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The History of Biology and its Importance for Gender Studies

Yusuke Kaneko[1]

1) Meiji University, Japan

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The History of Biology and its Importance for Gender Studies[1]

Yusuke Kaneko
Meiji University

Abstract

The aim of this paper is to call the attention, especially that of feminists, to the current progress in biology. It appears gender studies still confine themselves to outdated ideas of sex chromosomes like XX, XY (§10). However, science has been making progress. It no longer sticks to such matters as XX, XY. Its interest is now in Sry, a kind of gene (§11), and MIS, a kind of sex hormone (§14). Abnormalities of sex chromosomes are no longer evidence to deny the biological approaches, for example. We shed light on this fact, putting gender studies in the context of chronologies of science as well (§§2-9).

Keywords: Gender studies, chronology of science, sex chromosomes, Sry, sex hormones

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La Historia de la Biología y su Importancia para los Estudios de Género[1]

Yusuke Kaneko
Meiji University

Resumen

El objetivo de este artículo es llamar la atención, sobre todo la de las feministas, sobre los avances actuales en biología. Parece que los estudios de género todavía se limitan a las ideas anticuadas de los cromosomas sexuales como XX, XY (§10). Sin embargo, la ciencia ha realizado progresos. Ya no se centra en cuestiones tales como XX, XY. Su interés está ahora en Sry, una especie de gen (§11), y MIS, un tipo de hormona sexual (§14). Las anomalías en los cromosomas sexuales ya no son la evidencia para negar los enfoques biológicos, por ejemplo. Para arrojar luz sobre este hecho, hay que también poner los estudios de género en el contexto de las cronologías de la ciencia (§§2-9).

Palabras clave: Estudios de género, cronología de la ciencia, cromosomas sexuales, Sry, hormonas sexuales

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Feminism has consistently abhorred scientific approaches since the beginning of its study (cf. Mikkola, 2011, 1.1[2]). Following Beauvoir's slogan, *On ne naît pas femme: on le devient* (1949, Tome II), it has strictly distinguished gender, regarding it as a cultural concept, from sex, regarding it as a merely biological concept.

However, such arguments would not get so persuasive unless they convince scientists that gender studies are completely independent of scientific, biological approaches. But it seems difficult, because the current progress of biology is so amazing that it is about to take away the boundary between sex and gender.

Within this article, we do not go further than providing relevant materials, such as chronologies, concrete theories, and so on. Nevertheless, those would suffice for calling the attention, because most of them appear unknown to the feminists[3].

The research of this kind might perhaps discomfort feminists. But, to take their studies to higher stages, it is undoubtedly necessary. Even researchers of the humanities proper, therefore, should read through what will be stated in the following, hopefully.

Biological Determinism (2)[4]

Since the beginning, feminists have abhorred scientific approaches. One of the reasons for it is probably the patriarchal attitudes of scientists to sexual differences. A representative is the so-called *biological determinism* (cf. Mikkola, 2011, 1.1).

This view was originally put forward by Patric Geddes (1854-1932) and John Arthur Thompson (1861-1933) in their book, *The Evolution of Sex* (Geddes & Thompson, 1890)[5]. Around thirty years after *The Origin of Species* (Darwin, 1859)[6], they stated as follows:

> (1)[7] We have seen that a deep difference in constitution expresses itself in the distinctions between male and female, whether these be physical or mental. The differences may be exaggerated or lessened, but to obliterate them[,] it would be necessary to have all the evolution over again on a new basis. What was decided among

> the prehistoric Protozoa[8] cannot be annulled by Act of Parliament. (Geddes & Thompson, 1890, p. 267)

Biological conditions of sex cannot be changed by any artificial measures like "Act of Parliament,"[9] said Geddes & Thompson cynically.

With the impressive characterization that the males are "*katabolic*"[10] and the females "*anabolic*"[11] (Geddes & Thompson, 1890, p. 270), Geddes & Thompson moved on to the assertion that the males are determined to be "more active, energetic, eager, passionate, and variable," while the females "more passive, conservative, sluggish, and stable" (Geddes & Thompson, 1890, p.270)—a stereotype enough to make feminists angry.

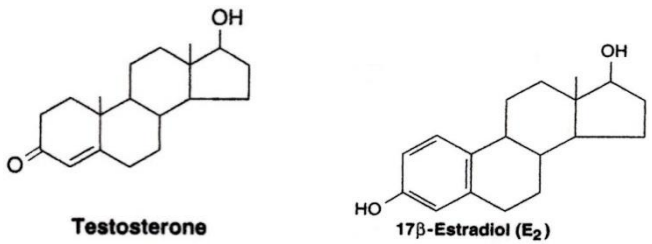
Toward Chronological Investigation (3)

The provocative arguments of Geddes & Thompson's apparently had an opposite effect to alienate feminists from biological researches. Since their theory was mainly based on Darwin's evolution theory alone[12], it was probably not so difficult for the opponents at that time to ignore or overcome their prejudices. This is how the atmosphere of anti-biology developed in gender studies.

But as a matter of course, the biological research itself was going on, and reached a higher level. Our age is situated at this stage. What, then, can we say about current biology?

Symbolically, the current biology appears characterized by the following figures:

Figure: (2) *A male hormone* (*left*) *& a female hormone* (*right*) (Ganong, 2005, p.429, p.440)



These are notations in chemistry showing the structural formulae of sex hormones. Sex hormones are what we will think to be a goal in the biological study of sex (§§15-16). As these figures suggest, a chemical manner of speech is a character of modern biology.

Here, then, arises another question. How and when did biologists acquire such manners of speech? In the following, we would like to begin our pursuit by discussing the history of biology, focusing mainly on this question.

An Angle of the Following Chronology (4)

By plotting in a time line a period of time when each thinker developed his or her ideas, we may overview the ideas from completely another angle. Feminists are no exception. Their thoughts are also chained to the times when they lived. This is serious, because gender studies are essentially concerned with scientific progress made as time passes.

Conversely, we may say, it is a time lag of this kind that allowed feminists to publicize their thought so radically. For example, John Stuart Mill (1806-1873), the author of *the Subjection of Women* in 1869, contributed to the *first wave feminism*[13], criticizing the status of women at that time as "slaves" (Mill, 1869, p.33). But he might have owed this bold arguments to the limitation of scientific progress at that time, when people never thought of the influential sex hormones, for instance (see the arguments in §§15-16 below).

Another example: Simone de Beauvoir (1908-1986), the author of *Le Deuxième Sexe* in 1949, was certainly so familiar with biological arguments at that time (Beauvoir, 1949, Chapter 1, Tome I), but it was slightly before the discovery of the *double helix structure* by Watson & Crick in 1953 (see *Chron*. (3) below)[14]. Thus, we may say, even she lacked the relevant knowledge of our age.

The same is true of contemporary feminists like Butler, Kristeva, and Irigaray. Apparently, they have no knowledge of Sry, for example (see *Chron*. (5) below).

It is not until researchers have enough knowledge of contemporary biology that gender studies get sufficiently persuasive. They should not look away from it. The importance of the following chronology would speak for itself[15].

A History of Biology (5)

Let us then embark on compilation of the chronology. As said above, our main interest is in the modern fashion of speech in biology, which relates itself with chemical analyses (§3). Viewed from this angle, one landmark would be the work of Kekulé, a German chemist. He opened up the path from chemistry to biology, which is marked as a great leap of *organic chemistry* (see *Chron*. (8) below).

Now we take the first step. There is a long way to go. To begin with