of kinetic theory and natural philosophy resulted in what he called a new theory of motion. This is still considered today to be a major influence on the development of later theories. Similarly, the influential natural philosophy of René Descartes (1596-1650) emerged from an attempt to give natural philosophy the certainty of geometric reasoning. The new natural philosophy of Isaac Newton (1642-1727) was based on mathematical principles, as the title of his major work suggests.

What happened in the Scientific Revolution? Simply put, we can summarize that in the Middle Ages, natural philosophy had nothing to do with mathematics or experimentation, but when the Scientific Revolution took place, these different kinds of natural research methods and natural philosophy merged to create what we might think of as a science.

Where early modernity is concerned, the use of the term “natural philosophy” in place of “science” is by no means desirable. Science” and ‘natural philosophy’ are not the same concept. One of the reasons the Scientific Revolution was revolutionary is that throughout this period natural philosophy was transformed into something different and closer to what we think of as science.

The term scientific revolution

Descartes likened true learning (philosophie) as a whole to a tree. The roots are metaphysics, the trunk is physics, and the branches from the trunk are the sciences. This can be called Descartes' tree of sciences. Descartes listed medicine, mechanics, and moral philosophy as the sciences that are branches of this tree. Moral science is the ultimate in wisdom, which is the totality of knowledge of the other sciences. Descartes' way of explaining this shows the historical flow of the history of European academic thought. Descartes did not intend to take the whole of science and call it “science,” but rather to call physics, mechanics, medicine, etc. all together “science,” as in Descartes' tree of learning.

The discussion here covers the period from Galileo Galilei (1564-1642) to the time of Newton in the 16th and 17th centuries, some 300-400 years ago. The Scientific Revolution is aptly described as the establishment of modern natural science in the 17th century. Let me explain a little about the significance of discussing events in Europe 300-400 years ago here and now.

The Significance of the Scientific Revolution

Nowhere is there any denial that the present age is an age of technological revolution, and to truly understand the nature of 20th century science well, we must go back to its starting point. The key to unlocking the secrets of our turbulent times can be found in the history of science in the 16th and 17th centuries. History without the history of the development of science and technology is meaningless. The history of the scientific age should be centered on the history of science. Within that history of science, the idea of scientific revolution forms the framework of the whole.

In the modern society in which we live, the enormous power of modern science, symbolized by nuclear power and satellites, is truly overwhelming, and no cultural, social, or political event can be described apart from its enormous influence. It is literally the center of modern civilization, and it is no exaggeration to say that the future fate of mankind depends on the progress of this science. The overwhelming power of science, which has now become the destiny of mankind, actually originated in the "Scientific Revolution," a one-time historical event that took place in the 17th century, and modern civilization is nothing but the direct result of this revolution. It was here that the prototype of "modernity," which is directly linked to the modern age, was created.

Herbert Butterfield (1900-1979), a distinguished historian of science at Cambridge University, emphasized the significance of the Scientific Revolution. This revolution overturned the authority of science not only in the Middle Ages but also in the ancient world. Not only did it bring down scholastic philosophy, but it also led to the destruction of Aristotle's (384 B.C. - 322 B.C.) natural science, which shines above all others since the rise of Christianity. The scientific revolution became the true genesis of the modern world and the modern spirit, transforming the character of habitual human intellectual activity and transforming the whole structure of the physical universe and of human life itself. According to him, the traditional historical classification of the Renaissance and the Reformation as the beginning of "modernity" is no longer appropriate, and the Scientific Revolution must now be regarded as the decisive moment that made the modern world modern. It was this revolution that formed a new intellectual attitude toward nature that did not exist in ancient times or in the Middle Ages, and by carrying out a fundamental intellectual transformation, laid the foundation for the infinite progress that man has made since then, from which there can be no turning back.

And so we are situated in the midst of this process of progress, trying to understand the immense significance of this transformation that took place 300 years ago. Is not the ultimate significance of the scientific revolution even more important than the discovery of agriculture, which made civilization itself possible? For in science is built in the potential for unlimited progress.

Meaning of Scientific Revolution

Assuming that the historical significance of the Scientific Revolution is as described above, in what sense is the Scientific Revolution called a "revolution"? What is the meaning of the scientific revolution as a revolution in the history of science? To grasp the establishment of modern science as a truly revolutionary event, the first thing to consider is that what is meant by "science" when it is called Greek science or medieval science is not science in today's sense, but a system conceived under a different worldview, view of nature, and values. It is important to know that "science" was not science in today's sense, but rather a system conceived from a different worldview, view of nature, and sense of values, and that it was essentially different in its purpose, orientation, methods, and structure.
It was only after the Scientific Revolution that the concept of science, which is identical to today's science, was created, and it is fundamentally false to assume that the concepts and methods of today's science existed in ancient and medieval times.

According to the British historian of science A. Rupert Hall (1920-2009), it was during the course of the "scientific revolution" that the "scientific attitude" in the modern sense was formed for the first time. There, a new principle method of recognizing nature, the so-called scientific method, was established, and science thereafter took on a cummulative character. This new scientific attitude and method required not only observation but also rigorous standards of constructive experimentation. It also expelled the spiritual and hidden qualities from the realm of natural cognition and limited its focus to empirical phenomena. It also required a strict distinction between theories with sufficient experimental evidence and conjectural hypotheses or mere speculation. It was also important that the systematic experimentation supporting the theory be tightly coupled with numerical and quantitative treatment. The "scientific method," the natural understanding first formed, remained unchanged no matter how the content of science subsequently developed, allowing for the cumulative advancement of scientific knowledge in the years to come.

However great the renewal of ideas of matter, time, space, and causality, it is a renewal of the "content" of science, not of the "structure" of science itself. Newton was not shown to be wrong by Albert Einstein (1879-1955). Nor was Antoine-Laurent de Lavoisier (1743-1794) shown to be wrong by Ernest Rutherford (1871-1937). Formulations of scientific propositions are changed and the limitations of their application are recognized, but they still retain their validity within the domain in which they were found to be head-first correct.
In general, after a scientific revolution, later theories advance cumulatively by adding to or encompassing the earlier ones. However, this was not the case in the very scene where the "scientific revolution" was taking place. When the dynamics of the Scholastic philosophy of Aristotle is defeated and the dynamics of Galileo is established, the latter does not emerge by adding something to the former, nor does the latter envelop the former. A new way of perceiving nature, combining experimental and mathematical methods, emerged, presenting the correct basic composition of nature and overturning the cosmological worldview that had existed from antiquity through the Middle Ages.
In the words of John Desmond Bernal (1901-1971), this scientific revolution overturned the entire structure of intellectual assumptions handed down from the Greeks and firmly defended by Muslim and Christian theologians, and a radically new system It was replaced by a radically new system. The hierarchical structure of Aristotle's universe gave way to Newton's mechanistic vision of the world.

What the Scientific Revolution Revitalized

The Scientific Revolution not only corrected erroneous theories and facts, but also shattered and removed in one fell swoop the old conceptual framework itself and the old worldview, view of nature, and values that had dominated for more than a thousand years since the Greeks and were inextricably linked to it. By carrying out a fundamental intellectual turn, he laid the foundation stone for an entirely new understanding of nature and established a new method of inquiry into nature that we today call the "scientific method. This turn established for the first time the concept of science as we know it, and the subsequent development of science was based on the foundation stone laid here, allowing for a series of perceptions pioneered by the scientific method. In mechanics, from Galilei to Newton; in astronomy, from Nicolaus Copernicus (1473-1543) to Johannes Kepler (1571-1630); and in chemistry, from Sir Robert Boyle (1627-1691) to Lavoisier. Herein lies the meaning of the term "revolution" in the Scientific Revolution.
The scientific revolution cannot be attributed merely to the revival of past ideological traditions; it is the birth of a completely new intellectual attitude, and this "newness" must be

made possible by factors unique to the modern age. It is the accumulation of technological practice since the Renaissance, and the theoretical understanding of this technology is the hallmark of modern science. If we believe that the scientific revolution occurred simply because of the rise of technological practice, I believe that we are not grasping the situation correctly.

Why were the technologists of the Renaissance unable to create modern science? Galilei, Descartes, Francis Bacon (1561-1626), and Boyle were well educated in the universities, were familiar with the ideological heritage of the past, and were interested in modern technical problems. Why did they establish modern science for the first time? It can be said that the Scientific Revolution was the result of a unique combination of the theoretical heritage of the Greeks and the technological practices of the late Middle Ages, and the creation of a completely new method of inquiry into nature. In the Greek and medieval periods, "rational thought" and "technical practice" were separated from each other. I think this is the reason why science could not arise. In Greece, for example, the former was the exclusive property of philosophers and the latter of slaves, and in the Middle Ages, the former belonged to the theologians and the latter to uneducated craftsmen.

One of the problems of the current "scientific revolution theory" is to pursue the specific ways of combining, linking, and inter-blending the theoretical heritage belonging to this scholarly tradition and the technical practice belonging to the artisanal tradition, and to identify the scene where this dual structure is unified. Only then will the unique "structure" of the modern scientific revolution be revealed. The methodological product of the scientific revolution, the combination of the "mathematical method" and the "experimental method," is also deeply related to this. This is because the former is in the theoretical heritage since the Greeks, while the latter was forged in the technical practice of modern craftsmen.

Craftsmanship is not just a matter of being theoretically sound; it cannot go a step further without actually making things and experimenting with them. Craftsmen, however, were unable to make these experimental facts into a universal theory, only to confine them to their long years of experience. It was modern scholars, armed with rational theory and interested in technical practice, who did so. Let us trace the broad vein of this union and unification.

After writing his book on the origins of modern science, Butterfield noted that the scientific revolution was the true father of the modern world and the modern spirit. And the significance of the scientific revolution is unparalleled since the advent of Christianity. But if we want to know the cause of the Scientific Revolution, we must look for it in that great change in European history called the Renaissance. The Scientific Revolution cannot be discussed without mentioning the Renaissance. The Scientific Revolution, like the Reformation, can be seen as a consequence of the Renaissance.

The Role of the Renaissance

The Renaissance led intellectuals to a deepening interest in history. A consciousness was born that positioned themselves as heirs to the intellectual glory of ancient Rome or ancient Greece. Their concern was to restore to our time the wisdom of the ancients, which had never been surpassed by man, and for many, could never be surpassed by man. Some of them went through the libraries of monasteries all over Europe and discovered many ancient manuscripts that had been buried without being read by the monks. Thanks to printing technology, these manuscripts were preserved and made available to readers throughout Europe with relative ease. Most of the ancient writings we have today were collected and preserved by Renaissance humanists.
To get an idea of the impact of the humanists of the time, one need only look at their influence on traditional Aristotelianism as it was then taught in European universities. For example, the rediscovery by humanists of Diogenes Laertius (active around the 3rd century) in his "Philosophical Chronicles" and Marcus Tullius Cicero (106 B.C. - 43 B.C.) in his "On the Nature of the Gods), it can be mentioned that Aristotle, who was considered the highest authority on philosophy in the Middle Ages, was not the only philosopher in antiquity. Furthermore, it was clear at a glance that Aristotle was not the most respected philosopher in antiquity. The subsequent discovery of the writings of other philosophers, such as Plato (427 BC - 347 BC), the Neoplatonists, the Stoics, and the Epicureans, provided an excellent source for learning about philosophical views different from those of the dominant Aristotelianism of the time. Among the ancient philosophies thus restored is the skepticism of the late Academia. The Late Academia was the revered school founded by Plato. The situation was further complicated by the revival of writings on mathematics and magical thought. Aristotle did not emphasize mathematics, whereas Plato saw it as a pathway to certain knowledge. That alone was enough to generate a sudden surge of interest in mathematics.

Writings on ancient magical thought included those by Iamblichus (245-325) and Porphyry of Tyre (234-305). Among others, thanks to the writings attributed to Hermes Trismegistus, who was considered to be an ancient sage contemporary with Moses (active around the 16th or 13th century B.C.), more and more people believed that witchcraft was the oldest source of wisdom. This is the reason why witchcraft was considered to be the oldest form of wisdom. This is why witchcraft also came to be considered knowledge in the legitimate sense of the word. The Church was opposed to witchcraft, not least because of its association with demonology, but despite its protests, interest in witchcraft continued. The intellectual situation became more chaotic with the offer of ancient knowledge, but it was a chaos of possibilities. As a result, during the Renaissance, traditional Aristotelian natural philosophy lost its intellectual authority, and a new natural philosophy emerged. It was also a time of new thinking on the question of how knowledge of sufficient certainty should be discovered and confirmed. Authority at the time came to be seen as fallacious and unreliable. The emergence of new philosophical systems, such as skepticism, and the focus on non-philosophical approaches, such as mathematics and magic, put the pursuit of only conventional knowledge at risk. As a result, emphasis was placed on discovering the truth by relying solely on one's own experience and efforts.

The Revival of Greek Philosophy

The revival of ancient writings during the Renaissance had a variety of intellectual consequences, one of which was a growing interest in the magical tradition. I believe this was due in part to the fact that ancient Neoplatonic writings were read.
Newton was also an alchemist. Newton's alchemical research was long dismissed as irrelevant to his scientific work, but in recent years it has been found to have influenced his theory of matter. Betty Jo Teeter Dobbs (1930-1994) and Richard S. Westfall (1924-1996) emphasize that the fact that the hidden forces of inter-particle attraction and repulsion exist at the foundation of Newton's natural philosophy was possible because of Newton's familiarity with alchemical modes of thought.

Even if knowledge of alchemy alone is not sufficient to explain Newton's belief in hidden forces, alchemy is important for understanding one aspect of Newton's scientific thought: from his early paper “A Hypothesis of Light” sent to the Royal Society in 1675 and from his “Optics” (third edition 1717), Newton clearly had much grounding in the theory of light in alchemy. Alchemy believed that light could interact with matter and give it a certain active character. The origins of Newton's notion of gravitation may lie elsewhere, but the idea that matter has some sort of active principle latent in it seems to be taken directly from the alchemical tradition. It is possible that such an active principle was thought to be the cause of universal gravitation.
Within this Platonism, a particle theory view of matter began to develop. For example, it is clear that Newton believed in the particle-like structure of matter, and with respect to light, he oscillated between particle and wave properties, gradually leaning toward particle nature

and approaching the idea that a universal gravitation force is inherent in those particles. Newton himself carefully left room for contrary interpretations in cases that could not be determined experimentally or theoretically, but his followers in the 18th century reinterpreted this and pushed toward a more rigorous form of atomic theory. However, there was still room for a "first push" by God in the image of nature as depicted by the Principia, which consisted of atoms.

Medieval Thought and the Scientific Revolution

In the Dialogue Concerning the Two Chief World, published in 1632, Galileo begins his discussion of the law of natural falling motion with the following dialogue. Salviati, speaking on Galileo's behalf, says, "It is not enough to know that natural falling motion is a straight line. We must know whether it always maintains the same speed, or whether it decelerates or accelerates. After clarifying that this is an accelerated motion, he then says, "It is not enough to know that it is an accelerated motion. He goes on to say that we must know what ratio the accelerated motion is made up of. Finally, I do not think that this problem has already been clarified by any philosopher or mathematician. In this way, Galileo emphasizes that the acceleration rate of natural falling motion is an extremely important problem that has never been studied or solved by anyone before.

In response, Simplicius, another interlocutor who represents the Aristotelian school of scholars, develops the following counterargument: "Philosophers are primarily concerned with universal matters. They find definitions and the most general criteria. They leave to mathematicians certain subtle and trivial matters that are the object of curiosity. He then goes on to say that Aristotle gave a good definition of what motion in general is. He is also satisfied with showing that the primary attributes of locomotion are naturalness, violence, simplicity, composition, equality and acceleration. Furthermore, he states that he is satisfied with the basis of acceleration for accelerated motion, and leaves the pursuit of such acceleration rates and other more specific events to the experts in mechanics and other lowly craftsmen. In this way, he indirectly defends Aristotle by arguing that the study of the acceleration rate of natural falling motion, which Galileo is so proud of, is not research that should be done by philosophers.

People who supported the Scientific Revolution

It must be said that the reformist ideas of humanists played a major role in the origins of the Scientific Revolution. Let's look at three characteristics of the Scientific Revolution.

1. The use of mathematics to understand the workings of the natural world.
2. The use of observation and experimentation to discover truth.
3. It broadened the concept of the usefulness of knowledge, which had previously been limited to the lowly mathematical artisans and sorcerers, to include natural knowledge.

Humanism was necessary for the knowledge that would bring about the Scientific Revolution to take root in people's minds.

Mathematics came to be used not only to describe the natural world, but also to explain it, and this was not limited to the field of astronomy. At the time, there was a growing interest in exploration against the backdrop of the development of trade and the expansion of colonial rule. This also led to an interest in practical mathematics, such as navigation, surveying and map-making. Leading intellectuals began to turn their attention to these fields, and it also became possible for artisans to rise socially and intellectually. It is thought that this also led to the emergence of people from the upper classes who became interested in mathematics.

The Jesuits also contributed to the introduction of mathematics into natural philosophy through their active educational activities. Their emphasis on mathematics education can be seen in the fact that mathematics was taught alongside natural philosophy and metaphysics at their schools. The educational activities of the Jesuits are important in history. Their attitude towards mathematics at their schools reflects the major trend of improving the status of mathematicians. It also impressed upon many students the importance of mathematics.

At least two thinkers studied at Jesuit schools and later contributed to the mathematical description of the world in their own way: Marin Mersenne (1588-1648) and Descartes. Mersenne became a monk of the Order of the Minims in 1611 and devoted his life to learning in order to defend his faith with the support of the order.

Mersenne was also opposed to skepticism, and he considered mathematics to be the most reliable kind of knowledge, through which it is possible for humans to reach the knowledge of God. Mersenne wrote energetically, and he also encouraged other mathematicians to publish their research. What he was even more enthusiastic about was exchanging letters with prominent scholars all over Europe. For scholars working in similar fields, Mersenne's network became a common source of information. He would send the results of his latest research to others who needed them. At the same time, he also used this personal information network to spread his own ideas and his personal belief in the importance of mathematics for philosophy.

People who are not interested in the scientific revolution

Now, the question we are going to address here is not to describe historically or concretely how Galileo broke through the conservative shell of Aristotle's scholastic students and

achieved brilliant modern scientific achievements. What we want to discuss here is why philosophers and thinkers of the time did not themselves undertake work such as Galileo's formulation of the law of natural falling motion, which should have been highly valued for its originality and novelty, but instead left it to lowly craftsmen.
Let's take another example. In 1609, Galileo heard that in Holland, a pair of glasses had been invented that made distant objects appear closer, and he set about making them himself, and succeeded in making a telescope. Galileo immediately pointed it at the sky and made a surprising number of discoveries for the time. What surprised people the most was that the moon also had mountains, and that Jupiter had four moons, just like the earth. According to Aristotle's scholastic theory, the moon and other celestial bodies were made of a higher fifth element called 'aether', which was different from the four elements of earth, water, air and fire that make up the earth and its surroundings, and it was also said that their shape was also the highest form suitable for this element, a perfect sphere. Therefore, it was considered completely ridiculous that the moon, which is a celestial body, would have mountains and valleys.

The teachings of scholastic philosophy

In response to the simple wonder and strong curiosity of ordinary people, the scholastic scholars were extremely critical of these new inventions and discoveries. When they heard about the telescope, some of them said that it was not a new invention or anything, and that Aristotle had already recorded it. Aristotle recorded in one of his texts that it is possible to see the stars even in the daytime from the bottom of a deep well. He gave the reason for this as being that the steam that accumulates in the well strengthens human eyesight. He was enlightened by the idea of a telescope tube from the idea of a deep well, and the idea of a lens from the idea of steam in a well. This is a completely ridiculous story to us today, but it is believed that this is not something that Galileo exaggerated or made up, but a true story that actually happened at the time.

Scholastic philosophy that only thinks

We cannot attribute the reason why the Aristotelian scholastics did not try to look through the telescope that Galileo had made, as Galileo said, simply to their cowardice. This is not enough, and it seems that there was something more significant and profound than personality at play in the difference between the attitude of the Aristotelian scholastics and Galileo's attitude towards learning. Research into the rate of acceleration or looking through a telescope would not have been such a big deal or such a frightening thing to do. Therefore, the reason they did not do this research or look through the telescope was not because they were too lazy to do these things, or because they simply did not want to do them, but because they did not feel the need to do them. They must not have felt the need to do them, and they must not have been interested in them. Then, why did the Scholastics, represented by Cesare Cremonini (1550-1631), not feel the need for such things and not take an interest in them?

What the Scholastic Philosophy Sought

For Galileo, the greatest concern during his many years of research was, of course, the formulation of the various laws of motion of objects. To put it simply in his own words, it was “to gain concrete knowledge of natural events”. This was the greatest and ultimate goal of Galileo's “science”. However, the ultimate goal of the scholastic's “science” was not this. The greatest research topic for the scholastic students was, in a word, the relationship between man and God, and clarifying this connection. The connection between God as the creator of these creatures, and the order that exists between these creatures, especially man, was the subject of their research, and the clear description of this order was the goal of their research. Aristotle's texts were also studied, developed and used in this way, and in a sense were distorted and incorporated into the hierarchical framework of Catholic belief. And the concept of “nature” was also understood as the way in which the order laid down by God as the Creator manifested itself in the created world, or in other words, as the “true nature” of things. Nature is a catalyst for human beings, who are rational beings, to become aware of their own true nature and to strive towards the highest good, God, through this awareness. Therefore, nature in the materialistic sense, which is independent of human thought and intention, as we think of it today, does not have the rationality to be aware of this, even though it has its own order and true nature as God's creation. Therefore, as a conscious effort towards God, who is the highest good, was considered impossible, such things were evaluated as being one level lower than beings with human-like reason. Therefore, in the world of Catholic faith, which begins with humans and ends with God, things of the materialistic world were not worthy of study.

Scholastic philosophy seeks a sacred world

Once the acceleration rate of natural falling bodies has been established, how much will it contribute to solving the various important issues surrounding the relationship between humans and God? And even if it is proven that the curve described by a projectile is a parabola, rather than a circle, a straight line, or a combination of the two, how much light will it shed on the extremely important question of the origin of evil found in human actions? It was far more urgent and relevant to deepen research into how much of the human soul is immortal than to be distracted by toys like telescopes, which were incomprehensible. When you think about it like this, it is better to think that the reason that the philosophers of Galileo's time were unable to recognize the greatness and importance of Galileo's science was not because they were all second-rate or third-rate scholars of the dying days of scholasticism scholars, but rather that they also believed in the same scholastic doctrines that were in their heyday, and were confined to that worldview.

The Role of the Reformation

This new attitude can also be seen in the Reformation. Martin Luther (1483-1546) refused to obey not only the Pope, but also local priests. Luther, who advocated the idea that “every believer is a priest”, encouraged Protestants to read the Bible for themselves and to feel God's will for themselves. This may seem like just a reaffirmation of the authority of the Bible, but in reality it was something new. Until then, Roman Catholics were not supposed to read the Bible, but rather to consult with priests and wait for them to guide them. For Luther, this authority of the priest was mistaken, and he argued that each person should go back to the Bible and discover the truth for themselves. In the 16th century, the natural world was often compared to “another book of God”, and here we can see the similarities between the Reformation and the Scientific Revolution. In the scientific revolution, we can see an emphasis on experience and observation as a method for discovering truth. There is no doubt that the emergence of this new empirical or experimental attitude towards the study of nature had to go through the changes brought about by the Renaissance.

Galileo's view of the world

The world view of the scholastic scholars was different from that of Galileo. So, what was Galileo's view of the world? It is very difficult to extract Galileo's view of the world from his own letters and writings in a clear form. However, from fragments of his words, etc., we can deduce that Galileo was particularly keen to assert that his heliocentric theory did not contradict the words of the Bible. For example, in a letter dated December 21, 1613 to the mathematician Benedetto Castelli (1578-1643), and in a letter to Cristina di Lorena (1565-1637) in 1615, Cristina di Lorena (1565-1637), it says, “The words of the Bible, while necessary for the salvation of the human soul and the consolidation of faith, have no direct relationship to natural philosophy.” From this sentence, we can infer that Galileo thought that the world of humans and nature, which had once been united and had a hierarchical relationship within the Catholic faith, had been completely separated and was now asserting its own existence. In this sense, I think we can find Galileo's world view, which he did not describe as a clear philosophical system, in Descartes' dualism.

The historical background of the scientific revolution

The scientific revolution was achieved through the establishment of experimental methods, and the 17th century is said to be the age in which experimentation was modernized. This method of experimentation was only made possible by the combination of Newton's empiricist attitude and Descartes' rationalist attitude. The reality of the 17th century was one of division, contradiction, endless trial and error, and the confusion of many perceptions. In a sense, human senses and reason in experimentation were more likely to negate each other than cooperate, leading to many foolish conclusions.

The contradictions in the methods lead to serious skepticism, and the trial and error process leads to despair. And this skepticism and despair were the characteristics of the 17th century. In the first volume of his main work, Novum Organum, Bacon energetically discusses his despair of human knowledge in aphorisms 94 to 115. Bacon, the proponent of the experimental method of the time, was the first person to experience this tragedy of experimentation. Boyle also left a significant mark on the promotion of the experimental method of the 17th century, but his outlook on life was also always accompanied by a pessimistic awareness of “the necessary imperfection of human nature”.

Needless to say, it was Newton who perfected this experimental method, but when he said in his dying words that he was “only like a boy playing on the sea shore”, it is clear that the pessimism of the 17th century never left him and followed him throughout his life. Michel de Montaigne (1533-1592) and Heinrich Cornelius Agrippa (1486-1535) were skeptics who rejected and destroyed the ancient authority of Aristotle in the 16th century authority, but the skepticism of the 17th century was different from the skepticism of the time, which was directed externally. The skepticism of the 17th century was deeply directed inward, and it formed a kind of anguish that even the scientists of the time could not solve. Historians refer to this as the “critical years” and speak of it as an unprecedented “age of skepticism”.

The scientific revolution of the 17th century was accomplished through the persistence of this skepticism. It progressed in spite of all despair. It was a time of methodological schism, a time of great experimental activity, a “century of absurdities” and a “century of genius”. It was also a time of crisis and a time of the marvels of science. As a time of transition from tragedy and chaos, or a time of transition for modern intellect, the flow of science in the 17th century can truly be called a time of “change” or “revolution”. When we talk about the 17th century as the age of the scientific revolution, we should not mean that a new system replaced an old system, but that the name “scientific revolution” should be given to it in that it rose above the tragedy despite the anxiety and despair caused by the alternation of old and new ideas, and despite the suffering of skepticism about all things human.

The arrival of the scientific revolution

Newton's Philosophiae Naturalis Principia Mathematica (1687), or Principia, is probably the pinnacle of the mathematization of the world image. What is famous about this book is that it established that the planets revolve around the sun due to the same force that causes an apple to fall to the ground, but its content is far richer than that. In it, Kepler's laws of planetary motion were mathematically proven for the first time, and the theory of the moon and comets was modernized for the first time. Newton's laws of motion replaced Descartes' laws of nature, and as a result, the theory of the collision of objects was brought one step closer to completion. Newton also succeeded in theorizing oblique collisions, which Descartes had been unable to deal with. Newton also fully understood centrifugal force. He also pioneered the theory of the motion of objects in fluids, and based on this research he was able to conceive of an acoustic theory that focused on the speed of sound propagation, which changes according to the pressure and density of the medium. Of particular significance for the mechanistic philosophy supported by many of his contemporaries, including Newton himself, was his mathematical demonstration of how macroscopic, visible phenomena could be explained in terms of microscopic phenomena.

With the publication of Newton's Principia, the trend towards the mathematical description of natural philosophy that began in the 16th century was completed. Perhaps the reason for this high regard is that, unlike Galileo and Descartes, Newton arrived at the correct answer, both mathematically and in terms of natural science.

Galileo's Achievements

The men who triggered the scientific revolution were Galileo and Descartes. Although Galileo was the elder of the two and his scientific activities began at the end of the 16th century, their main periods of activity overlapped. Both began their academic careers under the influence of Aristotle's system, and after carrying out fundamental critical work on that system, they formed their own sciences.

The first reason why Galileo was able to break free from the influence of Aristotelian natural philosophy, which was dominant until his time, was his mastery of the science of Archimedes (c. 287 BC - c. 212 BC), which was only fully introduced and absorbed in the second half of the 16th century. Archimedes was the founder of “statics”, which deals with “levers” and “balance”, and he was a mathematician who presented a mathematical formulation of the subject. This was a clear example of how mathematics expresses the laws of natural phenomena and controls those phenomena. This science of Archimedes also directed the scientific activities of Descartes, who we will look at next. It shook up Aristotle's position on natural science, which held that “abstract mathematics” could not practically constitute “concrete natural science”.

Justification of the Copernican Theory

Until then, the world of celestial bodies was thought to be eternal and unchanging. Galileo actively supported the Copernican Theory based on his own astronomical observations and theoretical evidence. Here are the reasons for this. First, his observations of sunspots showed that they were created and disappeared. The fact that the sun also has a unique property of creation and destruction, which had been thought to be specific to the world on earth, means that the two worlds are not different. For Galileo, this means that the circular motion that had been thought to be a unique motion of celestial bodies can also be applied to the motion of the earth itself.

Secondly, the main reason why the geocentric theory had been rejected up until that point was that it could not explain the fact that when you drop an object from the top of a high mast on a moving ship, the object will fall directly below the mast. In response to this, Galileo explained it by arguing that all objects on the ground share the same horizontal uniform motion of the earth, and that objects that share the same uniform motion in the same direction are mutually at rest. This theory would later be called “Galileo's Principle of Relativity”.

The heliocentric theory would lead to a reinterpretation of the real structure of the universe and the world on earth, not according to our everyday perceptual experience, but from the perspective of “the rotation of the earth”. The celestial world and the terrestrial world are seen as being of the same nature, and the concept of “up and down” is no longer absolute, but is understood as being relative to our perception. In this way, the Aristotelian teleological and hierarchical order that had been thought to constitute the universe and nature is fundamentally dismantled.

Identifying abstract mathematics with concrete natural science

In this way, the phenomena experienced through our sensory perception do not indicate the real structure of nature, but are merely phenomena relative to our sensory perception.
In his Dialogue Concerning the Two Chief World (1632), Galileo makes an Aristotelianist appear as a character and has him argue for the views of Aristotelian natural philosophy, which he then refutes.
In this, the Aristotelianists say that mathematics deals with abstract objects, whereas natural science is a discipline that studies concrete phenomena in the real world, and that it is misguided to try to construct concrete natural science using abstract mathematics. In response, Galileo states that "what occurs concretely in natural phenomena also occurs in the same way in the abstract", and he argues that it is possible to appeal to rigorous mathematics and pursue the rigorous laws within natural phenomena in the abstract.

Through these works, Galileo brought about a new, modern scientific methodology. The first of these was the "idealization" method. Anticipating the Aristotelian objection that his analysis of the motion of projectiles was an imaginary analysis that ignored many of the factors involved in natural phenomena and did not analyze natural phenomena themselves, Galileo argued as follows He argued that in order to deal with a problem using a scientific method, it was necessary to isolate difficulties such as air resistance. For this reason, when applying the theorem to the real world, it was necessary to use it with the constraints taught by experience.
Secondly, he showed the efficacy of mathematical reasoning in the work of natural science. In his analysis of natural phenomena, Galileo said that "knowledge of a single fact, obtained by discovering its mathematical reason, makes us understand and verify other facts without having to repeat the experiment" and that mathematical reasoning can "prove things that have never been observed before through empirical observation" through deductive reasoning.
In fact, he used this mathematical kinetic theory to prove that projectiles follow parabolic trajectories and that their maximum range is at an angle of 45 degrees. In this way, he demonstrated the "productivity" of mathematical natural philosophy, which brings new knowledge about nature through reasoning, independently of sensory experience.

The British and the Continent, with their different approaches to experimentation

In order to give mathematical sciences the same kind of authority as Aristotelian natural philosophy, it was necessary for artificially created phenomena to be as obvious to the general public as everyday phenomena. There were attempts to solve this problem by conducting experiments in public places, for example by dropping weights from the tops of church steeples. However, the most popular method was to record the experiment in detail in a publication. In many cases, the explanations followed the format of a geometry textbook. The author would give specific instructions on how to construct the experimental apparatus, the procedure for the experiment, and the results of the experiment. It was noted that the experiment had already been repeated many times and that many experts had observed it. Eventually, this format became established as the way to report experiments.

Cornell University professor Peter Dear (1958-) has described how this kind of experimental practice became widespread on the continent. However, the experimental philosophy that took root in Britain was quite different. For example, when explaining experiments, the French philosopher Blaise Pascal (1623-1662) took a general perspective, as if the experiments were expressing the truth of things, and said that if you did these things, this would surely happen. This was not the case with Robert Boyle, the leader of British experimental philosophy. From his point of view, Pascal's explanation can only be based on the theory that Pascal himself assumes. As Bacon says, people can conduct experiments to affirm their own preconceptions.

The experimental method in Britain, as advocated by a group of members of the Royal Society led by Boyle, was said to reveal only the facts. This was different from the experimental method on the continent, and was said to be free from theoretical preconceptions.

There are two fundamentally opposing schools of thought in the study of nature. The first is based on the idea of trying to understand nature in a unified way based on certain principles. The second is based on the idea of trying to understand nature as it is, concretely and holistically. In terms of scientific methodology, the former is based on deduction and the latter on induction, but it is not that simple.

The former method ignores minor phenomena and focuses on the unifying principles that govern nature. Once it has reached these principles, it then uses them to explain every corner of the world. Any phenomenon or law derived from them can only serve to reinforce these principles.

For the latter, they describe things and phenomena objectively without paying any attention

to questions such as what can be derived from the thing or phenomenon, what the law that lies at the root of the phenomenon is, and how nature can be explained by that law. There is a spirit of thorough documentation there that refuses to accept conclusions.
The history of science developed through the violent clash of these two trends. Individual thought was also torn apart by these two trends. Let us call the former the trend of cosmology and the latter the trend of encyclopedias. In the first half of the 17th century, the former was typified by Descartes' cosmological conception, and the latter by Bacon's method of natural history.

The British Method of Experiment

Universal statements made no sense to many British Protestants, because they were based on false beliefs - the belief that the way the world is must be inevitable. For example, statements such as “there must be a vacuum” or “the smallest parts of matter must be indivisible”. To them, necessary statements seemed to unjustly limit the omnipotence of God, who could arbitrarily make any philosophical system a truth. The English tended to think that God could make any matter a truth without being bound by philosophical possibilities or impossibilities. Once their method was established in natural philosophy, it would have been a general method for justifying knowledge. The British experimental method was expected to be a means of agreement essential for a community that could create spontaneous order without the need for tyrannical authority.

The difference in experimental methods originated in religion

There was an effort to abandon the Aristotelian method of trying to do natural philosophy using syllogism and instead use reliable experiments, but the issue here is not just an abstract epistemological shift. The credibility of traditional Aristotelian natural philosophy came from the fact that the premises used were self-evident, but this credibility itself needed to be replaced with something else. Like mathematical propositions, experimental knowledge is not self-evident. In order to convince people of its truth, if it was not to be accepted on a personal level, it was necessary to explain the procedure in detail. For experimental philosophers like Boyle and Pascal, it was impossible to expect everyone around them to become experts in experimental philosophy and mathematics. So they took the path of emphasizing how reliable their arguments were.
So where did the difference between Englishmen like Boyle and continental Europeans like Pascal come from? As an explanation, Dear emphasizes the role of religious factors. While

miracles were still believed in the Catholic world of continental Europe, for English Protestants the age of miracles was long past. According to Catholics, nature follows laws, but that regularity could be overturned by a single event (i.e. a miracle). Therefore, for them, experiments that are one-off events are meaningless. A few experiments are just one example of a law of nature. On the other hand, for example, a universal statement about atmospheric pressure tells us something about the order of the natural world. In Protestant Britain, on the other hand, since the existence of miracles is denied from the outset, there is no need for a belief in the laws of nature. Even a one-off experiment is considered meaningful in deepening our understanding of how nature works.

On the other hand, universal statements made no sense to many English Protestants, because they were based on false beliefs - the belief that the way the world is is inevitable. This is expressed in statements such as “a vacuum must exist” or “the smallest parts of matter must be indivisible”. To them, these necessary statements seemed to unjustly limit the omnipotence of God, who could arbitrarily make any philosophical system a truth. The English tended to think that God could make any matter a truth without being bound by philosophical possibilities or impossibilities.

Considerations on the Experimental Method

In contrast to Dear, Steven Shapin (1943-) and Simon Schaffer (1955-) explain that the Royal Society's unique experimental methodology was based on the social turmoil that 17th century British society was in. They link the unique experimental philosophy of England to the need to guarantee peace and stability during the Restoration. They say that the Boyle school thought that discovering the facts as they were would make it possible to end the disputes in natural philosophy. Even those who dispute whether matter can be infinitely divided would not argue if it were the facts themselves. This seemed to be a path that natural philosophers could follow to help restore social order. If their method could be established in natural philosophy, it would be nothing less than the acquisition of a general method for justifying knowledge, and it would lead to the end of disputes in other fields such as politics and religion. The experimental method in England was expected to be a means of agreement essential for communities that could create spontaneous order without the need for tyrannical authority.

Even though there is some room for debate in the arguments of Dear, Shaping and Schaffer, I think their research has given us a deeper understanding of how the 'experimental method' developed in the context of 17th century England, and how it took a different direction from the thinking on the continent. Their research also makes us think about the background to the great power of the experimental method in modern science. As Shaping and Schaffer point out, it is easy to think that experimental knowledge is clearly superior to other intellectual methods and that this is why it has achieved great success. In reality, however, as their research shows, our faith in experimentalism, like the experimental method itself, emerged in early modern society in conjunction with various political, social, and rhetorical strategies that were clearly limited in time and place and taken for specific purposes.

The Role of the Royal Society of London

It is often pointed out that the rise of the empirical method led to the formation of groups of natural philosophers and experimenters. These groups were sometimes formal and sometimes informal, and were represented by the Accademia del Cimento in Italy (1657), the Royal Society in London (1660), and the Académie royale des Sciences in Paris (1666). This point of view is based on the idea that the experimental method requires the collaboration of scientists. This view can be clearly seen in Bacon's utopian work, “New Atlantis” (published in 1627 as an unfinished work), which describes the House of Salomon. It is said that the House of Salomon served as the prototype for the idea of the Royal Society and the Royal Academy of Sciences. Both of these learned societies grew out of small groups of scientists devoted to experimental methods, and they were the most successful of the new learned societies.

The Success of the Royal Society of London

The Royal Society of London for Improving Natural Knowledge was established in 1662 as an organization for natural researchers. Its establishment signified the transformation of science, which had been more or less an arbitrary product of individuals, into the crystallization of a clearly directed collective effort, and the beginning of science as an institution fulfilling an indispensable function within the nation and society. Science first took on its modern form through the Royal Society. So it can be said that this was a landmark event in the history of the establishment of modern science.

The people of the Society intended to carry out their work in a collective and organized manner, and as the name suggests, their aim was to (improve natural knowledge). They adopted a new organization for this purpose, discovered effective methods, set up a systematic program as a goal for their joint enterprise, and devoted all their efforts to achieving this goal. In just 30 years, the level of science in Britain surpassed that of the advanced countries on the

continent. Newton's "Mathematical Principles of Natural Philosophy" (1687) helped to establish the Royal Society as the absolute authority in the world of science.
Around 1645, several circles of natural researchers were formed in London. The people who gathered there were large merchants, landowners, the new aristocracy, and intellectuals closely connected to them. Many of them sympathized with Parliament, and while some were loyal to the king, regardless of which side they stood on, they were by no means enthusiastic supporters. There were also Puritans, but most of them were rather moderate Anglicans who valued tolerance and reason, or in other words, the broad church.

According to the History of the Royal Society of London (1667) written later by one of them, Thomas Sprat (1635-1713), religious and political issues, which were also the focus of debate in the period, were also of great interest to them. However, this was a source of unbearable pain for these moderate, calm intellectuals. They sought solace in the study of nature during these "gloomy times". They often met to discuss new inventions and discoveries. At first, they did not have a fixed method or promote systematic research. Eventually, they began to understand what the new science meant to them. When they discovered a research method that was appropriate for this, they began to have a systematic vision for the study of nature, and they came to realize that they were the disciples of Bacon more than anyone else.
Science gives humans new inventions and power, and enriches human life. This is what Bacon believed. According to Bacon, the first step in the study of nature was to create a "Natural History". In other words, as many phenomena as possible were to be described without "rash speculation", and then arranged and organized into appropriate categories. Once a complete natural history was prepared, the principles that govern nature could be derived from it. The achievement of this project required the collective cooperation of natural researchers. Bacon dreamed of a "New Atlantis".

A collection of useful knowledge about nature and technology is called a natural history or natural technology journal. The creation of natural history was the "primary and ultimate purpose" of the Society in its early days. It is important to note that natural history in the 17th century was not a field of science like that of the 18th century. It was a method for collecting knowledge as a method or a way of recognizing facts, and it was also a collection of knowledge that resulted from the application of that method. In a word, natural history was a method of recording.
In the 17th century, it was a revolutionary event to collect knowledge with a certain sense of purpose, and to promote mutual exchange, rather than leaving knowledge to the limited collection of individuals or to the accidental transmission between individuals. Even if there

were no new inventions or discoveries, the goal of "improving natural knowledge" would have been achieved to the extent that it would have satisfied many of the members of the society. For us today, who think based on the premise of knowledge that is systematically collected and immediately transmitted, it seems difficult to grasp the revolutionary significance of the efforts of the society.

The various communities that formed the cells of the social structure of the Middle Ages each formed a complete, closed society. The members of the community were subject to strict rules in all aspects of production and life. These rules also extended to knowledge. If knowledge provided the reason for the existence of the community, it was kept secret to prevent it from leaking out. In principle, there was no mutual exchange of knowledge between communities. For example, in the guilds of merchants and producers, the secrets of the "technology" of commodity production are kept strictly. Even if the guilds collapse and the stage of large-scale handicraft production comes, the situation does not change as long as the technical basis of large-scale handicraft production is handicraft. The secrets of technology are persistently protected.

As the domestic market is formed and overseas markets expand, it becomes impossible to rest on traditional technology. New technology is required. In a situation where knowledge is confined to a closed society, the demand for new technology leads to efforts to steal each other's "secrets" rather than to invention.

This closed nature of knowledge is not limited to the production sector. In the fields of thought and learning, the invention of printing was changing things, but it was still only having a very limited effect. The people of the Royal Society challenged this situation.

In the 17th century, when knowledge was confined to a closed society, the basic conditions for the advancement of science were to break down this closed-off nature, to promote mutual exchange, and to collect and accumulate the intellectual achievements of humanity. It was able to respond to both the intellectual ambition of the capitalist class to grasp the world as a whole, that is, the idea of an encyclopedia, and the practical interest in increasing production through technological improvement and developing markets for raw materials and goods. The great merchants and landowners who had seized political power set about this task. They used their own organizational forms to create a system of collective cooperation, and they adopted the method of recording "natural history" to make efforts to collect useful knowledge.

The Society, which was strongly influenced by the Whig Party, became a social force with its leaders serving as successive presidents, but it did not achieve its goal of creating a complete natural history. Even when they tried to systematize it, the reports were incomplete and fragmented, and could not be used as they were. There were not many talented people. The

Society was run by the members' investments, but the finances tended to be sluggish, and it did not go well. However, the decisive factor was that they did not have a “principle”. In order to organize, categorize and systematize the miscellaneous cognitive materials that had been collected, a certain principle was needed. Not only did they not have one, but they consciously rejected it, believing that they could create a system of encyclopedic knowledge using only a “recording method”. What a great illusion! The impasse was clear to everyone. In the face of the vast amount of material, they began to explore their hypotheses and principles. Newton, who had been an outsider to the Society up until this point, would now take center stage.

“The public are not the possessors of useful knowledge, but are at best only capable of obstructing the truth. It is always only a select few who know the truth.” Newton, who wrote this in his first letter to the Society, was in direct opposition to Robert Hooke (1635-1703), the true leader of the Society in its early days. From the start, the Society was not a comfortable place for Newton.
However, things changed. The Society reached out to Newton. Even if the inverse square law was Hooke's idea, it could not have been theorized without Newton's systematic conceptual ability. The Society's activities effectively came to an end with the publication of “Philosophiæ Naturalis Principia Mathematica” in the year before the Glorious Revolution. The solution of that problem was left to the 18th century.
The systematization of natural research, which had acquired principles, began. Natural history shifted from method to field. Although it was belated, the honor of being the editor of the first modern encyclopedia, the “Lexicon technicum” (1704), fell to John Harris (1666-1719), the secretary of the Royal Society. After him, the program of the Society was taken over by the French Encyclopédistes. The Society gradually moved away from the tradition of experimental science. Hooke inherited the experimental tradition of science from Galileo, but in the 18th century, with the rise of Newton, the power of theoretical science increased, and natural history shifted towards natural philosophy. However, the spirit of recording, which seeks to describe objects in an objective and factual manner, and the methods of natural history were not lost. They continue to pulse at the base of modern science.

The Rise of Mechanistic Philosophy

In the 17th century, people began to call for a new philosophy that would make it possible to throw out Aristotelian philosophy once and for all. Several new philosophies were proposed and competed with each other, but at the time they were all collectively referred to as 'mechanistic philosophy'. By the end of the 17th century, mechanistic philosophy had effectively replaced Aristotelian scholastic philosophy and become dominant. It was thought to be the key to understanding all aspects of the natural world, from the propagation of light to the development of animals, from the theory of atmospheric pressure to the explanation of respiration, and from chemistry to astronomy. The mechanistic philosophy was fundamentally different from the past. In fact, it was natural philosophy at the height of the scientific revolution.

In the mechanistic philosophy, all phenomena are explained using the basic concepts of mechanized mathematics, or mechanics. These are concepts such as shape, size, quantity and motion. In principle, contact action is considered to be the cause of all change. Mechanism likens the workings of nature to the workings of machines. The cause of natural change is considered to be the interaction of objects, which are thought of as being like the cogs of a clock. Or, the cause is also considered to be the collision of objects and the propagation of motion that accompanies this.

Aristotle's teleology explains the behavior of objects in terms of the purpose inherent in them. For example, the reason acorns grow is because they become oak trees and provide wood for humans. In the mechanistic theory, explanations using vitalism and teleology are rejected. The true properties of objects, such as size, shape, motion and rest, are strictly distinguished from the secondary properties that objects merely have. The latter are derived from the true properties, such as color, taste, smell, heat and cold. For example, it was explained that vinegar does not have the property of “taste”, but that it actually only tastes sour because the particles that make up vinegar are sharp and irritate the tongue. It is worth noting that the obvious qualities mentioned in Aristotelianism are reduced to mere secondary qualities in the mechanistic theory. Secondary qualities are attributed to the invisible minute particles that make up objects. At the same time, the hidden qualities that had been explained using Aristotelian principles are also explained using mechanistic principles. The distinction between obvious and hidden qualities in Aristotelianism has no meaning in mechanistic theory. This is because natural phenomena are ultimately explained in terms of the motion and interaction of particles that are imperceptible to the senses.

The final important characteristic of mechanistic philosophy is the assumption that all objects are composed of invisible atoms or particles. It is not surprising that the background to the emergence of various mechanistic philosophies was the revival of ancient atomistic natural philosophy. The revival of the theories of Democritus (c. 460 BC - c. 370 BC) and, in particular, Epicurus (c. 341 BC - c. 270 BC) was important. In fact, Pierre Gassendi (1592-1655), a leading thinker of the mechanistic school, developed his own system in the process of reconstructing Epicurus's ideas. However, not all mechanists thought in terms of indivisible atoms. It was not impossible for a mechanist to think that matter could be divided infinitely and that all observable changes were caused by particles as the smallest units of matter. The existence of something smaller than an atom was also considered. An important result of this reform was the establishment of the idea of indivisible yet sizeable particles. The major difficulty with the atomic theory of the time was that it was not clearly distinguished from what could be called the mathematical atomic theory. In the mathematical atomic theory, the reason particles were indivisible was because they were geometric points that had no extension. However, in mathematical atomism, it was unclear how atoms without extension could play a role in the natural transformation of objects with extension. Since a point has no size, no matter how many of them are gathered together, they cannot have size, or extension.

If we take a closer look at the content of scientific research in the 17th century, we can see that the science of the 17th century was based on a mechanical and mechanistic view of nature, and that it rarely went beyond the limits of this. The revolutionary development of science in the 17th century was almost entirely an expression of the victory of the mechanical view of nature over the ancient and medieval cosmological view of nature. Therefore, we could call the transformation of this dominant view of nature the triumph of mechanistic philosophy.
The breakthrough that led to the victory of this mechanistic view of nature was Copernicus' heliocentric theory and Galileo's research into mechanics and the heliocentric theory. As the saying goes, “Ignorance of motion is ignorance of nature”, which has been passed down in the tradition of Greek philosophy since ancient times, the question of mechanics is a fundamental issue in natural philosophy, and is related to the question of world view. Aristotle's scholastic view of nature is also based on his unique interpretation of the interaction between force and motion, and any discussion touching on the fundamentals of motion is inevitably influenced by whether or not this view of nature is accepted.
By the way, in the 17th century there was no such thing as a distinction between physicists, chemists and biologists. All scientists at the time were natural philosophers, and these natural philosophers would discuss biological, mechanical or mathematical subjects according to their interests at the time. In the 17th century, all science was unified in the person of the natural philosopher, and the successes in one field of natural research were immediately applied to other fields of natural research. Galileo's mechanics and heliocentric theory could thus become the starting point for all scientific research in the 17th century.

The Role of Mathematics in the Scientific Revolution

There are probably many different ways of defining the “scientific revolution”. Here, we will follow the common view and refer to the period from the appearance of Copernicus' heliocentric theory (1543) to the establishment of Newtonian mechanics (1687), a period of about a century and a half that saw a dramatic development of science, centered on mechanics and astronomy.

The Renaissance (15th-16th centuries) was a period of transition from the creation of modern mathematics to its establishment. During this period, mathematics gradually shed its Greek form. Commercial arithmetic, which had appeared in India, Arabia and late medieval Europe, spread rapidly with the advent of modern capitalist society, which pursued profit and required advanced measurement and calculation, and the Indian (Arabic) numerals and calculation methods that were convenient for calculation became popular among the general public in the 16th century. The invention of double-entry bookkeeping by Italian Fra Luca Bartolomeo de Pacioli (1445-1514) in 1494 was also a product of this trend.

The decimal system of fractions devised by the Belgian mathematician, natural scientist and engineer Simon Stevin (1548-1620) and the establishment of the method for calculating them (1585) led to a dramatic development in calculation power. Also, between the end of the 16th century and the beginning of the next century, the logarithms invented by John Napier (1550-1617) of Scotland and Jost Bürgi (1558-1632) of Switzerland greatly simplified the complex calculations astronomers had to perform. In relation to the development of these calculation methods, algebra also progressed. The algebra that the Renaissance inherited from the Middle Ages was the so-called "word algebra" that used inconvenient symbols, and it was inferior to Indian algebra. Eventually, the process of symbolization of algebra began, and the symbols necessary for algebraic calculations, such as the symbols for the four basic arithmetic operations, the equal sign, the radical sign, and the parentheses, were introduced between the middle of the 15th century and the middle of the next century. The important concept of exponents and the symbols used to represent them were also introduced and refined between the 15th and early 17th centuries. Thus, the form of algebra seen in Descartes' famous "La Géométrie" is almost identical to modern notation.

Seventeenth century mathematics developed spectacularly, building on the foundations of the Renaissance. The seventeenth century can be said to be the most creative century in the history of mathematics. As mentioned earlier, algebra was almost fully modernized by Descartes. Based on this algebra, he and Pierre de Fermat (1601-1665) each established analytic geometry. The Greek "geometrical algebra" crushed the free computational power of algebra within the narrow confines of geometry. In contrast, analytic geometry cleverly links the world of geometry to the world of algebra, using the concept of coordinates as a medium, without damaging the computational power of algebra at all. This union was beneficial to both geometry and algebra. Thanks to this union, countless higher-order curves were discovered

in the world of geometry. In addition, the concepts of variables and functions were introduced into the world of algebra. Analytic geometry is an algebra of variables that can grasp how quantities change.
Now, how much of a role did this brilliant development of modern mathematics play in the progression of the scientific revolution, which was centered on astronomy and mechanics? Our question is, what kind of mathematics did astronomy and mechanics, the driving forces behind the "scientific revolution", use? The mathematics used by Copernicus was mainly classical Euclidean geometry and trigonometry. Needless to say, the development of trigonometry and precise trigonometric tables were necessary for the emergence of his heliocentric theory, but trigonometry was not a modern invention, and was first compiled by Hipparchus (c. 190 BC - c. 120 BC) of ancient Greece. Precise trigonometric tables had already been calculated through the efforts of people such as Regiomontanus (1436-1476).
What about Galileo? The mathematics used in his "Dialogue Concerning the Two Chief World" and "Discorsi e dimostrazioni matematiche intorno a due nuove scienze" is classical Greek geometry. What about Kepler? It is well known that he discovered that the orbits of the planets are elliptical, and it goes without saying that his theory required the use of conic sections. However, this theory had already been developed by Apollonius of Ancient Greece (262 BC - 190 BC). As Kepler's theory was a theory of planetary motion, it is only natural that the mathematics appropriate to its content should be the integral calculus. The integral calculus is necessary for an accurate grasp of his famous law of area velocity. Unfortunately, mathematics was completely lagging behind. He calculated these distances using a laborious procedure, assuming that the time required for a planet to travel a short unit distance in its orbit is proportional to the distance between the planet and the sun, and that the total of these times is proportional to the total of the corresponding distances, but this was an approximation that replaced integral calculations with the sum of a finite number of line segments. It was through this detour that Kepler finally arrived at his law of area velocity. In any case, his astronomy was in a quandary, waiting for the advent of new mathematics but unable to meet its demands.

What about Descartes, the founder of analytic geometry? As we have already mentioned, this geometry is a mathematics of variables, and so it was well suited to the mechanical view of nature of the time, which held that the essence of nature was extension and motion. However, it seems that this geometry did not play a particularly large role in his depiction of the mechanical view of nature. In his Cosmology and Principles of Philosophy, he says that his method is mathematical (geometrical), but this seems to mean that he considers matter in terms of extension and motion, and not necessarily that he applies full-fledged mathematical

processing.
Although he stated that “the study of motion is the main subject of pure mathematics”, he was unable to express the situation of celestial bodies moving within the space of the ether using mathematical equations. In modern terms, this is an issue that belongs to the dynamics of a continuum, and mathematically it requires partial differential equations, so it was something that Descartes's level of mathematics at the time was unable to handle. He skillfully applied mathematics to optics, the theory of falling bodies, and statics (he applied analytic geometry to optics), but in cosmology, which he regarded as the most important, he made little use of mathematics. Even in Pascal, the connection between new numbers and mechanics/physics is not close. One of his important mathematical achievements was a method of calculating areas using the concept of infinitesimal, but this had little connection with his experiments on atmospheric pressure or his research into hydrodynamics.
We have looked at some of the leading mathematicians and scientists of the 17th century and examined the relationship between mathematics and mechanics and astronomy in their work. The result is that the new mathematics of the modern era did not play a particularly active role in the “scientific revolution”. In astronomy, which requires a high level of mathematical skill, the tools used were trigonometry, which was the legacy of Alexandrian mathematics, classical Euclidean geometry, and, in Kepler's case, Apollonius's Conics. Of course, it is undeniable that the development of computational techniques during the Renaissance improved the computational abilities of astronomers. However, these were merely computational techniques, and they were not new mathematical theories suitable for modern dynamics and astronomy. Mathematics was completely lagging behind the pace of the development of the “scientific revolution”. It was probably thanks to the establishment of the differential and integral calculus by Newton and Gottfried Wilhelm Leibniz (1646-1716) that mathematics began to catch up with modern science. Newton's 'Principia' (1687) is written in the style of classical geometry, but the fluxion method (Newton's integral calculus) appears throughout, and his dynamics would probably not have been possible without this new mathematical weapon.
For the first time, he combined new mathematics and new mechanics, and they began to develop while mutually promoting each other. The 18th century was a continuation of this. In short, in the “scientific revolution”, modern mathematics had to wait for the advent of the calculus to begin to actively demonstrate its effectiveness.
If the establishment of Newtonian mechanics marks the end of the first act of the Scientific Revolution, it was just before the end of the first act that modern mathematics became a powerful weapon for the study of nature. It could be said that the first act of the Scientific Revolution ended because modern mathematics began to exert its influence.

A Treatise on the World by Descartes

In the first half of the 17th century, Descartes' new natural philosophy opposed Gassendi's Epicurean natural philosophy. Descartes' particle theory is debatable, but it is the most influential of all mechanistic theories and is also the most impressive in many respects. Descartes' natural philosophy was based on a new metaphysics, as well as the union of mathematics and natural science. According to Descartes, matter is defined solely by its extension. In principle, natural science can be reduced to a geometric analysis of the motion of extended objects. However, if we look at Descartes' actual natural philosophy, we see that there is almost no mathematical analysis. For example, in his explanation of celestial motion, Descartes points out that there is a relationship between the density of the planets and their distance from the sun, but he does not attempt to calculate that relationship. The reason Descartes does not doubt the mathematical certainty of his natural philosophy is probably because the whole thing has a axiomatic structure, its foundations are unquestionable, and all phenomena are carefully deduced from those foundations.

In his "World", Descartes first systematically considered natural philosophy. The "World" was written by 1633, but when news reached him that Galileo had been found guilty of supporting the Copernican theory, Descartes decided not to publish it. Descartes fully presented his mechanistic philosophy in his "Principles of Philosophy" of 1644. In the "Principles of Philosophy", Descartes still supports Copernicanism, but uses clever explanations to prove that all motion is relative, and on this basis, Descartes concludes that the earth is by definition stationary.

Descartes equated matter and extension, and used this as the starting point for his entire system, so he denied the existence of a vacuum and said that all interaction occurs through contact. Since the world is filled with matter, when one part of it moves, it affects the whole world. However, this seems unnatural, so Descartes instead says that local circles are formed, and this causes a change in the position of the matter relative to each other. In other words, when something moves forward, it pushes the object in front of it away, and that in turn pushes the object in front of that away, and so on. As a result of this continuous replacement, the whole thing bends in a curved direction for some reason, and at the end of the series, the object that was pushed last moves into the space where the first object that moved was originally located. All the moving objects become part of the circular motion of matter, and they all form a spiral, drawing in the tightly packed matter particles around them. Descartes' planetary system is self-regulating.

By the way, why do large particles accumulate to form planets? The explanation for this is a little vague, but once such a planet is formed, it is said to form its own small spiral around itself. The particles surrounding the planet tend to move away from it, and this is said to be the cause of gravity. There is another important assumption in Descartes' system. that the total amount of motion in the world is constant. None of Descartes' contemporaries questioned this. They criticized the details, but they were convinced that it was the most reliable and most fruitful way to understand the natural world.

Descartes' ideas were successful on the continent, and were particularly popular in France and the Netherlands, but not so much in England. The experimental philosophy that had developed in England was not easily receptive to any deductive system. Descartes recognized a certain role for experiments in natural philosophy, but they were of secondary status. They were nothing more than a reinforcement of the chain of reasoning for Descartes.

As a result, the experiments carried out by Cartesianists were limited to reporting what was expected to happen, based on the assumption that Descartes' reasoning was correct.

Protestants in England saw the rationalist system of thought as a way of unjustly limiting the omnipotence of God by forcing human beings to impose their own limitations on God. Cartesian experiments were also never adopted by prominent English experimental philosophers such as Boyle. It is not the case that Descartes' mechanistic philosophy itself was unpopular in England. All of the mainstream natural philosophers who were active after the Restoration of the Monarchy were followers of the mechanistic philosophy.

Although the mechanistic philosophy cannot be separated from the development of mathematical mechanics, kinetic theory and dynamics at the time, it was also a powerful idea in natural philosophy at the time in other respects. In order to demonstrate the effectiveness of their new philosophy, some mechanists expanded their research to include the form, function and life processes of living things. For the leading mechanists Descartes and Thomas Hobbes (1588-1679), it is not unreasonable to say that their main concern was to explain biological phenomena and the behavior of animals, including humans.

The role of Descartes

Here, we will look at Descartes' role as an intermediary in the transition from Galileo to Newton. If we examine Descartes' achievements in the history of mechanics in contrast to those of Galileo and Newton, it becomes clear that a simple composition such as the mechanics revolution does not fit the historical situation of the 17th century. Here, we can see the true face of historical reality, which twists and turns over time, rather than a clear-cut plot brought in from the outside.

It is to be expected that Descartes, who was born around 30 years after Galileo, was influenced by his predecessor Galileo. However, there is little evidence that Descartes learned the theoretical content of mechanics directly from Galileo. The two men's ideas about mechanics were each unique. Therefore, the differences between Galileo and Descartes are an important issue.

Before considering these differences, it is necessary to recall the common issue that reflects the historical situation of the first half of the 17th century, when the two men lived as contemporaries. This is the issue of the Copernican theory, which provides the ideological foundation for mechanics. Both Galileo and Descartes were followers of the Copernican theory, and in this respect they shared a common position that paved the way for modern thought. What is interesting is that we can see a change in the positions of the predecessors and successors in relation to this common issue. Since Galileo's way of life had a strong influence on Descartes' way of life, we should confirm the nature of this change.

It is well known that Galileo, who put forward the heliocentric theory, spent his final years in suffering. After publishing “Dialogue Concerning the Two Chief World” in 1632, he was put on trial by the Inquisition and forced to abandon his heliocentric theory. At the time, Descartes was writing his 'World' from the standpoint of “If the Copernican theory is false, then the whole basis of my philosophy will also be false”. So when Descartes heard about Galileo's case, he could not help but be greatly shocked.

While trying to avoid hurting the authority of the church, Descartes's scheming academic life, in which he tried to develop his philosophical beliefs in a logical way, also had an impact on the content of his research as a whole. Over the same issue of the Copernican theory, Galileo lived as a heretic after making his views public, while Descartes, who was afraid of this, lived in suspicion as a disguised convert, and each chose a different path. Here, we can see the complex relationship between the theories of scholars and the social thought that formed the background at the historical point in time of 1633.

Descartes would later turn his attention to Galileo again when he read the “Discorsi e dimostrazioni matematiche intorno a due nuove scienze”, which was published in 1638. A fairly detailed critique of Galileo's book can be found in a letter (dated 11 October 1638) that he wrote to Mersenne. This is a notable passage in comparing Descartes' academic stance with that of Galileo. At the beginning, Descartes agrees with Galileo's position, saying, “When he considers questions of physics, he tries to avoid the errors of the traditional Catholic school of thought as much as possible and to reach conclusions based on mathematical reasoning.”

However, here Descartes emphasizes not the similarities between Galileo and himself, but the differences. He criticizes Galileo's position, saying, “I think that his major fault is that he constantly digresses and goes off on tangents, and that he never calmly explains a single problem in full. In other words, it shows that he does not examine problems in an orderly fashion. He did not consider the first cause of nature, but merely sought the cause of specific results. The reason he arrived at such results is that he began building without laying the foundations."

At first glance, this may seem to be simply a difference between Galileo, the natural scientist, and Descartes, the metaphysician. While this is something that needs to be taken into account, it is not the only issue. Even if we limit the discussion to the field of mechanics, Descartes' criticism of Galileo is still very meaningful. When comparing and evaluating Galileo and Descartes in terms of the theoretical development of mechanics, the above words touch on an important point. This is a question about the law of inertia.

The law of inertia is a principle that is essential to the foundation of mechanics, which later became established as Newton's First Law. It is generally accepted that Galileo was the pioneer who discovered this law, and this is undoubtedly true. However, Galileo's reference to inertia was only a special case that applied to motion on a horizontal plane. From this, there is a large gap before the general expression of Newton's First Law, "All bodies continue in their state of rest or uniform motion unless acted upon by a force that changes their state," can be generalized. It is often thought that Newton overcame this gap and grasped the general law in one fell swoop, but this is not the case. The role of Descartes as an intermediary must be properly considered here.

Galileo, who was criticized by Descartes for "not considering the first cause of nature, but merely seeking the cause of particular results," said the following in the "Discorsi e dimostrazioni matematiche intorno a due nuove scienze." "We have seen that, whatever the velocity, once it is given to a moving body, it will be sustained without variation, provided the external causes of acceleration or deceleration are removed, but this condition is found only on a horizontal plane. This is because, in the case of a downward slope, there is already a cause for acceleration, and in the case of an upward slope, there is already a cause for deceleration. From this, we can see that motion along a horizontal plane is perpetual, because if it is at a constant speed, it cannot be reduced, lost, or increased. This is certainly a pioneering expression of the law of inertia.

It should be noted that Galileo did not intend to grasp this as a law. He merely predicted the existence of inertia as the cause of the "special result" of motion on a horizontal plane. It was none other than Descartes who grasped the law of inertia as a universal law by "considering the first cause of nature".

We can see this accurate expression in the "Principles of Philosophy" published in 1644.

Descartes carried out a fundamental reflection on the movement of nature here, and summarized it in three basic laws, and the first two of these are clear expressions of the law of inertia.

The first law of nature is “All bodies remain in the same state unless acted upon by a force from another body.”
The second law of nature is “All bodies in motion tend to continue in a straight line.”

When we compare these with Newton's expressions, we can see that Newton certainly inherited the fundamental grasp of the concept of inertia from Descartes. Of course, Newton re-examined the law of inertia in a unified way, both in terms of expression and content, according to his own original ideas, and here we can clearly see that he inherited not only from Descartes, but also from Galileo. Even so, Descartes was able to reach a fundamental grasp of the principle of inertia from a completely different mechanical conception from Galileo, and his role in the history of mechanics is also of great significance. This is because the attitude of Descartes' philosophical reflection, which seeks to “consider the first principles of nature”, was indispensable here. We have now been able to confirm once again that Descartes, who stands between Galileo and Newton, was an important figure who cannot be ignored in the development of mechanics.

Descartes's mechanical conception

Let's take a look back at how the three different inertial laws differed. First of all, Galileo was unable to actively grasp inertia as the fundamental state of object motion. He pointed out that when the cause of acceleration and deceleration, which changes velocity, does not work, velocity is maintained unaltered, and he only passively acknowledged that this condition was satisfied for an object in uniform motion on a horizontal plane. If we were to illustrate the relationship between speed and acceleration geometrically in terms of the relationship between time and distance, we would understand that this was only natural. This is because there was no intention to fundamentally confirm the first cause of motion here.
In contrast, Descartes showed little interest in the empirical concepts that Galileo always focused on, such as the speed and acceleration of moving objects. As a result, he lost sight of the procedure for accurately expressing changes in motion quantitatively, and his mathematical consideration of the motion of a single object (a point mass) was lacking in verve. However, he was relentless in his reflections in an attempt to gain a clear understanding of the first cause of motion. Ultimately, he arrived at the existence of a god who presides over

the natural order, and he grasped the essential content of motion in relation to this.
“God does not change. God's way of working is always the same and does not change.” From this, Descartes went on to think that all objects should fundamentally seek to maintain the same state. He thought, “Once an object begins to move, it will continue to move forever and will never stop moving by itself.” Inertia as the fundamental state of motion was thus elevated to a fundamental principle. The previous view of motion as “something that has a tendency to stop and is by nature inclined to remain still” was finally overcome. Whether motion or rest, as long as it continues, it can be considered to be a manifestation of the inertial state. If that is the case, how do changes in the state of motion occur? In this respect, Galileo only said that there are causes of acceleration or deceleration in the “change” of uniform motion, and he did not attempt to identify what those causes were.
Descartes was not satisfied with simply pointing out that there was a cause for change. He tried to determine the cause in principle. “Each object remains in the same state as much as possible, and does not change unless it collides with another object.” In other words, according to Descartes, changes in the state of motion are caused by “collisions with other objects”. Here we can see Descartes' unique mechanical conception. Of course, it was completely different from Newton's conception. Let's take a closer look at the expressions of Descartes and Newton in the previous law of inertia.

Both of them believe that there are certain conditions that must be met in order for the inertial state of continued motion to be established. Descartes says that the same state will be maintained unless something from the outside tries to change it, while Newton says that the same state will continue unless the state is changed by an added force.
In Descartes' case, it is clear that the “thing that tries to change it from the outside” is a collision with another object. Newton's idea of the cause of motion change is the action of force. When considering the causes of motion change from the fundamentally different perspectives of the collision theory and the action of force theory, it is only natural that different mechanical concepts would be developed. This difference becomes clear in the remaining parts of the three fundamental laws described by each of the two men.
The second and third of Newton's laws, which are well known in general, are
Second law: The change in momentum is proportional to the applied force of motion, and occurs in the direction of the straight line in which this force acts.
Third law: An action always has an equal and opposite reaction. In other words, the interaction of two objects that are relative to each other is in equal and opposite directions.
In any case, here we can clearly see Newton's desire to comprehensively understand the phenomenon of motion as an action of force. What Newton defined as the force of motion is

a quantity that is proportional to the change in momentum. This is ultimately expressed as the product of acceleration and mass, and what Galileo had previously only tentatively defined as the cause of acceleration (deceleration) is now clearly redefined as a concept of force. Here we can see a close theoretical relationship between Galileo and Newton. The mass referred to here must be a quantity that has meaning as a measure of inertia. Descartes' role as an intermediary who established inertia as a principle had a decisive influence on Newton's mechanical conception, which was similar to Galileo's.

By the way, what does the other of Descartes' fundamental laws refer to? The third law of nature is “When a moving object collides with an object having more momentum, it does not lose its momentum. When it collides with an object having less momentum and causes it to move, it loses as much momentum as it gives.” Interpreted from the current perspective, this is a law of conservation of momentum in the case of a collision.

However, this perspective was completely absent from Newton's mechanical thinking. Newton only considered the balance of action and reaction between two objects, and he never showed any desire to advance the idea of a collision phenomenon in which the exchange of momentum occurs. Newton tried to explain changes in motion through the action of force, but Descartes tried to explain changes in motion through the collision of two objects. Although the law of conservation of momentum was still in its infancy, the significance of Descartes' grasp of it in the history of mechanics was enormous. In the 19th century, the law of conservation of energy was established, and considering that theoretical development progressed in the future by focusing on the amount of energy exchanged through interaction rather than through the concept of force, Descartes' pioneering role in 17th century mechanics should be recognized.

Considering these things, I think that Descartes's position in the long history of mechanics, especially in modern physics, where we have come to know the limitations of Newtonian mechanics, should be properly evaluated. It would not be appropriate to ignore Descartes's work just because it was different from Newton's mechanical conception and did not directly support Newtonian mechanics. Rather, Descartes's conception of mechanics served to supplement Newtonian mechanics from a different perspective. And if we consider Descartes's existence, we should also be able to learn about some of the rich historical content of the history of mechanics in the 17th century.

Up until now, we have focused on Descartes as an intermediary between Galileo and Newton. This is not to say that we are placing particular importance on Descartes alone. Rather, we wanted to say that the history of mechanics in the 17th century cannot be summed up as a single process that leads to Newton.

The Metaphysical Foundation of Mathematical Natural Science

Descartes examined how the essence of material things is perceived. After his investigation, he concluded that the essence of material things is not perceived through the senses or imagination, but through the mathematical object of geometric extension, or the idea of space, which is given within human intellect.
However, I don't understand why a theory based on the abstract ideas of mathematical objects found within human intellect can be said to correspond to the physical nature outside of human beings in a real way.
Descartes responded by appealing to the metaphysics of an omnipotent God, and by the theory of innate ideas, which states that if God is omnipotent, he must have created and set up the mathematical objects that we can understand clearly and distinctly with our intellects as constituting the real structure of physical nature.
With this “innate theory” of mathematical objects, Descartes sought to reject the empiricist epistemology that formed the basis of Aristotle's natural philosophy, and to establish the view that the human mind can investigate the essence of physical objects independently of the senses and imagination, according to abstract ideas of mathematical objects that are given within the human intellect.
Descartes appealed to the metaphysics of the almighty God and put forward the thesis that God created and imprinted mathematical objects within us humans, and that this in turn constituted the laws of physical nature (natural laws). This thesis means that we can think of the mathematical objects found within our human intellect and the structures that make up physical nature as being fundamentally related. We humans are now able to theoretically investigate the structure of physical nature without relying on sensory experience, in accordance with the mathematical concepts we find within ourselves.

The Physiology of Harvey and Descartes

William Harvey (1578-1657) elegantly proved through experimentation that the spontaneous movement of the heart is due to its contraction, but Descartes' explanation contradicted this. Nevertheless, Descartes emphasized that his view was a conclusion that was inevitably drawn from the arrangement of the various parts of the heart. He likened it to the way the movement of a clock is necessarily derived from the arrangement of its gears. The fire of the heart, as conceived by Descartes, is thought to be equivalent to the fire that burns without giving off light, as can sometimes be seen in inanimate objects. Descartes seems to have had fermentation in mind, but it was not yet known at the time that fermentation was caused by the activity of microorganisms. He believed that this fire of the heart was the origin of all bodily movement.

Descartes then set about constructing a speculative theory of physiology. In it, the bodies of animals and humans are explained in terms of a complex, self-powered machine that works by hydraulic pressure. He presented his theory of the movement of the heart and blood in his “Discourse on Method” (1637). He did so with the intention of setting an example of mechanistic physiology. Descartes' ideas had a major impact. Attempts to explain biological phenomena in terms of mechanics gained increasing support throughout the 17th century.

It seems that our view of the world is largely defined by the mechanistic idea of animal mechanics. This is true in both biology and medicine. In this respect, Descartes' mechanistic physiology can be considered the origin of modern life science.

The starting point for Descartes in this area was the work of Harvey on the heart and blood. Descartes removed the vitalistic elements from Harvey's theory and, ignoring his explanation of the movement of the heart, came up with a mechanistic theory of blood circulation. Harvey disagreed with the theories of Claudius Galenus (129-200). In contrast to Galenus, Harvey believed that the spontaneous movement of the heart was during its systolic phase. He thought that the movement of the heart itself was caused and maintained by the vital force inherent in the blood. For him, blood was something that pulsated by itself. Descartes did not accept this theory. Instead, Descartes followed the old idea of the internal heat of living things and thought that there was something similar to fire in the left ventricle of the heart. The blood that enters the left ventricle from the cold lungs is immediately vaporized by the inherent heat there, causing the heart to rapidly expand. The vaporized blood then enters the arterial system through the aorta. Descartes thought that the heart would contract, and at the same time, new blood would be supplied from the lungs, and the same process would begin again.

Descartes put forward the dualism of mind and body in the fields of epistemology and metaphysics. On the other hand, he was the first in history to propose the idea of a mechanistic natural philosophy, or neurophysiology and brain science based solely on physics, in relation to the body and mental activity related to the body.

The neurophysiology and brain science that Descartes proposed, like his cosmological physics, was not a complete theory, and the specific theories it proposed had to be corrected. Descartes is the originator of the modern view of neurophysiology and brain science, which seeks to explore the functions of neurophysiology and brain activity in the context of physics and chemistry. Let's make sure of that point.

Descartes explained the circulation of the blood from a mechanistic perspective, regarding the heart as a kind of heat engine where the blood is heated. However, this was incorrect, and

Harvey's theory that the heart functions like a pump was correct.

Harvey explained the muscular movements, sensory perception and overall cognitive activity that are common to humans and other animals by appealing to the concept of “animal spirits”, which had been adopted since the ancient physician Galen as a type of vital substance that is added to the blood. However, Descartes brought about a decisive change in the history of medicine at the time. He essentially changed the meaning of the concept of “animal spirits”, stripping it of its vital meaning and reducing it to a purely physical object. According to Descartes, “animal spirits” were extremely fine objects that were heated and diluted in the heart, and only these could enter the empty spaces of the brain and fill the ventricles to perform various movements.

In this way, Descartes eliminated the “chance” between the state of mind and the state of the body from the physiological analysis he himself had opened up. On this basis, he thought that the mind could control the relationship between the body and the mind, and that the workings of the will originated in the mind, and that consciousness had the mind as its cause.

On the other hand, Descartes was the first in history to present a mechanistic view that explained not only physical nature, but also the entire human body, including the brain, and he stated that “my mind” as a “thinking thing” did not belong to that nature.

On the existence of free will

Trying to understand the act of “disagreeing” with something that is thought to be “skeptical” or “self-evident” is nothing other than an attempt to grasp the nature of “active will”, or to understand consciousness as active will. In fact, through his methodical doubt, Descartes not only presented the nature of the “consciousness of thinking” in “I think”, but also brought about the subjective awareness of free will, which is the ability to “disagree with anything”. For Descartes, decision-making is a “decision made by free will”, in which one chooses one option from a range of options, and has the ability to disagree with even things that seem obvious. The Cartesian consciousness is inseparable from the consciousness of the “subject” of “free will”. The question of how to understand and accept this free will is directly linked to the question of how to grasp “consciousness”.

When we try to understand the consciousness of the mind in relation to “skepticism” or the act of “disagreeing” with something that is normally considered self-evident, we are in fact trying to understand the nature of “active will” and grasping consciousness in terms of “active will”. This means that it is possible to “disagree” with something that is considered self-evident. We are able to “affirm or deny” things. 'Decision-making' is to take a position that acknowledges the existence of free will, which is to say that we actively choose one option

from among multiple choices.
If we follow ordinary, or naive psychology, we implicitly acknowledge the existence of the mind, and do not believe that it is spatially extended like an object. As long as we do not think of the mind as something that is spatially extended like an object, we are accepting the fundamental heterogeneity between the mind and objects. If this is the case, then while we recognize the uniqueness of “I move my arm” as a real experience, we are accepting a dualism between the non-spatial existence of the “mind” and the physical world with its spatial expansion.
I actively acknowledge the “freedom of choice” of the “will” based on Descartes' philosophy of the mind. Firstly, it is based on the fact that we can always willfully “doubt” and “disagree” with anything that can be the object of our thoughts. No matter how much we intellectually understand a certain system, we can disagree with it and even go against our understanding of it. When we affirm something, we are aware of the “decision to choose” that we are making when we affirm it. In the physical execution of this action, we experience the “causal efficacy of mental causation” that says “my mind moves my body”.
In this case, since we make free will the “principle” of our judgment and action decisions, free will is not an illusion. When we make judgments and action decisions in our “choices”, we are embodying freedom as a reality.
In order for us to recognize others as having an “other-self” that is equivalent to our own “self-self”, it is first of all essential to understand that others have self-consciousness and intentions. Secondly, it is crucial to understand that through verbal interaction with others, we cannot know what others will do intentionally towards us, in other words, that they are “free agents” who can please or deceive me.
We do not grant our pets, such as dogs and cats, the same status as ourselves. This is because we know that even if our pets are there to make us feel at ease, they are not capable of deliberately deceiving us using the same language as us.
In order for us to recognize the “other” as an equal “I”, it is necessary for us to experience “passivity” in relation to the other. Thus, in order to recognize the existence of the “other's mind”, a “reciprocal relationship” mediated by “linguistic action” is essential as a third point. In this way, we can recognize the “other” as an “other-self” equal to my own “self”. In order to recognize the “self” in the “other”, it is crucial to perceive, through mutual verbal action, a “free agent” within the other's activity who has rational intentions but whose actions cannot be predicted.

My opinion

In the world of American philosophy, the philosophy of mind has come to occupy a large area. It seems that the theory of the mind as an entity is examined, with the Cartesian dualism of mind and body being taken up first. And in most cases, the idea of the mind as an entity independent of the body is judged to be “metaphysical” in a bad sense, and in some cases even “mystical”, under the influence of “physicalism” and “naturalism”, which are currently having a major impact.

I think that the distinction between the mind that arises directly from the brain as a physical body and the mind that arises further from the mind is being neglected. The physical mind arises directly from the brain, but that mind makes the body act in a way that allows it to exist. The mind that arises from the mind generates a mind that makes it possible for the body to continue to exist for a longer period of time than the mind that arises directly from the brain as a physical body, and makes the body act in accordance with that thought. Having a social mind of this high dimension stabilizes one's own existence and makes one realize that one's own time of existence in the real world can be further extended.

Regarding the concept of “animal spirits” that Descartes thought of as a type of life substance that is added to blood, I think he may have imagined a substance that has the role of relating the functions of each organ, such as hormones, which are information transmitters in the modern world. This could not be discovered due to the limitations of medical technology at the time. As I am not a doctor, I do not have sufficient knowledge on these matters. I cannot judge how accurate Descartes' explanation of physiological functions is. Even if it is an explanation that differs from modern medical explanations, it can be seen that Descartes thought that there were physiological functions that were controlled by human will and functions that were controlled automatically and unconsciously.

If we consider the effects of consciousness or the mind on the mechanical physiological functions of the human body, we can see that the physiological functions of the human body operate automatically as a machine, independently of consciousness. However, the way in which these functions are controlled changes depending on the state of the mind or spirit, and this can cause various changes in the body. Descartes explains this in detail using the medical knowledge of his time. Descartes attended several dissections of the human body and studied them.

There are also two types of muscles: voluntary muscles, which can be moved at will, and involuntary muscles, which cannot be moved at will. For example, the skeletal muscles used in actions such as raising your arm or straightening your leg are voluntary muscles, as you can move them when you want to. In contrast, the heart and internal organs cannot be moved or

stopped by the will, so the cardiac muscle and smooth muscle are involuntary muscles. Many of the physiological functions of the human body are controlled automatically, regardless of our will. This is precisely why we are called an automatic machine.
If I had to sum up the scientific revolution in a few words, I would say that it was the addition of a perspective from outside the Earth to conventional knowledge. If you read various commentaries on Descartes' physics, you may find that some of them point out that there are a few errors in it. However, Descartes was a man chosen by God, so I think there is a higher-dimensional world in which his explanations are correctly expressed. Descartes did not discover his laws through experiments, as Galileo did, but rather expressed deeper, more fundamental laws through contemplation. Therefore, the world he expresses may be deeper.

This is a topic from the field of dentistry. It is taken from a previous post.

On Descartes' Theory of Biomechanics

(Descartes' philosophy and the problem of theory of biomechanics, Eitaro Honda, bulletin of the faculty of foreign studies, Aichi Prefectural University, No. 38, Language and Literature, "This text is excerpted and additionally edited from the PDF version")

Descartes' role in the history of the quest for scientific knowledge is undeniable. His mechanical world theory can be applied to various fields and, according to the traditional division of worldviews, is deeply relevant not only to the macrocosm, which is the universe, but also to the microcosm, which is the living organism. We should not look for the significance of the scientific revolution of the 17th century only in its physical achievements, but also in the fact that in Harvey and Descartes the human being became the subject of serious medical and physiological research. Descartes' unfinished book on physiology, "Description of the Human Body," which he was working on in his later years, describes the following.

William Harvey (1578-1657) was an anatomist and physician in England and the English Republic. While honing his skills as a physician and rising to the rank of court physician, he also studied anatomy and advocated the theory of blood circulation.

One of the important achievements of Hippocrates medicine was to separate it from primitive superstition and witchcraft and to develop it into an empirical science that emphasizes clinical practice and observation. Descartes' philosophy of the living body is not the kind of medicine that preserves the health of the human body, cures disease, and expels it, as in Hippocratic medicine. The distinctive feature of Descartes' philosophy of the living body, which is medicine, is that it remains in the realm of physiology, the full description of healthy human nature, which is the first division of its basic sciences.

It was Descartes who most clearly presented human and animal mechanism on the basis of a mechanistic view of nature, and given the magnitude of his influence, we are compelled to consider this issue in Descartes' terms. The characteristic feature of Descartes' idea of biomechanics is that the natural and the mechanical are homogeneous, since they can be interpreted by mathematics when illuminated from the viewpoint of natural science.

The central issue of natural science in the modern era may be considered to be the problem of motion of objects. In this case, two worlds are traditionally considered. One is the macroscopic world. It is the world of infinitely addable, decomposable, and thus open to infinity and infinitesimals. The other is the micro world of living organisms. It is a spatially limited and closed world whose underlying principle motion can be understood.

The former is the motion of celestial bodies, rooted in the principle of inertia that led to Galileo Galilei, Descartes, and Newton. The latter is the "perpetual circulatory motion" of the blood represented by Harvey's physiology. Thus, if we take the two motions as images, we can think of the motion of each world as represented by a straight line and a circle, respectively. The inertial motion of an object in a celestial body is a straight line. And the circulatory motion of blood in a living body is a circular motion. In this case, which seeks the principle model of mandibular motion in the field of dentistry from Descartes' biomechanics, the circulatory motion of blood in a living body is irrelevant, so I will not mention it here.

Descartes states that the motion of living bodies and the motion of machines are the same, so they do not require special principles, but are under the laws of the mechanics of objects, which are rooted in the law of inertia. The motion of living bodies and the motion of machines are continuous. We are entering the realm of mechanics, a point about as far removed from physiology or biology as we can be from the organism. Descartes, however, does not believe that this way of understanding the living organism lacks scientific verification and rigor.

Descartes' theory of living organisms is characterized by many references to machines. Descartes made many references to machines while relying on anatomy. Descartes relied on anatomy, but made many references to machines because he wanted to place the motion of living organisms in a mathematical dimension. This is because natural science is strictly the study of mathematics, and mathematics is the foundation on which mechanics is based.

The investigation of the motion of living organisms should not be thought of as an object of knowledge inquiry based on some unknown principle unrelated to the rigor of mathematics, since its object is a living object, i.e., life as an object that moves automatically. Descartes believed that anatomy and mechanics would reveal the direction of knowledge in the study of living organisms. The sure inference of the essential identity of the machine and the organism is disassembly in the case of the machine and anatomy in the case of the organism. Descartes attempted to elucidate the motion of living organisms from a mechanistic point of view, supported by an experimental spirit. Descartes' thought should not be easily judged as an argument that begins with dogmatic definitions and principles based on hypotheses.

Descartes' work may not be sufficient as a scientific truth, but it still holds great potency in the direction of the study of the physiology of the living body. As long as man is considered as an object of natural science, the functions of the body can be explained essentially on the basis of the laws of mechanics.

Descartes describes the difference between living organisms and machines as follows. "Man is capable of building many different kinds of automatic machines, moving machines that resemble animals. But the machines that imitate animals use very few parts compared to the multitude of bones, muscles, nerves, arteries, veins, and all the other parts of the living body. Since the human body is made by the hand of God, it may be regarded as a machine that has order and motion in it that is incomparably more orderly and marvelous than any machine that could be invented by man. We can think of the difference between a machine made by the hand of God and a machine made by the hand of man not as an intrinsic difference, but as a quantitative difference in degree of complexity."

If Descartes had rejected the past Gnathology and redefined the "centric relation", how do you think he would have done it?

From this heading, gnathology is already being described as a forsaken concept, but as a dental technologist, I don't think I am qualified to make a statement. What I am trying to say here is that gnathology was a discipline that aimed to study and treat the maxillofacial system as a functional unit, and it set the direction regarding subsequent dental treatment. As a matter of fact, in a report titled "Reconsidering the centric relation (Theory)" in the special issue of the July 2022 issue of Shikai Tenbo, it is reported that "Today, few clinicians record the terminal hinge axis."

Here I have tried to introduce the concept of autopoiesis into dental technology, although it is of course impossible to think about it without knowledge of dental technology. This is not something that I started by coming up with in my clinical experience in dental technology.

Hence, I thought that dental technologists, not dentists, could make some reference to gnathology. The concept of autopoiesis is not specifically related to dentistry. Descartes' theory of biomechanics is not specifically related to dentistry, but American dentists introduced it and created gnathology. I think that the introduction of the concept of autopoiesis into dental technology is similar to the introduction of Descartes' biomechanics.

The concept of autopoiesis is a theory in theoretical biology that was proposed in the early 1970s by the Chilean biologists Humberto Maturana and Francisco Varela as a way of answering the essential question of "what is the organic structure (organization) of life?". (From Wikipedia)

Gnathology is a discipline proposed by American dentists Harvey Stallard (1888-1974) and Beverly B. McCollum (1883-1968) that aims to restore oral and maxillofacial function, primarily through occlusal reconstruction of the dentulous jaw.

Let us consider the definition of an ideal bite. Ideal occlusion is the bite state assumed to be most appropriate for humans. Descartes does not mention the state of the human jaw or bite, but he states that the human body was created by the hand of God. If Descartes did mention the state of occlusion, he would have assumed that it was physically created in an ideal state. I tried to imagine how Descartes would have described it.

The human body is ideal, perfect and impeccable because it was created by God. Therefore, the human bite is also ideal. God created the human "design". However, the actual human bite, made of matter, was not directly created by God.

What does God's design look like? The upper and lower rows of teeth are ideally aligned. Furthermore, the occlusion of the upper and lower dentition is also ideal. When the mandible begins to open, the mandibular head initially moves in a pure rotational motion without any blurring. The ideal occlusion is one in which the mandibular head gradually moves forward and downward as the degree of opening of the mandible increases. However, we will not go into the specifics of how the individual teeth are aligned and how the upper and lower meshing is constructed.

(URL: https://krdental.com/project/centric-relation/)

What is the difference between "the real biological jawbone and dentition" and "the ideal jawbone and dentition designed by God?" Let us borrow a concept from Descartes' biomechanical theory to express the definition of centric relation.

When the mandible opens in the ideal state created by God, the mandibular head of the mandible undergoes a pure rotational motion with no blurring at all in the initial state of the opening motion. However, it is inconceivable that the mandibular head of the real jaw would rotate in a pure, unshakeable manner. I do not think that a pure hinged axis exists in a living organism. There are six degrees of freedom in a kinematic rigid body. Therefore, the mandible also has 6 degrees of freedom. Although a kinematically pure hinge axis exists in the mandible, I do not think that muscles can actually make the mandible do only geometrically pure hinge axis motion.

The centric relation can be described as the positional relationship between the condyle head of the mandible and the mandibular fossa of the maxilla when the upper and lower dentition are in the central occlusal position, which is the ideal state created by God. What is the difference between the ideal state created by God and the actual positional relationship between the condyle of the mandible and the mandibular fossa of the maxilla in the actual living organism?

I think the difference is whether the tissues around the joint head of the mandible, including the muscles and other driving systems that move the mandible, are optimized by the organism itself, or whether the tissues around the joint head of the mandible are built by God.

However, since the ideal state is God's design, humans cannot know what exactly it is like. The only example that can be used as a reference is the state of the tissues of similar parts of a healthy human being. This is the closest we can get to God's design. The ideal state is specifically unknown. Since God's design is an ideal, even an optimized version of reality may be slightly different from the original ideal state. The question is whether God's design and optimization in reality are congruent.

How have humans optimized their dentition, jaw bones, tissues around the mandible head, etc. during periods of physical growth and completion, etc.? In my opinion, perhaps the organism has a kind of divine blueprint and grows to match it. However, this may change depending on the individual's living environment and lifestyle. The meshing of the human dentition and the positional relationship between the condyle head of the mandible and the maxilla within the mandibular fossa/articular fossa would be expected to have gradually established a relationship as the body grew. Therefore, even if the centric relation must be determined in a short period of time for treatment, it will have to be done by trial and error.

When treatment requires occlusal reconstruction, a new centric relation must be determined. Conventional thinking, in order to understand Descartes' biomechanical theory in terms of the categories of "necessity and chance," has led dentists to dogmatically determine the position of the mandibular head as a matter of necessity.

I believe that "optimization" arising from autopoiesis, which I introduced, embodies the original Cartesian idea of biomechanics, rather than a dentist's dogmatic determination of the centric relation.

The centric relation is the kinematic reference position for the biomechanical theory. I think that the application of the dynamical systems theory of "variety and uniqueness" suits Descartes' biomechanical theory. When the ideal becomes reality, it is considered to be optimized by the organism itself, even if it does not coincide with the ideal for various reasons.

The terms "centric relation" and "terminal hinge-axis" are similar concepts, but I believe that "terminal hinge-axis" is the very "centric relation" designed by God in Descartes' biomechanical theory. I believe that the positioning of the upper and lower jaws in the centric occlusion of a healthy human being is referred to as the "centric relation". Descartes would have thought of it this way. Even if the movement of the mandible at the centric relation is different from the ideal, it can be said that this is the result of "optimization" in the real world. In other words, the "centric relation" in the real world is the position relationship (the position relationship between the condyle of the mandible and the mandibular fossa/articular fossa in the maxilla) of the upper and lower jaws in the centric occlusion of a healthy human being.

This is my opinion, but I think that conventional gnathology is an idea derived from Descartes' biomechanical theory, and that meaning is made in a theoretical system from the combined categories of necessity and chance. I think conventional gnathology is one way of expressing biomechanical theory in dentistry. The treatment from the combined categories of necessity and chance has been reworked into the problem of determining the position of the "centric relation". Although the term "inevitability" and "contingency" are used, the strict rules of inevitability and the ambiguity of contingency are so closely intertwined that it is difficult to separate them accurately in practice. It seems that Japanese dentists have had quite a bit of trouble with this. Some dentists took it seriously, but others were not interested in this kind of thing.

I first learned the word gnathology more than 40 years ago. It was some time after I became a dental technologist. What I learned then was that the human mandible has a purely rotational axis, like a robot's jaw. I thought, "This is a curious story." Other than that, I thought it made a reasonable amount of sense. But then again, this is all about diagnostics. It would be valuable to know where the "centric relation" is if the dentist himself were actually doing the dental work. However, I also thought that it would be meaningless for a dental technologist who specializes in making prosthetics to study such things.

The reason for this is that the dental technologist actually makes the dental prosthesis, but basically has no access to the patient in question. In difficult cases such as these with occlusal reconstructions, it is quite troublesome to try waxing up the dental prosthesis and ask the dentist for his/her opinion and correction at that time, due to the discretionary power regarding the fabrication of dental prosthetics. In addition, the dental technologist cannot see the result of the treatment. So, although it may not be a waste of time to think about this and that, it was tedious and I wondered how it would be done.

In fact, where the axis of rotation is located is a diagnostic matter and is not relevant to the dental technologist. Wherever it is, it is the dentist's own problem and does not directly concern the dental technologist. If it matters to the dental technologist, misalignment of the axis can lead to greater adjustment of the fabricated dental prosthesis and, in the worst case, possible remanufacturing.

Why was gnathology applied in this way to the movement of the mechanical human mandible, despite the fact that gnathology is about the movement of the human mandible? I found it very unnatural. I now wonder again if gnathology was not a starting point from the viewpoint of Descartes' theory of biomechanics, rather than dental medicine as preached from clinical experience in dentistry. The definition of the determination of the mandibular position, the central position associated with the terminal hinge axis, has changed many times over the course of time.

By the way, this is what I think now, that the gnathologists who first devised it asked the people of the world how to interpret the terminal hinge axis. I propose a way to use the "virtual kinematic axis" to address the first invented gnathologists' question that emerges from that deeper reading. The purpose of this is to urge that more consideration should have been given to metaphysical concepts rather than to the relationship between the real world and materialistic worldviews. In the real natural world, few things about motion have a purely rotational and translational component that is separate, and I believe that the motion of the mandible is no exception to this rule.

I believe that conventional gnathology has contributed to binding together the fragmented pieces of dental knowledge. In other words, it means to think of dentistry as a system. It also means treating not only the teeth but also the entire oral cavity, including the jaw joints, as a single unit. In conclusion, I think we need to raise the level of Descartes' theory of the ecological machine beyond what it has been up to now.

Metaphysics is a field of study or philosophy that considers the world beyond the senses and experience to be true existence and attempts to recognize the universal principles of the world through rational thought (or Logos). It considers things that transcend the senses, such as the reasons for the fundamental origins of the world (the root causes of the world) and the reasons and meanings for the existence of things and people. From Wikipedia

Examples of interpenetration of necessity and chance
If you line up 10 steel cubes with 10 mm on a side and measure their dimensions, they will probably be 100.1 mm or 99.9 mm, and they will rarely be exactly 100 mm. In mathematical or arithmetic terms, 10mm times 10 = 100mm. This is in an ideal world, and the reality is that even very small errors, invisible to the eye, can become unwieldy when added up. 10,000, 100 million, or 10 billion pieces would be more significant.

Two measurement and reproduction methods derived from ontology and epistemology

The method of measurement and reproduction from ontology is the so-called conventional pantograph method. Let us discuss the ontological mandibular movement.
As the mandible opens, it begins a rotational movement near the axis that penetrates the right and left intercondylar axes. As it opens more widely, the left and right mandibular heads slide anteroinferior almost equally as they rotate.
Next, let us consider right and left lateral movements. During right lateral movement, the right condyle head rotates with a small lateral shift within the mandibular fossa. In contrast,

the left condyle head slides anteriorly inferiorly medially. The opposite is true for left lateral movement. During left lateral movement, the opposite is true.

This is the method of consideration governed by the determinants of mandibular motion. For the anterior determinant, it is anterior guidance during contact movement. During mouth opening motion, there is no anterior determinant.

These expressions are ontological interpretations of mandibular movement derived from biological mechanisms. No one would dispute this. That is why conventional measurement methods used instruments such as pantographs to explore the position of the condyles under the skin to determine the intercondylar axis. They also examined the movement and rotation of the working and non-working condyles during left and right lateral movements. These measurements are truly “ontology-derived methods.

On the other hand, my proposed method of measuring and reproducing mandibular movement, the virtual kinematic axis method, is a method that does not derive from the biological mechanism of mandibular movement, the left and right condyles or anterior guidance.

What does the virtual kinematic axis method dependent on? It can only depend on how mandibular movement is measured. The mandible can be thought of as a rigid body. However, the mandible is covered by soft tissues such as muscle and skin, and it is not easy to locate the exact position of the mandibular head from the outside.

The mandible is connected to the dentition, which is exposed to the outer skin. The dentition and mandible are tightly integrated by the periodontal ligament. Thus, they can be considered as one rigid body.

In other words, measuring the movement of the mandibular dentition is measuring the movement of the mandible. This method of measurement is independent of the intercondylar distance, which varies from individual to individual. It is truly an epistemological measurement method.

The exact path of motion of the mandible can be obtained by giving the mandible three points on the dentition, which is tightly connected to the mandible by the periodontal ligament. These three points do not have to be set directly on the dentition. As shown in this example, a probe with three points can be rigidly connected to the dentition.

The path of movement of the mandibular cannot be known without mathematical processing of the displacement of three points in three-dimensional space. If we want to know the path of movement of a specific position of the mandible, such as the mandibular head, we need a 3D MRI image. In other words, these two measurement methods are complementary, and we need information from both to know the entire mandibular movement.

A face-bow transfer and a three-point motion pathway are sufficient to use the acquired data

in the articulator; MRI three-dimensional images are not required.
The virtual kinematic axis method measures three coordinate points attached to the dentition. This means that mandibular motion must be represented mathematically in three-dimensional space. When it is not necessary to strictly locate the position of the condyles, a face-bow transfer is all that is needed to make the rotational axis of the articulator the intercondylar axis of the organism.
The 3D MRI image data of the mandible can be superimposed on the dentition to view accurate condyle head movement. These methods can be achieved extremely easily with "general-purpose CAD".
Living organisms have a slightly different mode of motion than human-made machines. Unlike the geometric motion of a robot, the motion of a living body fluctuates. The detailed movement of the mandible can be viewed again and again by accurately extracting the subtle motions and restoring them on the CAD system.
In any three-point measurement, the left and right condyles and the anterior reference point can be likened to the oscillator since they are the determinants of mandibular motion. Any three points can be the transmitter of the position and path of motion of the entire mandible. The camera captures the movement of the dentition and changes in mandibular posture, so the camera and other sensors are the receivers.
The position of the condyle head can be reconstructed by superimposing the MRI image in the CAD. A face-bow transfer is sufficient to transfer the data to the articulator; if the only purpose is to know the path of mandibular motion within the CAD, a face-bow transfer is not necessary. This is possible because of the method derived from the measurement method.

Autopoiesis speaks for itself, looking for a new gnathology

The new gnathology, as I see it, begins with the transformation of the real world into the ideal world. The development of the technology of prosthetic dentistry was intended to obtain an indirect environment for the creation of dental prosthetics. In addition, it could be said that it was a history of searching for a kind of norm regarding the alignment of teeth and so on. Specifically, these norms are things like the relationship between the articulator, which is face-bow transferred and fitted with upper and lower dental models, and each reference point on the face, and the rules for how the teeth are aligned.
They ranged from complex to simple. For example, the ideal environment for the creation of dental prosthetics is the articulator. Since we cannot create dental prosthetics directly in the mouth, we need an indirect environment for fabrication. In addition, "Bonwill triangle," "curve of Spee," and "Monson's spherical theory" provide various guidelines for tooth

alignment, etc.

Recently I have come to believe that the gnathologists who first devised gnathology asked the people of the world how to interpret centric relation. I propose a way to answer that question using the "virtual kinematic axis" and the "Cartesian coordinate system". Today, computer technology, as represented by CAD, is well developed. Computer technology allows the dentist to obtain any number of mandibular motion paths if he or she so desires. In addition, the open/close movement of the mandible, which is not directly related to occlusion, can be added to the path of movement. Thus, instead of seeking an ideal environment in an actual "articulator" as in the past, we can consider mandibular motion in a flexible environment by using a new item called CAD.

In my opinion, the term "terminal hinge axis" or "centric relation" in gnathology is actually not of this world, but the ideal world in dentistry, or the central item in a metaphysical narrative. That is to say. In other words, it is not a real world story. There is a gap between the ideal world and the real world. It is not easy for an ideal world entity to appear in the real world. Some procedure is required.

It has been quite some time since the gnathology was published, and the definition of centric relation has changed many times in that time. That is how difficult it is to define. I think the cause of this difficulty lies in the gap between the ideal world and the real world. I feel that this gap has not been resolved for any length of time. In the real world, necessity and chance permeate each other, and one of the reasons is that it is very difficult to confirm only the pure rotational motion of the mandible in the intercondylar axis applied to the centric relation, i.e., the hinge axis alone.

This is not easy to do, no matter how much the patient himself tries to make only open-close movements that do not involve mandibular movement, and no matter how meticulously the dentist tries to guide the patient to make only purely open-close movements. This has been the experience of many dentists historically. However, it is not absolutely impossible.

If the mandibular head were perfectly spherical and the mandible were symmetrical, there might be only one axis of rotation. However, the human mandibular head is not perfectly spherical, and the mandible is not perfectly symmetrical. Furthermore, there may be two or more axes of rotation due to the presence of various buffering tissues as well as bones around the mandible. On the contrary, it may exist as an area. If that is the case, then there could be an infinite number of rotational axes. This is just a consideration, and the actual situation is not clear without careful investigation.

Let us now consider the relationship between the terminal hinge axis and the centric relation. As quoted from the article "Reconsidering the Centric Relation (Theory)" featured in the July 2022 issue of "Shikai Tenbo," we understand the definition as follows

（Centric relation in the terminal hinge position of the mandible , in which the hinge axis is constant to both the mandible and maxilla.）

Let us again consider the definition of terminal hinge axis or centric relation. The first question is whether the terminal hinge axis is a pure axis of rotation that does not allow even a micron of motion, or whether it allows some motion blur. Currently, there does not seem to be a strict definition of a terminal hinge axis. The latest situation in this area is featured in the July 2022 issue of “Shikai Tenbo,” a dental trade publication, which contains an article titled “Reconsidering the Centric Relation (Theory). It is written by a dentist named Ryushiro Sugita. According to this article, the rotation axis in the centric relation is not “not allowed to blur even one micron,” as defined by metaphysics, but rather “should not blur when visually observed.

On welcoming a “Centric Relation” with a terminal hinge axis to the Cartesian coordinate system

It will allow us to explore whether or not the initial pure mandibular intercondylar axis rotational movement, i.e., the initial rotational movement of the hinge axis only, is possible during the opening movement. It would also show, for example, the possibility that there is more than one. Any number of opening and closing motion paths can be taken, and any number of lateral movement, etc., can be added.

Applying the 3D Cartesian coordinate system to the analysis of the motion of artificial objects such as robots is easily accomplished. However, precisely analyzing the motion of living organisms is a difficult task because of the complex rotational and translational motions involved, which are difficult to reproduce exactly. If we introduce the 3D Cartesian coordinate system, which is the ideal world of computer-aided CAD for analyzing centric relations, we will be able to perform various analyses and verifications.

In CAD, the 3D Cartesian coordinate system allows for easy coordinate transformation. Even if the position where the mandible motion is measured on the body and the position of the drive unit of the articulator are different, the coordinate data of the measurement position can be converted to the coordinate data of the drive unit of the articulator. By using the coordinate conversion, it is possible to reproduce the motion of the mandible model on the articulator as it has been in the past. Also, by introducing the equation of motion, the mandible position can be managed in time because the equation of relationship between the mandible position

and time is created on the CAD.
As a procedure to achieve this, it would be good to introduce the dynamical systems theory, as detailed in the autopoiesis theory, to the dental field. In the history of gnathology, we read, "In 1921 McCollum devised the hinge-axis locator and demonstrated the existence of a terminal hinge-axis." However, this would only be at the visual level. No matter which dentist guides the mandible, there will always be a blur at the micron level. In the real world, it is not easy to find a pure terminal hinge axis that can be reproduced.
When the centric latch of the articulator is activated, the mandibular part of the articulator can only perform pure rotational motion without any blurring. I do not think it is possible to make the mandible move in the real world in a similar way. It would be quite difficult even if dentists applied manual restraints. In the real world, all or several of the "six degrees of freedom of motion" are intricately bound together by the body; in an ideal world using a three-dimensional Cartesian coordinate system, the intricately combined "six degrees of freedom of motion" of the mandible could be broken down to display each component.

About the Virtual Kinematic Axis Method

Why is it necessary to align the axis of rotation of the articulator with the hinge axis of the organism? Rather than a necessity, I believe it stems from the conventional method of measuring mandibular motion. The axis for opening the mandible set in the articulator would have had to be set in a position similar to that of the biological jaw. The July 2022 issue of "Shikai Tenbo," a dental trade publication, features the following article, "Reconsidering the Centric Relation (Theory)," which also states the following.
The terminal hinge axis is the central tenet of gnathology. The supreme goal of gnathology was to reproduce the patient's open/closed mouth motion on the articulator by identifying the terminal hinge axis and aligning it with the open/closed axis of the articulator. Once this is done accurately, the clinical benefits are immeasurable, as a dental prosthetic device fabricated with a modified occlusal vertical dimension on the articulator can be placed in the patient's mouth with minimal adjustment."
This is how the purpose of gnathology is described. As a matter of fact, the relationship between the terminal hinge axis and the centric relation in many people is such that in the centric occlusion, few people have the centric relation and terminal hinge axes coincide. The fact that these are misaligned does not seem to cause or predispose to TMJ disorder. While there are operational advantages for the dentist in the above statements, there does not seem to be a health reason for the purpose of gnathology. After all, gnathology is a concept derived from structuralism in accordance with the fundamentalist theory of biomechanics.

Structuralism is one of the modern philosophies of the 20th century. In a broad sense, the term has been extended from modern thought to refer to a methodology for extracting the latent structure of any phenomenon and using that structure to understand and, in some cases, control the phenomenon. Adapted from Wikipedia

If there are many teeth that have nothing to do with the treatment, the standard of occlusion is the centric occlusion. Usually, the tooth shape of a dental prosthesis is formed based on this position for both anterior teeth and molars. In the real world, if the centric relation of the living body and the axis of rotation of the articulator can truly be aligned, the centric occlusion can be freely determined on the articulator. This means that the height of the occlusion can be changed. This can be done simply by adjusting the incisal pin of the articulator. However, this can only be used in practice when creating dental prosthetics for the entire upper and lower dentition. It is useful, for example, when fabricating occlusal surfaces in ceramic.

In my opinion, in the real world, it is very likely that there is no pure axis of rotation of the mandible in a living organism. If there is even a micron of deviation, it is not the pure axis of rotation of the mandible. The pure axis of rotation of the mandible definitely exists in the ideal world. There is a gap between the ideal world and the real world, and they do not easily overlap. It is necessary to eliminate the gap or bridge the gap between the two. How can we bridge the gap between the ideal world and the real world?

One idea is the virtual kinematic axis method. What is the virtual kinematic axis method? In a few words, it can be described as follows. When the maxillary model is mounted on the articulator, the intercondylar axis of the articulator automatically becomes the kinematic axis of the mandibular model. When the maxillary dental model is mounted on the articulator by means of the face-bow transfer, the intercondylar axis of the mandible is set at the average position of the body. If done by eye, it will be set in a reasonable position. This is the virtual kinematic axis method.

The opening and closing motion of the biological mandible is different from the opening and closing motion of the articulator. Even if they are different, I do not think it is a problem. When making dental prosthetics, differences in the position of the axes in simple open-close motion have no effect on the tooth shape and do not cause any problems in the work. The virtual kinematic axis method is based on the idea that in the real world it is very difficult to find a purely rotational axis in the centric relation with a terminal hinge axis. In cases where only the centric occlusion is at issue, the coincidence of axes is irrelevant, so the virtual kinematic axis method is sufficient. We believe that the terminal hinge axis exists in an ideal world. I just haven't found a way to make that position appear in the real world.

The virtual kinematic axis method does not measure the amount of movement of the axis of

rotation when the patient moves the mandible open and closed. Nor does it have a method to reproduce it. Therefore, when the incisal pin of the articulator is adjusted to change the occlusal vertical dimension, an error will always occur. Whenever it is necessary to change the occlusal vertical dimension, in other words, to change the centric occlusion, it is necessary to obtain a mush bite for confirmation in vivo. The mandibular model must be reattached to the articulator using the mush bite.
If we want to know the true axis of open/closed mandibular motion, we need to load the MRI 3D image of the mandible into an environment where the upper and lower dental models are attached to the articulator on the CAD. When the 3D MRI image of the mandible is loaded and superimposed on the mandibular model, the left and right condyle heads of the organism are displayed. It will probably be slightly off from the intercondylar axis of the articulator. If you use the measured data to move the mandible, you can see on the CAD how the condylar part of the MRI 3D image of the mandible moves.
Dentists have probably never seen a video of the mandibular head moving in three dimensions because they have been measuring mandibular motion using conventional methods. In the conventional method, the three-dimensional movement of the mandibular head is determined based on the projected trajectory on a two-dimensional plane. It is also impossible to reproduce the opening and closing movements of the mandible on an actual articulator.

About the Ideal World

Let us invite the "centric relation with terminal hinge axis" to the ideal world. In the ideal world, there is no error. Even at the micron level, there is zero motion of the axis of rotation. In the ideal world, the "six degrees of freedom of rigid body motion" can be driven individually. It is also possible to combine multiple elements of motion and rotation. In the ideal world, time can move forward or backward. Objects can overlap, touch, or move away from each other, collide, or pass through each other. The ideal world may be the equivalent of the world described by mathematics, for example, theory or physics.
There is no error in the ideal world; there is error in the real world. This error refers to dimensional differences that occur unexpectedly due to chance and necessity. Even in the ideal world, depending on the setting, there can be a very large number of mathematical decimal places in the setting.
Also, in the ideal world, elements can exist individually, whereas in the real world, multiple elements exist in connection. This arises from the idea of interpenetration. They cannot be easily separated by humans. Therefore, there must be an interface between the real world and the ideal world, and trying to directly superimpose or connect the ideal world and the real

world will not work. To access the ideal world from the real world requires error resolution and interpretation of the ideal world from the real world.
It is the dentist who actually operates the mandibular measurements. Dentists and dental technologists operate CAD and other equipment, but the operation must be within the scope of their daily work. Equipment that is too expensive or time-consuming to operate is not acceptable for practical use.

About Ideal Parts

The component-related elements for mandibular movement that are indirectly represented are fabricated as "ideal parts" in CAD. For example, the length of the left-right intercondylar axis in the ideal world is the same for all, 110mm. In the conventional method, the inter-condylar distance would have to be changed. In the ideal world, the shape of the left and right condyles of the mandible are perfectly spherical and perfectly symmetrical in position with the midsagittal plane. There is only one axis of rotation. The reason for this is that the focus is on accurately reproducing the motion of the dentition rather than the mandible. These were made possible by performing a "coordinate transformation" in a three-dimensional Cartesian coordinate system.
If the maxillary dental model is mounted on the articulator without face-bow transfer, the maxillary dental model will be mounted off the reference plane of the articulator. Even in such a case, the virtual kinematic axis method does not cause any error in the motion data of the mandible. There is only an error between the reference plane of the organism and the reference plane set in the articulator. If no face-bow transfer is used, the Bennet angle and Condylar guidance inclination and the Angle of incisal path may deviate from the average values.
In the virtual kinematic axis method, the length of the left and right intercondylar axis is fixed at 110 mm. There is no difference between men and women, no difference in age, and no difference in ethnicity. It is constant in all. If for some reason we want to know the true left-right condylar motion, we can do so by showing the positional relationship between the mandibular dentition and the left-right condylar regions of the organism on CAD. The length of the left-right intercondylar axis is 110 mm, which is the length currently employed in articulators of similar size to the living body. The technique of "coordinate transformation" in a three-dimensional Cartesian coordinate system makes this possible.
The left and right condylar areas of the articulator are the reference for manipulating the movement of the mandibular portion of the articulator. The length of the axis between the left and right condyles in a living body differs from person to person. In addition, the three-

dimensional position of the condyles in a living body is not perfectly symmetrical about the median plane. What is important in this virtual kinematic axis method is the change in the three-dimensional position of the mandibular dentition in relation to the maxillary dentition. Three-dimensional positional changes of the mandibular dentition are collected using the "pre-labial measurement method". This data is used to reproduce the displacement of the mandibular model position on the articulator in the CAD. The data collected in front of the lips is converted into the motion of the condylar ball and the tip of the incisal pin on a virtual kinematic axis with a left-right intercondylar axis length of 110 mm. It is not a reproduction of the specific positional motion pathways of the left and right mandibular heads that exist in the organism.

About Precision Provisional Restorations for Measurement

When fabricating a dental prosthesis with a large number of teeth, a precise provisional restoration will probably be needed to measure the positioning of the maxillary and mandibular dentition. Its anterior tooth county portion has anatomical morphology and is given accurate anterior guidance. The molars have a occlusal vertical dimension that the centric occlusion is maintained and reproduced. It would be even better if the molars also had an anatomical form. A 3D printer could be used.

What can you do in an ideal world?

There are ideas from the categories of coincidence and inevitability, but suddenly something interferes or leads to something else, and this was a story that works among those who look only at the real world. When we stick to the real world in this way, there is nothing definite about the future. There is always uncertainty.

Also, the term "ideal world" does not mean a world of convenience. In the ideal world, the future is already determined, and there is no such thing as a future based on ideas of chance and inevitability. In the ideal world, the past, the future, and everything else is already known. Even if you hide in the shadows, you will be found. Everything is in full view. It is like the world of Adam and Eve in the Old Testament book of Genesis.

However, not everything about the ideal world is revealed to humans. And although humans are trying, they still do not have full access to the ideal world. The categories of chance and inevitability cannot describe, explain, or access the ideal world because they belong to different worlds. Thus, we cannot interact with the ideal world from the categories of chance and necessity.

To access the ideal world, we need to think from uniqueness and diversity. Thinking in terms of uniqueness and diversity, we think of convergence to one reality out of many possibilities. In the ideal world there are all possibilities, but not all can be realized in the real world. This is because there is a consistency problem. The ideal world is a higher concept than the real world, and by sharing the ideal world with the real world, the real world can be brought closer to the ideal world. The ideal world may be paraphrased as dealing with the abstract world from the perspective of the real world.

The term symmetry is used as a means of explaining or expressing the connection between the ideal world and the real world. Symmetry has a slightly different meaning depending on the academic discipline with which it deals. In general, symmetry refers to operations that do not change appearance, such as symmetric transformations. Also, in physics, symmetry is the symmetry of a physical system, that is, the invariance of the appearance of the system under a particular transformation. In mathematics, there are issues such as the solvability of equations, as in Galois theory, and the representation of constructive methods of algebraic structure, as revealed by the exercise of group theory.

Symmetry is the property that "moving it does not change its appearance". Therefore, it is inversely related to "movement" or "change". This property could be used to analyze the change of space between occlusal surfaces. I believe that the study of the proximity relationship between the occlusal surfaces of the maxillary and mandibular molars and the mechanism of mastication has not been the subject of much research or has been done. I believe that symmetry is the key to solving the problem of changes in the space between the occlusal surfaces. The shape of the occlusal surfaces of the maxillary and mandibular molars may change, but what remains the same is the occlusal vertical dimension at the centric occlusion. What shape of the occlusal surface should be used for a good bite? In addition, there are many factors to be studied, such as the shape of the occlusal surface that is physiologically reasonable when considering the load on the roots of the teeth.

No matter how good a tooth is, it is impossible to talk about function without considering the opposing teeth. In other words, analysis of the shape of the occlusal surfaces of the molars is meaningless without taking into account the opposing teeth. Function is largely a function of the movement of the mandible. This means analyzing the proximity of the occlusal surfaces of the upper and lower molars, or to put it another way, looking at the shape of the occlusal surfaces in terms of symmetry. In summary, I believe that rather than studying the occlusal surfaces of the teeth themselves, we should now study the changes in the space they create, which will lead to the discovery of new functions.

It is true that the concavity and convexity of the occlusal surfaces of molars exist in response to the concavity and convexity of the opposing teeth, but why are they shaped the way they

are? We don’t know what is the purpose of the shape of the occlusal surfaces. I don’t think it is just a random unevenness, but I don’t know why. Of course, I think it is shaped based on the presence of the opposing teeth and the movement of the mandible.
In dentistry, symmetry is the study of how the space between the occlusal surfaces changes with the opposing teeth. The use of finite element methods and fluid analysis is important. Symmetry is the mechanism of the natural world, which is made up of structure and energy. Symmetry allows us to know the whole from one part or half of things, based on relationships, etc. By abstracting things, idealizing things, and using mathematical models, we can create a depth and breadth that has never been seen before. Humans extracted the abstract world from the real world, but I believe that the ideal world actually preceded the real world, and the real world was created by the fruition of the abstract world.

For dentists interested in dental technology

One reason for the decline of gnathology is that dental technology has been transferred to dental technologists over time. Dental technology has become less involved with dentists. To fully and freely design a dental prosthesis requires 100% discretion over the treatment. I believe that dentists who embrace and practice gnathology have an extraordinary interest in dental technology. This is evident in the history of dentistry. The history of the construction of the occlusal appliance, an ideal environment that simulates the living body, was intended to produce an ideal dental prosthesis, and I think there is a strong recognition that dentists should be actively involved in dental technology as well. Today, we have entered an era in which the use of artificial intelligence is becoming possible in earnest. I believe that many dentists would like to design their own dental prosthetics. I would like to see the “design of dental prosthetics” put back in the hands of dentists with the help of artificial intelligence.

End of topics in the dental field.

Part II

Diversity and uniqueness came about as a solution to skepticism

Bibliography quoted in the Second Part.

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Richard Henry Popkin
Matao Noda, Akio Iwatsubo (Translator)

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Katsuhiko Ito

On Skepticism

This research is not about a series of doubts directed at traditional religious beliefs, but rather about skepticism as a philosophical view that has its origins in ancient Greek thought. The diverse skeptical reflections and skeptical attitudes of the early Greek thinkers were divided into two main schools during the Hellenistic period. One is the view of Academic Skepticism, which states that no knowledge is possible. The other is the view of Pyrrhonist Skepticism, which developed into a set of arguments proving the view that, as there is only inadequate evidence to determine whether or not some knowledge is possible, we must refrain from making any judgments on any issues concerning knowledge.
The term “Academia Skepticism” is derived from the fact that it was formulated in the third century BC at the Academy of Plato. It developed from the Socratic (c. 470 BC - 399 BC) reflection that “What I know is that I know nothing”. Above all, they developed a series of arguments to show that nothing can be known, in opposition to the cognitivist claims of the Stoic philosophers. I think that doubting is one of the wisest ways to proceed with an argument. A categoricalist philosopher is one who asserts that they have ascertained some truth about the real nature of things. The aim of the Academy school of sceptical philosophers was to show, through a series of arguments and questions, that categoricalist philosophers could not be certain that they were perceiving things with absolute certainty. The Academicians formulated a series of difficulties that showed that the information we obtain through our senses cannot be relied on, that we cannot be sure that our reasoning is reliable, and that we do not have any

guaranteed signs or criteria for determining which of our judgments are true and which are false.

The beginning of the Pyrrhonist movement was the legendary philosopher Pyrrho (c. 360-275 BC) from Elis in ancient Greece, and his pupil Timon of Phlius (c. 315-225 BC). The stories that are told about Pyrrho tell us that he was not a theorist, but a living example of a thoroughly skeptical person who never got involved in any judgment that went beyond what was apparent at the time. His main interest seems to have been ethical and moral. In this area he tried to avoid the misfortune that naturally arises from the acceptance of value theory and the judgments that result from it. If such a value theory is even slightly doubtful, then its acceptance and use will only cause mental anguish. Pyrrhonism, as a theoretically formulated form of skepticism, was founded by Aenesidemus (c. 100-40 BC). When the categoricalists say "something can be known" and the Academicians say "nothing can be known", the Pyrrhonists thought that "both of them are categorical".

From around the 2nd century BC to the time of Sextus Empiricus (2nd to 3rd century AD), the Pyrrhonist movement seems to have flourished mainly among the medical community around Alexandria as an antidote to the categoricalism of other medical communities, both positive and negative.

This position is still known today through the writings of Sextus Empiricus, author of "Outline of Pyrrhonist Philosophy", and his magnum opus "Refutation of the Scholars", which uses skepticism to destroy and demolish all kinds of laws, from logic and mathematics to astronomy and grammar.

These two schools of skepticism had little impact after the Hellenistic period. The Pyrrhonist view was almost unknown in the West until its rediscovery in the 16th century. The Academy view was mainly known and discussed through the writings of St. Aurelius Augustine (354-430). Even before the period we are about to discuss, there were signs of a skeptical mindset among anti-rational theologians, whether Jewish, Muslim or Christian. This theological movement reached its peak in the 15th century in the writings of Nicolaus Cusanus (1401-1464) in the West, and many skeptical arguments were used to overturn the conviction of religious awareness and a rational approach to religious truth.

The period we will be discussing, 1500-1650 AD, is not the only time when ancient skepticism had an impact on modern thought. We can also see the influence of ancient skeptics before and after this period.

Skepticism seems to have played a unique role in the period from the Reformation to the formulation of Descartes' philosophy. This particular role is based on the fact that the intellectual crisis caused by the Reformation coincided with the rediscovery and revival of the arguments of the ancient Greek skeptics. In the 16th century, the rediscovery of a manuscript of the works of Sextus revived interest in ancient skepticism and the application of its views to contemporary problems.

We do not mean to downplay the other role that the views of ancient skepticism played in attracting the attention of thinkers in the 16th and 17th centuries. However, Sextus' work seems to have played a particular and powerful role for many of the philosophers, theologians and scientists we are considering here. It is also thought that Sextus was the direct or indirect source of many of their arguments, concepts and theories. It is only in Sextus's work that we find a complete introduction to the position of the Pyrrhonian Skeptics and all of the weapons of dialectic (dialectics) that they used to oppose so many philosophical arguments.

For this reason, thinkers such as Montaigne, Mersenne and Gassendi looked to Sextus for material to use in dealing with the issues of the day. I also think that this crisis is more appropriately described as a "Pyrrhonist crisis" than as an "Academian crisis".

At the end of the 17th century, the great skeptic Pierre Bayle (1647-1706) thought that the reintroduction of the Sextus debate was the beginning of modern philosophy. Many writers of this period used the term "sceptic" as being the same as "Pyrrhonist", and they often followed Sextus's view that the Academic sceptics were not really sceptics, but negative categoricalists.

The history of skepticism we will consider here ends with the death of Descartes. The reason for this limitation is that it seems to me that skepticism played one role up to this point and another role after that.

The exact opposite of skepticism is categoricalism, the view that it is possible to present evidence to prove that a particular non-empirical proposition cannot be false in any way. Like the skeptic we are considering here, I also cast doubt on the categoricalist claim, and ultimately I think this claim is based more on faith than on evidence. If this is the case, then any categoricalist view will be more or less faith-based. If this is demonstrated, then the skeptic will be convinced of something and become a categoricalist.

The source of diversity is Herbert of Cherbury's book "On Truth"

Neither Edward Herbert, 1st Baron Herbert of Cherbury (1583-1648) nor Jean de Silhon (1596-1667) fully recognized the depth to which the "new Pyrrhonism" had overturned the foundations of human cognition. However, they both knew that this problem had to be dealt with in a new way. The former proposed an elaborate method for discovering truth, and the latter tried to present some fundamental truths that could not be doubted. However, René Descartes, the greatest opponent of skepticism, realized that both of them were making a fatal mistake because they did not understand the fundamental point of contention. Silhon wrote

the books “Two Truths” and “On the Immortality of the Soul”.
Herbert was the ambassador to France from 1618 to 1624, and it was there that he came into contact with the current of skepticism and the attempts to counter it. It was also during this time that he became acquainted with Mersenne, who is thought to have translated his book into French, and with Gassendi, to whom he gave a copy of his book.
After spending many years on this great work (which he began in 1617, before becoming ambassador to Paris), he was overcome with fear and trepidation about whether the book would be accepted by the world, but Herbert accepted what he thought was a message from on high, and finally published “On Truth” in 1624.
The book begins with a description of the miserable state of learning at the time, the confusion of beliefs, and the various disputes. There are people in the world who can perceive everything, and there are people who can perceive nothing. Herbert claimed that he did not belong to either of these schools of thought.
Or to be more precise, he thought that something could be recognized. What we need to recognize and evaluate our perceptions is a definition of truth, a sign of truth, and a method of discovering truth. When we discover all of these, we will no longer be able to remain skeptical, because we will understand that there are certain conditions that allow us to recognize objects with our abilities.

The first proposition of “On Truth” explicitly states that “Truth exists”. Herbert says that “the sole purpose of this proposition is to assert the existence of truth to the foolish and the skeptic”. In order to show his opposition to the ideas of the “new Pyrrhonists”, Herbert set out to show what truth is and how we can arrive at it. He says that there are four types of truth.
(1) The truth of things as they really are in themselves, (2) the truth of the appearances that things show to us, (3) the truth of the concepts we form about things, and (4) the common concepts that we judge by means of appearances and concepts, which are our subjective truths, or intellectual truths. These are mainly based on Aristotle's analysis of the means of acquiring true perception. What is this treasure, the common concept? It is the truth of the intellect, a certain common concept that exists in all normal human beings, and these concepts are the building blocks of all things, derived from universal wisdom and imprinted on the soul by the dictates of nature itself.
The truth in (1) is absolute. It is “things as they are”, and this is what we seek to recognize using the other three conditional truths. These other three truths are related to the perceiver rather than the object itself. Our task is to discover a criterion or sign that determines whether our subjective information is in agreement with the truth of the object itself, starting from the information we have.

Here, I will show you the procedure for how truth is judged. What we perceive from appearances can deceive or mislead us as a guide to what the real object is. However, appearances are always true as appearances, and they appear as they appear. However, it is not necessarily an indication of the truth of the thing itself. The concepts we form based on our experiences are entirely our own, and these concepts may or may not correspond to the things they are supposed to be concepts about. If our sensory organs are imperfect, if they are inferior, if our minds are full of deceptive prejudices, then our concepts will be completely undermined. Therefore, the final truth, the truth of the intellect, determines whether our subjective faculties have sufficiently exercised their cognitive functions through their innate faculties and common concepts. It is by this standard or sign that we can determine whether there is a correspondence between the personal subjective truth of an appearance or concept and the truth of the thing. Therefore, we can determine whether we have objective knowledge. Herbert then went on to explain in such a cumbersome way, step by step, the method for arriving at the subjective or conditional truth of each item, the method for ascertaining the common concepts or signs by which to judge whether the subjective truth coincides with the truth of things, and finally, the method for applying this whole mechanism to the search for truth. Because there are difficulties raised by skeptics at each stage, we must carefully state the conditions for confirming the truth of each item.

Thus, Herbert said, "In my view, universal consent must be considered the beginning and end of theology and philosophy. God has given us all of these truths through providence. Therefore, they are the only basis we have for gaining knowledge of the real world, and they are trustworthy.

Herbert's proposal for dealing with skepticism was certainly widely accepted at the time as an antidote, but it was severely criticized by Gassendi and Descartes. Gassendi attacked Herbert's proposal as categoricalism that failed to conquer the skeptics and was indefensible. Descartes also attacked Herbert's proposal as incomplete categoricalism that failed to refute Pyrrhonism because it did not grasp the fundamental point of contention.

Gassendi's criticism

Two documents have survived concerning Gassendi's refutation. One is a polite letter that was never sent to Herbert, in which he raised several fundamental issues. The other is a letter to a mutual friend, Diodati, which contained harsh accusations. The latter was Gassendi's true opinion of Herbert's new philosophical system in response to the challenge of skepticism. It expressed the opinion that Herbert's diagram was a confused labyrinth that led nowhere.

Gassendi said that the truth that Herbert claimed to have discovered was unrecognizable and unrecognizable. Even if we don't know what truth is, we can see that Herbert failed to find it and did not respond to the skeptics. Even if we don't have another categoricalism to replace Herbert's scheme, we can understand that there is something wrong with Herbert's scheme. His new system is just a kind of dialectic. However, I think it has such merits.

After this commentary, Gassendi tried to make Herbert's entire effort come to naught, and he simply formulated the difficulties of skepticism as he saw them. According to Herbert's diagram, the sign or standard of truth is natural instinct and our common sense. He says that this allows each of us to judge the true nature of things. If this is true, how can we explain the terrible disagreement in judgments that arises on almost every issue?

Everyone is convinced of their own natural instincts and inner abilities. If each person uses Herbert's method of explaining this disagreement, each person will say that the other person is “not sound and complete”. And each person will believe it based on the truth of their own intellect, and they will get stuck in a dead end. Because each person will naturally think that he is right, and they appeal to the same internal standard. They have no sign to determine whose view is true. Who can be the judge in the first place, and who can prove that they have the right not to decide?

As long as there is disagreement on practically everything, the same difficult problem of skepticism that was raised at the time of the Reformation will also trouble Herbert's philosophy. Each individual will be able to subjectively find the truth of things according to the standards within themselves. But when the opinions of different people do not match up and each person is convinced subjectively, who can judge the truth? Excepting the mentally handicapped and infants, Herbert claimed that there is universal agreement on certain fundamental matters. But then, if the opposing parties each claim to possess soundness, mental health, and mental maturity, who or what can be the judge of these qualities? Therefore, Herbert's scheme has no ability to determine the truth of real essence, because it is based on changeable and weak criteria such as natural instinct and inner conviction, concluded Gassendi.

Descartes's criticism

A different, and perhaps more biting, criticism of 'On Truth' was made by Descartes. Unlike Gassendi, he deeply sympathized with the book's aim of refuting skepticism, and so he was even more aware of the fundamental fallacy of the book. In 1639, Mersenne sent a copy of Herbert's book to Descartes, and received a detailed treatise on the book in response. “This book deals with a subject that I have been investigating all my life, but it takes a very different path from the one I have followed,” Descartes commented. The fundamental difference between Descartes' work and Herbert's work is that the former is a concept so clear that it is impossible not to know ‘truth’. Therefore, he claimed that he had no doubts or objections about truth. The latter was trying to discover what truth is.

As Descartes saw, the fundamental problem with Herbert's research method is that if truth is not recognized in advance, there is no way to learn about truth at all. In order to accept his conclusion that the diagram in “On Truth” is a method for measuring or discovering truth, it is necessary to recognize what truth is in advance. The concept of truth is something that is recognized intuitively, as are some other fundamental concepts such as form, size, motion, position, and time. If we try to define them, we end up with ambiguity.

Herbert had many measuring devices for knowing the truth, but he could not know what they measured. Descartes started from the intuitive recognition of a single truth and constructed his truth measurement criteria. Descartes found cogito, a method of cognition for testing that “truth”. Herbert may have had a single “truth”, but he could not know whether it was the real truth.

Herbert's new philosophy was a proposal about the truth of diversity

Gassendi saw that this new scheme could not discover the truth of things, and that it was practically a kind of skepticism, because there was no universal agreement on practically anything. Descartes saw that Herbert had started from the wrong place and had failed to propose sufficient signs for finding the truth. In order to overcome skepticism, we must recognize what is true. We must not seek truth through countless procedures whose relationship to the search for truth is not determined. And we must have a sign to recognize truth that does not confuse true and false or doubtful things. Herbert was unable to provide a sufficient answer to the Pyrrhonist crisis.

My opinion

From our perspective in the modern world, I think that skepticism contains a way of thinking that encourages diversity. When discussing the truth, categoricalism comes first, and then skepticism, which contains opposing ideas, appears. Skepticism expresses the idea that there is no single answer. I think it is good that discussions can be broadened, but sometimes it is difficult because the conclusions do not converge. Therefore, various ideas have been devised to avoid the crisis of skepticism, but no decisive solution has appeared. The Pyrrhonist Crisis refers to the fact that what was required of humans by the gods was not being achieved. Someone had to respond to the gods in some way and declare the results. This is where

Herbert's proposal came in. His new philosophy seems to be the prototype of what we would call "diversity" today. At the time, it seems to have been rejected by Gassendi and Descartes, but it could be said that skepticism died and was resurrected in the era of the scientific revolution, opening the door to diversity. In the modern era, the idea of diversity is one way of solving such problems. I think Herbert discovered one of the truths of diversity, discovering a new philosophical source.

The king of skepticism is Descartes

In a letter to Father Pierre Burdin (1595-1653), Descartes declared that he was the first person to have overcome the skepticism of the skeptics. More than 100 years later, one of his admirers said, "There were skeptics before Descartes, but they were just ordinary skeptics. However, Descartes mastered the method of deriving philosophical certainty from skepticism. At the time, there was little attention paid to Descartes' intellectual reform movement from the perspective of the skeptical crisis. Descartes expressed a deep interest in skepticism of the time. He also showed that he was well-versed in the writings of the Pyrrhonists of ancient times and of his own time. He also developed his philosophy through his confrontation with the serious 'Pyrrhonist crisis' of 1628-1629. Descartes said that his philosophical system was the only intellectual fortress that could withstand the attacks of the skeptics.

It seems that he was well aware not only of the Pyrrhonist classics, but also of the growing danger of the skeptical trend of the time for learning and religion. In a letter to Father Bourdan, he wrote, "We must not think that the school of ancient skeptics has long since disappeared. It is still flourishing, and always has been. He wrote, "Most people who think they have some kind of ability that surpasses that of other people find nothing satisfying in ordinary philosophy, and since they cannot find any other truth, they take refuge in skepticism."

Not only was Descartes familiar with some of the skeptical literature, but he also had a deep awareness of the Pyrrhonist crisis as a current issue. As mentioned above, he examined Herbert's writings. In addition, in the autobiographical parts of the "Discourse on Method" and in his letters, we find evidence that around 1628 or 1629 Descartes was acutely aware of the need for a new and powerful response to the attacks being made by the full force of skepticism. This awakening to the threat of skepticism led Descartes, while in Paris, to launch his philosophical revolution in an attempt to discover something so solid and certain that it could not be shaken by any of the extravagant assumptions of the skeptics.

Descartes left Paris. In order to find a solution to the Pyrrhonist crisis, he sought a new truth and reflected on it in his hiding place in Holland. His interest shifted from science and mathematics to theological metaphysics in order to discover the immovable foundation of

human cognition.
The onslaught of the Reformation, the Scientific Revolution and skepticism had destroyed all the old foundations of human intellectual achievement that he had previously supported. The new age demanded a new basis to justify and guarantee what they had discovered. Descartes, standing in the tradition of the greatest medieval minds, sought to provide this foundation by combining the foundation of an omnipotent God with the superstructure of human natural cognition. Here we see Descartes' sense of mission as a man chosen by God.

A Mysterious Experience in the Furnace Room

According to the biographer of Descartes, A. Baillet (1649-1706), in a now-lost manuscript by Descartes, he wrote, "On November 10, 1619, inspired, I was discovering the foundations of a remarkable science…" There is no doubt that this was a phrase commemorating "A Day of Contemplation in the Furnace Room". On this night, Descartes had three dreams. In these dreams, Descartes felt that the spirit of truth had been sent by God, and he believed that God had given him the vocation to renew the entire philosophy by himself. He considered this to be the most important event of his life, and, filled with the emotion that his future work had been blessed by God, he made a vow to make a pilgrimage to the Basilica of Our Lady of Loreto on his way to Italy, where he was planning to go. These events are recorded in A. Baillet's "Life of Descartes" (1691), and as far as we can believe his testimony, it seems that this was an event that determined Descartes' ideological life from then on.

Awareness of "I"

At the beginning of the second part of "A Discourse of a Method", he reports in a calm tone what he thought about in the furnace room in Ulm. There is not a single mention of dreams. What is discussed there is firstly that "in a work composed of many parts and made by the hands of various craftsmen, there is no such perfection as in a work finished by a single person". A building designed and completed by a single architect is usually far more beautiful and orderly than one that has been repaired by many people using old walls that were built for other purposes. Old cities that were once small villages but have grown over time into large towns are usually less well-balanced than regular towns designed and built by a single engineer in the middle of a plain. The same is true of the laws of a country. When a single legislator, such as Lycurgus of ancient Sparta (who lived between the 11th and 8th centuries BC), sets out a policy and makes laws on his own, it results in something that is well-organized and consistent with a single purpose. The same is true of learning: a scholastic discipline that has no basis in evidence and no logical arguments, and which has been gradually constructed and expanded by many different people, cannot be as close to the truth as the simple reasoning that a single sensible person can do with his or her natural abilities when it comes to matters that appear before him or her. In other words, he is arguing that only a system of knowledge that has been derived by a single person using the correct method can be called true learning.

Awakening to Philosophy

When he left the furnace room of a small village near Ulm, Descartes became a philosopher. Before that, he was a natural philosopher. He was just a natural inquirer who was interested in individual applied technical research.

After being awakened to theoretical research through his encounter with Isaac Beeckman (1588-1677), Descartes gradually began to devote himself to research that treated physics mathematically. What is even more remarkable is that in a letter to Beeckman dated March 4, 1619, he mentions the problem of method and expresses the idea of generalizing these methods. He says that if mathematics is universalized in this way, a completely new discipline should be born, and that according to this, one should be able to solve all the problems presented, whether they are of a continuous or discontinuous nature.

Here, Descartes is aiming for something more than just mathematics. He is moving towards a new method of thought. It is not just a matter of applying algebraic methods to geometry. In his book 'Rules for the Direction of the Mind', Descartes says, “The name ‘mathematics(mathesis)’ originally meant just the same as ‘study’, so in that respect all studies would be called mathematics with the same rights as geometry itself.” In other words, he thought that astronomy, music, optics, mechanics and many other things could be described using mathematics. Descartes gradually approached the idea of universal mathematics (Mathesis Universalis). However, such a universal discipline would never be completed by a single person. In the same letter (the letter to Bekman dated March 26), he also wrote, “This is an infinite task, and it is impossible for a single person to accomplish it. It is also an incredibly ambitious task that is hard to believe.”

Here, he is still speaking as a natural scientist. Given the nature of the study of natural science, it is not something that can be completed by a single person in a single stroke. The mysteries of nature are only revealed through the continuation of research by the cooperation of almost an infinite number of people, with the achievements of previous generations being passed on and inherited from one era to the next. However, from the day of his divine revelation on November 10th 1619, Descartes resolutely turned away from the path of the communal nature of natural science. He then decided to build his studies on a completely new foundation, relying solely on his own strength. How did this sudden transformation come about? Why did Descartes abandon the path of the scientist to become a philosopher? This is a truly interesting question.

Walking alone in the darkness

On November 10th, 1619, it was a fateful day. He was deep in thought in the furnace room of a small village near Ulm. When he left there, he was a philosopher. Or to be more precise, he had begun his journey to becoming a philosopher. "I will proceed as if walking alone in the darkness. I have decided to pay the closest attention to everything. ..." (Discourse on the Method, Part II) However, it was a steady, unerring step, one step at a time. While walking carefully and cautiously through the darkness, he gradually pushes back the darkness and tries to make the light appear from far away. What is he searching for? It is the mystery of the world (the universe). The outline of the chaotic world gradually becomes clear. Within the jumble of things that have no definite shape, a clear shape and order can be seen. He is searching for that order. He is searching for the world's order, its orderly structure. He is trying to gradually bring to light the rationally ordered form of the world, following a method. In a nutshell, it is the path from "chaos to cosmos". It is a path that leads from contemplation in the furnace room to "Cogito, ergo sum" through a journey around the world.

Universal Wisdom

What the philosopher Descartes is searching for is a holistic image of the world. A systematized and ordered view of the world, in other words, a "world (cosmology) theory". However, this cannot be captured through the collaborative work of many natural scientists. Natural scientists can precisely elucidate parts of the world from a specific angle, but they cannot capture these parts in relation to the whole. No matter how skillfully the partial world views of each scientist are combined and organized, it is impossible to grasp a truly unified, holistic view of the world. The arithmetic sum of the parts is by no means a living whole. In this sense, the task of a single philosopher is similar to that of a single engineer, who designs and builds an ideal city with a well-ordered structure in a wilderness with no buildings. A sensible philosopher, that is, Descartes, would realize a new system of learning, or universal wisdom, by guiding reason in an orderly fashion according to the most universal method and expanding the field of knowledge as much as possible. That was what he aimed to achieve.
"All things that are potentially within the range of human cognition are connected in the same way. We must be careful not to accept as true that which is not true. In this way, when we

reason from one thing to another, if we follow the necessary order, we will eventually reach even those things that are far apart. We will also eventually discover those things that are cleverly hidden.”
(From the second part of “Discourse on the Method”)
Here, the Cartesian ideal of method is clearly expressed. He is considering the most universal method that would lead to all objects that are cognizable by humans in the same way. The scholastic scholars were fundamentally mistaken in believing that “different disciplines should be distinguished from each other by the difference of their objects, and studied separately and independently of all others.” For “every discipline is human wisdom. It must always retain its identity, no matter how it is applied to different subjects. Just as the light of the sun shines on everything without discrimination, we must treat all matters without discrimination."
(From ‘Rules for the Direction of the Mind,’ 1)
The idea of the differentiation and specialization of modern science was completely foreign to Descartes. He sought to place all possible objects within a homogeneous and continuous order of cognition.

The autobiographical section of the Discourse on the Method shows that Descartes began his philosophical revolution in 1628 or 1629. This revolution was begun by applying his method of systematic doubt to the whole mechanism of human cognition in order to discover a sure foundation for human knowledge. In the Discourse on the Method, the Meditations on First Philosophy and the Search for Truth by Natural Light, he set out a procedure for advancing skepticism that was more powerful than anything developed by the Pyrrhonists of ancient times or of his own day. It began with the following rule

“I shall not accept anything as true without having clearly recognized it as such. In other words, I shall carefully avoid hasty judgments and prejudices, and shall not include in my judgment anything other than what appears to my mind with such clarity and certainty that I have no reason to doubt it.”

Descartes tried to clearly define the limits beyond which the temptation to doubt could not arise. This rule itself is very similar to one previously proposed in Pierre Charron's (1541-1603) book “La Sagesse” (Wisdom). Applying these ideas, Descartes showed that the depth of his skepticism went far beyond the simple and mild stages introduced by previous skeptics. The first two stages merely raise standard reasons for skepticism. The first stage of skepticism shows that there are several grounds for questioning the reliability or sincerity of our everyday sensory experience. The second stage of skepticism creates within itself the inducement to doubt the reality of the world we perceive, in that there is the possibility that our entire experience is part of a dream. Based on these two stages, the standard arguments for skepticism fully illustrate the possibility that our ordinary beliefs about everyday experience are doubtful or false.

Furthermore, the demon hypothesis, which is the next stage, is very effective in expressing the uncertainty of what we think we perceive. This possibility reveals the full extent of skepticism in the most obvious way, and exposes the foundations of skepticism that no one has touched on before. If there are evil spirits that can distort the information we have or our ability to evaluate and test the information we possess, then what should we do?

If the criteria or labels we use to recognize things are potentially contaminated by evil spirits, then no matter how we examine the reliability of what we perceive, there will still be room for doubt.

Descartes thoroughly considered the possibility of skepticism leading to the most fundamental and thorough devastation. This is because the information we have is not only deceptive, illusory and misleading, but there is also the possibility that our ability to verify it may be wrong, even under the best of circumstances. Descartes realized that unless we can raise the heat of skepticism to this highest level and then overcome it, nothing can be certain. Because there is always a persistent doubt that contaminates everything we perceive and makes everything uncertain in some way.

Descartes clearly understood the overwhelming importance of this demon belief, or skepticism, about our ability to test. There is the fact that our senses sometimes make mistakes, and the fact that our reason sometimes produces illogical conclusions. Descartes also rejected everything he had previously accepted, on the basis of the fact that anyone else could easily fall into the same kind of error.

In his Meditations on First Philosophy, Descartes pointed out that it is possible for me to be mistaken every time I add 2 and 3 together (in mathematics), every time I count the sides of a square (in geometry), or every time I judge something if I can imagine something easier. The possibility that we are constantly being deceived by some evil power calls into question even the most obvious things and the most obvious criteria.

Descartes arrived at the highest point of skepticism. When it is proposed that even the reliability of our most rational faculties can be called into question, then man is transformed from a repository of truth into a den of uncertainty and error.

We can only overcome the power of skepticism when it is pushed to its ultimate situation, and a Pyrrhonist crisis even deeper than that which the “new Pyrrhonists” once dreamed of arises. Unless we pursue the possibility of skepticism to its ultimate conclusion, we will never have any hope of discovering a truth that is not tainted by skepticism or uncertainty. By transforming ordinary skepticism into a thorough denial, Descartes laid the groundwork for the unparalleled and overwhelming power of cogito. Therefore, by recognizing the certainty of cogito, it becomes impossible to oppose it by any willful action.

Skeptics did not believe that we humans possessed any kind of truth. On the other hand, Descartes was convinced that we humans do possess truth, but we just can't see it. He said that these preconceptions and beliefs that blind us can be removed by doubting and denying, and then the truth will shine forth. The ultimate goal for Descartes was to create a standard for the cognition of completely certain truth. The skeptical method of searching for this goal is to apply skepticism to everything we perceive. By daring to jump into this “swamp of uncertainty” of skepticism, Descartes finds a solution in “cogito”, and skepticism is thoroughly defeated. In the “Discourse on the Method”, Descartes said

"While I was trying to think that everything was false, I realized that I, who was thinking that, must necessarily be something. And I recognized that this truth, “I think, therefore I am” (Latin: Cogito ergo sum, English: I think, therefore I am), is so solidly certain that it cannot be shaken by any extravagant assumptions of the skeptic. I judged that this truth could be the “first principle of philosophy” that I was seeking.

Cogito functions as the conclusion of skepticism. By taking skepticism to its extreme, we come face to face with a truth that cannot be doubted in any way. In other words, cogito is the essence of thinking. The process of doubting forces a person to recognize what they themselves are aware of, and also forces them to know that they are doubting, thinking, and existing here. The discovery of true knowledge is not miraculous, nor is it a special action of divine grace. The discovery of the absolutely certain single truth of cogito may overthrow the skeptical attitude that everything is uncertain. However, this single truth does not constitute a system of cognition about existence. The experience of being confronted with cogito is a firm and solid starting point, and a series of bridges must be built between cogito and the discovery or justification of our perception of the nature of things. The first step in this is to establish a clear and intelligible principle that will lead us from our intellectual truth to the truth about reality. This is to give us the first bridge from the subjective cognition of a truth about our ideas to the cognition of reality.

Descartes' Metaphysics

For our existence and cognition, there must be a God on whom we are wholly dependent. However, it is God's responsibility to justify this. With this concept of God, based on a clear and distinct idea of God, Descartes was now ready to march triumphantly into his promised land, the new world of categoricalism, where recognition of truth and reality was guaranteed to be complete.
God is my creator, and he cannot deceive. I have been created with the ability to judge that whatever I clearly and distinctly perceive is true, so my ability to judge is guaranteed by God. Not only must I believe that whatever I clearly and distinctly perceive is true, but by God's grace it actually is true. With this tremendous guarantee, Descartes was able to dissipate the skepticism of his Meditations on First Philosophy.
Since evil spirits have been driven out of heaven and earth, there is no question about the truth of mathematics, and mathematical truths are clear and distinct. We are forced to believe them, and God is not a deceiver. Therefore, we can be at ease in this compulsion. Our connection with the truth of nature is also discovered through our trust in God. We can be confident that there is in fact a natural world that corresponds to the true nature of the objects of pure extension that arise from our ideas. This is because God would not have made us think in this way if such a world that transcends the scope of our ideas did not in fact exist.

Regarding atheists

Atheists cannot have this assurance of the objective truth of clear and distinct ideas, because they have no God to assure them of what they think they perceive. In response to Mersenne's claim that atheists can also perceive mathematical truths as clear and distinct, Descartes said the following

“I do not deny that, but I only maintain that the atheist does not acknowledge it by true and certain knowledge, because every possible doubt ought not to be called knowledge. Perhaps such a doubt does not occur to him. But if he examines it, or if it is pointed out to him by others, he will still be aware of the doubt. Therefore, unless he first recognizes God, he will never be free from the danger of harboring such doubts."

Therefore, the atheist, no matter what truths he knows, can never be thoroughly convinced that they are true, because no matter how convinced he is, he can never completely rule out the possibility that he is being deceived. There is no worldly guarantee or basis for certainty.

In the secular world, even in the most obvious matters, there is always the possibility of deception by evil spirits or self-deception. Thus, in a world separated from God, any truth can be considered doubtful. And no true and certain knowledge will be discovered. Only God can eliminate all skepticism when we recognize that He is not a deceiver. Therefore, only God can guarantee that the truth we recognize in mathematics and the natural sciences is more than just a similarity to the truth within our spirit.

My opinion

Descartes aimed to be freed from the Pyrrhonist crisis. It was a request from the almighty God. Someone had to accomplish it, but I don't think God is waiting with equal opportunities for everyone. He designates people. Descartes was chosen. He expressed this in his writings and letters.

What does God want from human beings? I think it is to exist forever as the manager of the created world. Then, why do you say that? If you think about how God created the world, you will come to that conclusion. I think that the liberation from the crisis of skepticism was also an important element for the human world to continue forever.

Now, what does skepticism mean? I think it is a state of unreliability in which the truth is coherent and the general gist is understood, but the categorical statements presented seem to have problems in relation to the real world and metaphysics. Or, to put it another way, you could say that doubting is a way of refining the truth.

Descartes was chosen by God to overcome the Pyrrhonist crisis. Descartes discovered “cogito”, which I think is the same as the “uniqueness” we know today. I think “cogito” is God's approval. This is an idea that only Descartes, who was chosen by God, could come up with, and it may be difficult for others to understand. At the time, only Descartes himself would have understood this. However, Descartes needed to explain the importance of this to others so that they would understand. Cogito expresses “uniqueness” and does not oppose “diversity”. “Uniqueness” is the selectivity of human consciousness, and “diversity” and “uniqueness” can coexist without opposing each other. The authority to make choices was given to humans by God. Descartes succeeded in describing the process of discovering “uniqueness” in detail and philosophically.

The concept of harmony and unity is one in which the relationship between the internal elements is loose, but the match is ideal and there is no compromise at all, like a jigsaw puzzle. The concept of harmony and unity is one in which the relationship between the internal elements may collapse if the discipline is too strict. Match is a higher concept than harmony or unity. Even though it is difficult to achieve a perfect match in the real world, with no gaps,

it can be said to be the ultimate ideal. Therefore, it is possible to coexist with diversity. There are two ways of thinking in human consciousness: one that accepts many opinions, such as “diversity”, and one that requires us to choose one. In some cases, the two concepts may be complexly combined.
Since the 17th century, the relationship between skepticism and categoricalism has gradually changed from a conflicting relationship to a relationship between two partners that can coexist, namely 'diversity' and 'uniqueness'. The coexistence of 'diversity' and 'uniqueness' contributed to the scientific revolution that took place in the 17th century and beyond. I think that the “uniqueness” discovered by Descartes is a concept that played a part in this. “Cogito” is Descartes himself, chosen by God. Perhaps no one else could have discovered it. Descartes discovered it as a representative of humanity, chosen by God.

Humans must construct the universe in their minds. Academics are necessary for this purpose. The scientific revolution was a major catalyst for the evolution of traditional academics. Humans' conception of the world must be aligned with the almighty God's conception of the world. The real world seems to be more than just what can be seen, touched, and felt. We must go beyond the worldview of the human senses and search for and find things that are not easily accessible, and make them available to humans. The way we describe the world must change from confrontation to coexistence.

Descartes, misunderstood

When Descartes proudly demonstrated his method for vanquishing the evil dragon of skepticism, he immediately found himself accused of being a dangerous Pyrrhonist and of being a failed categoricalist whose theory was nothing more than fantasy and illusion. The orthodox and traditional thinkers saw Descartes as a malicious skeptic. This is because his method of skepticism rejects the very foundations of traditional systems of thought. Therefore, no matter what Descartes himself tried to explain, he was seen as the culmination of a 2000-year history of Pyrrhonists, which began with Pyrrho of Elis. On the other hand, those with a skeptical bent, although reluctantly and grudgingly, recognized Descartes as one of their own, and tried to show that he had achieved nothing and that everything he claimed was nothing more than a conjecture without certainty. The categoricalists also strongly attacked the Meditations on First Philosophy.
Even after Descartes, modern philosophy had to take into account the Pyrrhonist crisis. If someone tried to ignore it, all their basic assumptions and all their conclusions would be open to doubt and they might be attacked by some new Pyrrhonist.

My opinion

Descartes published his philosophy, but it seems that he was misunderstood and attacked. Perhaps Descartes did not explain something clearly enough when he published his work. I think that he was assuming the idea of diversity in order to discover cogito. I think that this was not explained clearly enough. Perhaps this is why he was misunderstood. From our perspective today, it's something that's easy to understand, but people at the time may not have understood the premise of the story.

Part III

A Universe of Consciousness How Matter become Imagination

	Contingency	Double contingency
	It means "chance," "contingency," "uncertainty," "accident," etc. It can also mean "It also means "to depend on. "Contingency theory" is a Japanese term that translates to "environmental adaptation theory. This theory states that there are various environments in the world, and since there is no single best system, the system should change as the environment changes.	This is equivalent to "double conditional dependence." To make a choice is a negation of the potential that could have been otherwise, and in that sense is a double negation. By experiencing the other as another self that is opaque to oneself, the potential denied in choice is preserved and stabilized as a mutually implied, but unrealized, possibility in both oneself and the other. Luhmann called this situation a double contingency.
1	ontology	epistemology
2	continue	change
3	design	optimization
4	relativity	symmetry
5	digital	analog
6	environment	system
7	cause and effect	cycle
8	finite (time)	infinity (space)
9	class	network
10	diversity	unique
11	death	resurrection
12	unification (harmony)	match
13	secular	sacred
14	body(substance)	soul(life)
15	experience	knowledge
16	object	word

17	value	meaning
18	phenomenon	cause
19	think	feel
20	until the end (until you finish)	as (much) as possible
21	theory of relativity	quantum mechanics
22	Particle (quantum mechanics)	Wave (quantum mechanics)
23	mass	energy
24	macro	micro
25	natural science (Approach from the nature side)	social science (approach from the human side)
26	luck	technology(probability)
27	(memory) self-awareness	(power of) imagination
28	evolution	creation
29	form	function
30	(past to present) ever	(from present to future) from now on

An explanation of this table can be found in a previous post. If you would like to know more, please see that post.

Bibliography quoted in the Third Part.
A Universe Of Consciousness: How Matter Becomes Imagination (English Edition)
Gerald M. Edelman (Author), Giulio Tononi (Author)

Preface

Consciousness has long been considered both a mystery and the source of mysteries. It has been one of the main objects of philosophical inquiry, but only recently has it become a scientific object worthy of experimental study. This is because, although all scientific theories presuppose consciousness and its application requires conscious sensation and perception, the means to investigate consciousness itself scientifically have only recently become available. We cannot directly observe consciousness in the same way that physicists observe objects. While introspection is not scientifically satisfactory and while people's reports of their consciousness are informative, they do not reveal the underlying brain activity. And the study of the physical brain alone cannot tell us objectively what consciousness is like. These limitations show that a special approach is needed to incorporate consciousness into science. Our answer is based on the assumption that consciousness arises within the material order of certain living organisms, because more advanced brain functions require interaction with the world and other people. We hope that by the time you finish reading this text, you will have a new perspective on how matter becomes imagination.

The Knots of the World

In the modern world, we recognize that the world of conscious experience is closely dependent on the delicate workings of the brain. Consciousness can be extinguished by even the slightest lesion or chemical imbalance in a certain part of the brain. In fact, our consciousness is extinguished every time our brain activity changes and we fall into a dreamless sleep.

Even the whole world exists only as a part of our consciousness. It disappears at the same time as our consciousness disappears. Arthur Schopenhauer (1788-1860) brilliantly called this mystery, which is shrouded in the mystery of how subjective experience is related to objectively describable events, "the knot of the world".

Is consciousness a philosophical paradox or a scientific object?

The theme of consciousness used to be the exclusive domain of philosophers, but recently both psychologists and neuroscientists have begun to focus on it as a matter of mind and body, or, to borrow Schopenhauer's thought-provoking phrase, as "the knot of the world." Everyone knows what consciousness is, but it abandons you every night when you go to sleep, and then reappears when you wake up the next morning.

Since Descartes, no other theme has consistently troubled the minds of philosophers as much as the mystery of consciousness. For Descartes, consciousness was synonymous with "thinking". In his "Meditations on First Philosophy", Descartes proposed "I think, therefore I am" (cogito, ergo sum) as the foundation of philosophy, and this directly recognized the centrality of consciousness in both ontology (what is) and epistemology (what and how we know). In practical terms, this approach leads to an idealistic position that places more importance on the mind than on matter. However, idealistic philosophies that start from the mind struggle to explain matter.

Why take matter as the starting point?

Descartes argued that there is an absolute distinction between mind and matter. The characteristic of matter is that it occupies space and can be extended in a way that allows for physical explanation. On the other hand, the characteristic of mind is to be aware of things or, in a broader sense, to think. Descartes proposed this kind of dualism. This is a way of thinking that is not scientifically convincing, but it seems to be an intuitively simple and attractive way of thinking when trying to explain the relationship between mind and body.

There is a fundamental limitation in philosophical efforts to determine the origin of consciousness. This is partly due to the assumption that the source of consciousness can be revealed by thinking alone. This assumption is clearly inadequate, just as it was in the old days when people tried to understand the universe, the fundamentals of life, and the fine structure of matter without scientific observation or experimentation.
Moreover, given how unique consciousness is as a scientific object, it is perhaps inevitable that such errors should occur. From now on, we will argue that consciousness is a process, not an object, and that this perspective means that consciousness is worthy of scientific study.

A Special Problem of Consciousness

Science has always tried to eliminate subjectivity from its descriptions of the world. But if subjectivity itself is the object, is it possible to eliminate subjectivity from descriptions?

We can describe water in ordinary language, but in principle we can also describe it in terms of the laws of atomic and quantum mechanics. What we are actually doing is combining two levels of description of the same external entity: a mundane description and a very powerful and predictable scientific description. Both levels of description refer to an entity that is assumed to exist and to exist independently of a conscious observer: liquid water or a particular arrangement of atoms that obey the laws of quantum mechanics.
We want to explain why we have consciousness and how subjective and experiential qualities arise. In other words, we want to explain "I think, therefore I am", which Descartes took as the first obvious evidence that should be the basis of all philosophy. No matter how accurate a description, it may not be able to fully explain subjective experience. No matter how it is explained, it is very difficult to explain the occurrence of first-person phenomenological experience.

The Conscious Observer and Some Methodological Assumptions

What is so special about consciousness? What makes consciousness special is that, unlike the objects of other scientific descriptions, the neural processes we try to characterize when studying the neural basis of consciousness refer to ourselves. Therefore, we cannot implicitly exclude ourselves as observers of consciousness, as we do when studying other scientific domains.

The only physical processes that are used to satisfactorily explain consciousness are conventional physical processes. In particular, it is assumed that consciousness is a special physical process that occurs within a certain type of brain structure and dynamics. As a physical process, the experience of consciousness is characterized by two general or fundamental properties. One is that the experience of consciousness is integrated, and the conscious state cannot be subdivided into independent components. The other is that consciousness is highly differentiated, and that people can experience billions of different states of consciousness. The scientific challenge is to describe a specific physical process that can explain these properties at the same time.

It seems that selection principles similar to evolutionary theory have been applied to the actual workings of the human brain long before logical principles were applied. This idea is now called selectionism. To summarize our position, selectionism precedes logic. It is predicted that selectionist principles and logical principles are each at the root of a powerful mode of thought. It is essential to grasp that selectionist principles are applied to the physical brain, while logical principles are something that individuals with brains learn later.

Private Theatre for the Public: Progressive Unity, Infinite Diversity

Our strategy for explaining the neural basis of consciousness is to focus on the properties of consciousness that are common to all states of consciousness, or general. One of the most important of these properties is integration or unity. Integration means that a state of consciousness cannot be broken down into independent components at any time by its experiencer. This property is related to the fact that we cannot consciously do two or more things at the same time, for example, adding up a check while continuing a heated argument. The scope and variety of conscious phenomenology extends as far as our experience and imagination can take us. It is our private theater. Books have been written to classify these areas of consciousness, and entire philosophical systems have been constructed based on attempts to decipher their structure. States of consciousness manifest as perceptions, images, thoughts, inner speech, emotions, will, self, familiarity, and so on. These states occur in every conceivable combination of subdivided categories: sight, hearing, touch, smell, taste, proprioception (sensation of one's own body), kinesthesia (sensation of one's body position), pleasure, pain, etc.

Consciousness and the Brain

The fact that the entire philosophical system has been constructed based on the conscious experience of a single individual devoted to subjective phenomenology, or philosophy, may be a reflection of human arrogance. Such arrogance is partially justified, as Descartes recognized and used as a starting point, because our conscious experience is the only ontology we have direct evidence for.

In order to understand consciousness as a process, we must understand how the brain functions. This section focuses on the most important features of the brain, its anatomical organization, and the amazing dynamics it produces, and provides a useful, but by no means exhaustive, overview of the brain. Although it is written in broad strokes, this section is necessary for understanding how consciousness emerges.

The brain is undoubtedly one of the most complex objects in the universe and one of the most amazing structures to have emerged in the course of evolution. Even before the advent of modern neuroscience, it was well known that the brain was necessary for perception, emotion and thought. As an object and as a system, the human brain is unique. Its connectivity, dynamics, modes of functioning, and relationship to the body and the world are something that science has yet to encounter. We are far from grasping the whole picture, but even a partial grasp is better than none.

The brain is not a computer

A cursory review of neuroanatomy and neurodynamics reveals that the brain has special characteristics in terms of its organization and function. The brain is interconnected in a way that is not found in man-made devices. First, the billions and billions of connections that make up the brain's connections are not precise. If you ask whether two brains of the same size are connected in the same way as computers of the same make, the answer is no. Even identical twins, when viewed on the most minute scale, still have brains that are not exactly the same. This observation fundamentally challenges models of the brain based on commands and calculations. This data provides strong support for the so-called "selective brain theory," a theory that relies on actual variation to explain brain function.

Lessons from practice: conscious and automatic performance

Much of our cognitive life may be the product of highly automated routines. When it comes to speaking, listening, reading, writing and remembering, we are all like accomplished pianists. When we read, all kinds of neural processes are at work, recognizing letters regardless of font or size, parsing words, accessing vocabulary, and considering syntactic structure.

There was a time when we had to learn letters and words in a conscious, laborious way. How our brains perform this difficult task is still largely unknown. When we consciously add two numbers together, it seems as if we simply tell our brain what to do, and then it carries out the operation and gives us the answer. When we search for an item in our memory, we formulate a question in our consciousness. Without us realizing it, our brain carries out the search for a while, and then suddenly the response comes back to our consciousness again.

This kind of automation is widespread in our lives as adults, and it shows that conscious control is only exercised in important situations where we have to make clear choices or plans. By having unconscious routines continually activated and carried out, our consciousness is freed from all the details, and we can make grand plans and understand things. In both action and perception, consciousness is only available at the level of final control and analysis, and everything else appears to be proceeding automatically. Because of this characteristic, many people conclude that we are aware of the results of the "calculations" taking place in our brains, but not of the calculations themselves.

The Mechanism of Consciousness: Darwin's Point of View

From now on, we will focus on the primary consciousness of the brain and explain the ability to construct an integrated mental scene in the present that does not require language or a true sense of self. The perceptual classification of sensory stimuli in this integrated mental scene is not limited to the "present". We believe that it is also dependent on the interaction with categorized memories, or the "past". In other words, this integrated mental scene is a "remembered present".

In his later years, Charles Robert Darwin (1809-1882) was in fierce conflict with Alfred Russel Wallace (1823-1913), who co-discovered natural selection. Wallace was a spiritualist who argued that the human brain and mind did not arise through evolutionary natural selection. Wallace argued that primitive people, who have brains almost the same size as those of civilized people, do not understand mathematics and are unable to fully engage in abstract thought, and he argued that it is difficult to believe that natural selection through evolution has caused the size of their brains to become the same.

The principles of Darwin's theory of evolution are also important in terms of our basic understanding of brain function. In particular, there are huge differences in the structure and function of the brains of vertebrates. No two human brains are exactly alike. Furthermore, each individual's brain is constantly changing, and these changes occur at all levels, from the brain's biochemistry to its external form, and the strength of the countless synapses is constantly changing with experience. This enormous degree of diversity is strong evidence against the notion that the brain is like a computer, made up of fixed program codes and registered information.

Values

Values, which are one of the elements that make up our consciousness, are something that is built into the basic mechanisms of the human body. It is important to emphasize that values are not the same as categories. Values are merely the preconditions for reaching perceptual and behavioral responses. Such categorical responses depend on whether or not a choice actually occurs. Perceptual categorization usually manifests as a result of a choice during actual behavior in the real world. Value may be necessary to get a baby to look at a light source, but it is not enough to recognize different objects.

From perception to memory: the remembered present

In order to understand the neural mechanisms of consciousness, it is useful to keep in mind the distinction between primary consciousness and higher-order consciousness. Primary consciousness is found in animals with brain structures similar to our own. These animals appear to be able to construct mental scenes, but they have limited semantic and symbolic abilities and do not have true language. It is only found in humans, and the higher-order consciousness that presupposes the coexistence of primary consciousness has self-consciousness and the ability to clearly construct scenes from the past and future in the waking state. This requires at least semantic ability, and in its most developed form, linguistic ability.

Two more elements are necessary for conscious experience. One is the emergence of categorical memory that responds to value, and the other is the activity of recursivity, which is a basic integration mechanism in the higher brain. We infer that primary consciousness emerged during the course of evolution when the posterior regions of the brain, which are involved in the categorization of perception, were dynamically linked to the prefrontal regions that are responsible for value-based memory through the emergence of new circuits that mediate recursivity. With such a circuit in place, animals can construct a remembered present. In other words, they can construct a situation in which they adaptively link the most recent event or imagined event to their past history of value-driven behavior.

The processes involved in these conscious experiences include perceptual categorization, concepts, values, memories, and, at the neural level, the special dynamic processes of the cortical thalamic organization. Without this understanding, the complex experiences of various sensations, moods, scenes, situations, thoughts, feelings, and emotions, which appear to occur simultaneously, would seem hopelessly irrelevant, even if they could be explained by brain-based mechanisms.

Prerequisites for a model of primary consciousness

When analyzing consciousness, we deliberately avoid tackling too many difficult problems at once or being distracted by its rich phenomenology. In accordance with this restraint, we emphasize the useful distinction between primary consciousness and higher-order consciousness. Primary consciousness is the ability to generate mental scenes that integrate large amounts of diverse information for the purpose of directing current or immediate action, and is found in animals with brain structures similar to our own.

Such animals seem to be able to construct scenes in their minds, but, unlike us, they have limited semantic or symbolic abilities and no true language ability. The rich, higher-order consciousness that we humans have is built on the foundation provided by primary consciousness, and is supported by self-consciousness and the ability to clearly construct and connect past and future scenes in the waking state. In its most developed form, it requires semantic and linguistic abilities.

For this reason, only humans with higher-order consciousness can report on their states of consciousness and talk about consciousness. They can be conscious of being conscious. In the following, we will mainly consider primary consciousness, but we will also discuss higher-order consciousness where experimental insights are available. Finally, we will discuss some of the more interesting aspects of higher-order consciousness, such as thought, language, self-concept, and self-reference.

Before considering a model of the mechanisms by which primary consciousness emerges during evolution, let's briefly review some important neural processes. One such process is perceptual categorization, a trait shared by all animals, which is the ability to perceive and subdivide the world in ways that are useful to a particular species in an environment governed by physical laws.

The next process necessary for understanding primary consciousness is the formation of concepts. Here, the term "concept" refers to the ability to combine various perceptual categories related to a scene or object and construct a "universal" concept that reflects abstract features common to various perceptions. For example, although different faces have many different features, the brain is able to recognize general features that are common to them.

The Mechanism of Primary Consciousness

By understanding the concepts of the mechanisms of regression and perceptual categorization, concept formation, and memory of value categories, we can model how primary consciousness arose during the course of evolution. The short-term memory that forms the basis of primary consciousness reflects past categorized conceptual experiences. Perceptually new things are quickly incorporated into memories that arise from past categorization. The ability to construct a conscious scene is the ability to construct a remembered present in a short time of a few tenths of a second.

Even animals that do not have such a system can still act and react to specific stimuli, and can survive in certain environments. However, they cannot construct complex situations by linking events and external signals, and they cannot build relationships based on their own history of value-dependent reactions. They often cannot imagine situations or avoid complex dangers. The emergence of this ability is linked to consciousness and is the basis for the evolutionary selection advantage of consciousness.
With this kind of process in place, animals will be able to plan and connect contingent events constructively and adaptively based on their past history of value-based behavior, at least in the present that is remembered.

Coping with a Huge Amount of Information: The Dynamic Core Hypothesis

We have proposed that scientific analysis of consciousness should take into account the basic properties of conscious experience, that is, the properties that are common to all conscious states. These basic properties include the following two. First, consciousness is highly integrated or unified, and all conscious states constitute an integrated whole that cannot be effectively subdivided into independent components. Second, conversely, it is highly differentiated or informational, and there are an enormous number of different conscious states.

The distributed neural processes that underlie conscious experience are also highly integrated and highly differentiated at the same time. We believe that this coincidence between neurobiology and phenomenology is not a mere coincidence. We will further develop our ideas about the neural basis of conscious experience by explaining the unity and information content of conscious experience and providing a solid theoretical framework for the concepts of integration and differentiation. First, we must clarify what integration and differentiation mean. Next, we must deal more precisely with how integration and differentiation are actually realized in the brain. From the results of this analysis, we propose a hypothesis called the "dynamic core hypothesis," which is a concise operational description of the special nature of the activity of the neuronal population that underlies conscious experience.

Integration and Regression

When we are driving a car, the visual scene contains various objects such as cars, pedestrians, trees, and the sky, which occupy specific positions within our field of vision. The objects may also be moving, and may emit specific sounds or smells. These objects may be related to each other in specific meaningful ways. Even in this amazingly rich and diverse world, what we experience moment by moment is a unified, conscious scene that only makes sense as a whole and cannot be divided into independent components while it is being experienced. That scene is constantly changing.

We aim to gain a more complete scientific understanding of the neural processes that explain the unity and integration of conscious experience. To this end, we will clearly define what integration means, how it can be measured, and how integrated neural processes can be identified. To this end, we will introduce a new concept, "functional clusters."

Neuroimaging techniques such as PET and fMRI can examine the activity of millions of synapses and brain regions at once, but they cannot track the fate of individual neural signals due to their insufficient spatial and temporal resolution. To examine the behavior of such large populations of interacting cells, we must rely on neural modeling. Large-scale computer simulations have made it possible not only to track the activity of individual neurons in a complex system, but also to examine how the spatial and temporal patterns of firing in tens of thousands of neurons develop after a specific visual stimulus is presented, for example.

The most important point about the results obtained with this model is that the correct output is not obtained by the binding or integration of the appropriate attributes of objects in any one specific cortical area or any one specific group of neurons. Therefore, integration is not achieved in a specific location, but is achieved through a consistent process. In addition to the remarkable ability to integrate the activity of distributed neurons, this model had an unexpected feature that reminded us of a characteristic we encounter when we reflect on our own conscious experience: the limits of our ability.

In a more detailed model of the thalamocortical system, in which the thalamic regions were interconnected, we investigated the dynamics of the recursive interactions within the thalamocortical system in more detail. The results of these simulations show that recurrent signaling within the cortex and between the cortex and thalamus can be enhanced by rapid changes in synaptic transmission efficiency and spontaneous activity within the network, allowing transient global alignment processes to be rapidly established. In this way, a set of elements that are functionally distinct from other parts of the system and interact strongly with each other can be called a "functional cluster". There is general agreement that clusters should be defined in terms of internal coherence and external isolation.

The concept of functional clustering has provided a measure of integration that can be applied to neurophysiological data to characterize the neural processes underlying consciousness. The fact that a neural process constitutes a functional cluster means that, at a given time, the process is functionally integrated, i.e., it cannot be decomposed into completely or nearly independent components.

Consciousness and Complexity

We experience specific states of consciousness that are chosen from among billions of possible states at any given time. If this is the case, then the neural processes underlying conscious experience must also be highly discriminative and informative. The information content of such a system can be expressed in terms of a statistical measure called "neural complexity". This measure of complexity can be used to estimate the degree of differentiation of the integrated neural processes. The aim is to show that consciousness and complexity are closely related, and to explain how complexity is realized in the brain.

The fact that the state of one part of a system affects other parts means that the system is integrated. If the system were not integrated, the states of different parts of the system would be independent. Therefore, we reach the important conclusion that complexity corresponds to an optimal synthesis of functional specialization and functional integration within a system. This is clearly the case for systems like the brain, where different areas and groups of neurons do different things at the same time and interact with each other to produce a unified conscious scene and unified behavior. We conclude that the complexity of neural processes in the thalamocortical system is dynamically influenced by its neurophysiological structure as well as its neuroanatomical structure. This dynamic nature means that the same normal brain can be complex or simple depending on the level of arousal.

There are two aspects of brain complexity that all experts agree on. Firstly, in order to be complex, it must be made up of many parts that interact in different ways. For example, the Oxford English Dictionary defines complexity as "a whole made up of a number of parts joined or connected together". Secondly, it is now generally accepted that something is not complex if it is completely random, and it is also not complex if it is completely regular. For example, it is thought that neither an ideal gas nor a perfect crystal is complex. Only those things that have both order and disorder, regularity and irregularity, diversity and universality, constancy and change, and stability and instability are worthy of being called complex. Biological systems, from cells to brains to organisms to societies, are prime examples of complex organizations. We can see that high complexity arises from the continuous interaction between the brain and the external environment, which has far greater potential complexity. According to simulations using simple linear systems, the complexity of systems with random connectivity is low. However, when the connectivity of these systems is changed by a selection procedure that increases their conformity with the statistical regularity of the external environment, their complexity increases significantly. Furthermore, all other things being equal, the more complex the environment, the greater the complexity of the system with a high degree of agreement. This is also clear from the fact that consciousness disappears when neural activity is uniformly or excessively synchronized, as in slow-wave sleep or generalized epileptic seizures.

The Dynamic Core Hypothesis

We call the assemblies of neurons that interact strongly with each other on a time scale of a few milliseconds and have clear functional boundaries with other parts of the brain "dynamic cores", emphasizing their integrity and constantly changing composition. Dynamic cores are processes defined in terms of neural interactions. Therefore, the dynamic core is neither a thing nor a place, and it is not a specific neural location, connectivity, or activity. The dynamic core is spatially extended, but it is distributed and its composition changes, so it cannot be limited to a specific location in the brain. Furthermore, even if such functional clusters are identified, it is predicted that they will only be associated with conscious experience if the recursive interactions are sufficiently differentiated. It is very difficult to visually represent the characteristics of the dynamic core. In order to integrate a large amount of information in an instant, a highly integrated yet differentiated organization is required, and to the best of our knowledge, such an organization exists only in the human brain.

Higher Consciousness

We have not yet clearly addressed the relationship between consciousness and the limits of language, thought and knowledge. As we have shown, this relationship is based on higher consciousness, which makes possible the development of concepts of self, past and future. In order to untangle the knots of the world, or at least to re-tie them in a less tangled way, we believe it is appropriate to end with a reflection on these major issues. Higher consciousness is clearly necessary for the scientific exploration of the characteristics of the consciousness process. As long as we are conscious, we cannot completely eliminate higher consciousness, and it is quite strange to think that we are only driven and acted upon by the continuous emotions of primary consciousness.

Let us focus on a brief exploration of some of the subjects related to higher consciousness, such as the origins of language, the self, thought, information, and the origins and scope of perception. It is time to ask what we can expect from scientific observers who seek to understand the processes of consciousness and to report on them to themselves and to others.

Language and the Self

We will examine some issues that have central meaning for human beings from a new perspective. We will consider the aspect of language evolution because it is thought that the emergence of higher consciousness is due to changes in the nerves connected to language.

When higher consciousness begins to emerge, the self is constructed from social and emotional relationships. The self as a subject with self-consciousness becomes something far beyond the biological individuality of animals with primary consciousness. The emergence of the self refines our phenomenological experience and links together emotion, thought, culture and belief. It frees the imagination and opens our thinking to the vast realm of metaphor. It can even temporarily free us from the temporal constraints of the remembered present while maintaining consciousness. The three mysteries - the mystery of the present progressive consciousness, the mystery of one's own consciousness, and the mystery of the construction of stories, plans, and fantasies - can be elucidated to some extent, if not completely, by considering primary consciousness and higher consciousness together.

Let's consider the changes in the structure of the brain that lead to higher-order consciousness. Even animals that only have primary consciousness can generate “mental images”, or scenes based on the recursive integration activities of the Dynamic Core. These scenes are largely determined by the succession of actual events in the environment, and to some extent are also determined by the unconscious subcortical activities. Such animals have biological individuality, but they do not have a true self that is aware of itself. They have a “remembered present” maintained by the real-time activity of the dynamic core, but they have no concept of the past or the future.

These concepts emerged only after the ability to express emotions and refer to objects and events through symbolic means, or semantic ability, appeared in the evolution of hominids. Inevitably, higher consciousness is accompanied by social interaction. Syntactic and semantic systems provided new types of memory that mediated higher consciousness, becoming new means for symbolic construction. It became possible to be aware of awareness.

In the evolution of hominids and the emergence of language, a new recursive loop appeared, just as in the case of primary consciousness. The acquisition of semantic abilities and, in turn, a new kind of memory through language led to an explosive expansion of concepts. As a result, the concepts of self, past, and future became linked to primary consciousness, making self-consciousness possible.

At that point, the individual is freed to some extent from the constraints of the remembered present. If primary consciousness connects the individual to real time, higher consciousness allows at least a temporary detachment. It is now possible to experience and remember a whole new world of intentionality, classification, and identification. As a result, concepts and thought are promoted. Scenes are enriched by symbols. Values are connected to meaning and intentionality. By evolving the neural system to link individual learning to changes in the value system itself, it is possible to change itself in a richer and more adaptive way. When higher consciousness develops along with language, the self is constructed from social and emotional relationships.

Animals that only have primary consciousness do not have symbolic abilities, so there is no possibility for them to develop concepts of self, past, or future. However, for babies with language abilities, from an early age, external cues are influenced by emotional interactions with their mothers, and begin to take on movement and conceptual meaning. The foundations for phonological and semantic development are laid early on, and they are also able to understand the meaning of interactions with their mothers.

Thought

Here, we will ask the question, "What is happening in your head when you think of something?" William James (1842-1910) was probably the first person to seriously attempt this. If we repeat this exercise based on our current understanding of the neural basis of consciousness, it supports the conclusion that a great deal happens in the brain every time we think, and most of it happens in parallel, based on surprisingly complex and rich associations. A significant part of this information is far more complex than the capabilities of current computers.

Philosophical thought is not sufficient on its own and must be supplemented by analysis of brain function. We believe that epistemology should be based on biology, particularly neuroscience, when considering how information and consciousness arise in nature. From this perspective, three important philosophical conclusions can be drawn Namely, "existence precedes description", "choice precedes logic", and "action precedes understanding in the development of thought".

We have primary consciousness, which is primary in the sense that it is essential for the development of higher-order consciousness. This is why we have focused so much on primary consciousness. However, it is higher-order consciousness that is central.

Our position is that higher-order consciousness, including the ability to be conscious of being conscious, depends on the emergence of meaning and, by extension, language. Along with these features, we also have a true self that emerges from social interaction, as well as concepts of past and future. Through primary consciousness and the remembered present, we are able to create stories, fiction and history through symbolic exchange and higher-order consciousness. We can ask ourselves how it is possible to know, and in doing so, lead ourselves to the threshold of philosophy.

Perceiving consciousness as a physical process

I have argued that consciousness arises from a specific arrangement of material order in the brain. It is common to have the prejudice that to call something material is to deny its entry into the realm of the sublime, that is, the mind, spirit, and pure thought. The word material is used to refer to many things and states. This applies to the world of the senses or the measurable, the world that we generally call the real world, and the world that scientists study. That world is far more subtle than it appears at first glance. Stars are also matter, as are atoms and subatomic particles. They are made up of matter and energy.

The mind is completely dependent on and rooted in the physical processes that occur in ourselves and in other minds, and in the events that involve communication. There is no complete separation between the material and mental realms, and there is no basis for dualism. However, there is clearly a realm that is created by the physical order of the brain, body, and social world, and in which meaning is consciously created. This meaning is essential to our description and scientific understanding of the world. The incredibly complex material structure of the nervous system and the body gives rise to dynamic mental processes and meaning.

My opinion

When I asked Microsoft Copilot, “Did Descartes himself coin the term ‘mind-body dualism’?” the answer was, “Descartes himself did not use the term ‘mind-body dualism’, but his philosophy laid the foundations for this concept. Descartes saw the mind (the mind) and matter (the body) as independent entities, and called them “res cogitans” and “res extensa”. This time, I read several of Descartes' works and commentaries on Descartes. I think that the term “mind-body dualism” was not coined by Descartes himself, but by philosophers of the time or later generations, who used it to comment on Descartes' work. In my opinion, Descartes' philosophy is not a mind-body dualism, but a dualism of consciousness between the “mind of the flesh” and the “mind born of the mind of the flesh”. Or, to put it another way, it could also be called 'emergent dualism'.

In the book 'The Universe of Consciousness' by Gerald Edelman and Giulio Tononi, primary consciousness corresponds to the 'fleshly mind', and higher-order consciousness corresponds to the 'mind born of the fleshly mind'. The fleshly mind is a primitive existence. The fleshly mind is a mind that defends and maintains its own existence. The mind that is born from the mind of the flesh arises through an emergent process, but that mind expresses measures for maintaining that individual's social adaptation to the real world for an even longer period of time. The table at the beginning of this chapter shows this.

In the physical world, if an individual wants to do something, it needs a functional structure made of matter. Without a structure, it cannot move or perform any functions. Just arranging matter will not make it move on its own. I think that the same is true in theory, and that a structure is necessary.

I think that it is not the case that something like a spirit inhabits human beings through emergent phenomena in the brain, but rather that the human brain is able to imagine something like a spirit. This is still just a hypothesis, but the higher-dimensional existence that arises through emergent phenomena may be derived from string theory. It is possible that matter has the ability to make humans imagine such a world, or to access such a world, implicitly. However, this is only true at subatomic particle level and below. In order to access these higher dimensional worlds, we need a level of complexity similar to that of the human brain. I think that the ability to access higher dimensions through emergent phenomena is a normal function of the brain, and not the creation of illusions or hallucinations.

However, I think that the sacred world can only be considered meaningful and valuable if it is juxtaposed with the secular world in which our brains exist. The sacred world is the goal of the secular world. From the perspective of the real world, the sacred world only exists because of the secular world. If the secular world were to disappear, we would lose all understanding of the meaning and value of the sacred world. In other words, the sacred world only has a role to play if the secular world in which we live continues forever. The role of the sacred world is to make humans continue to live in the secular world. If the secular world disappears, the sacred world will also disappear. I don't think anyone would ever think about a world where only the sacred world exists. If the secular world in which human beings exist disappears, the sacred world alone will have no meaning or value for human beings. In other words, when the end of the earthly world comes and the world is devastated and human beings disappear, even if there is a sacred world, it will no longer be relevant to human beings.

The End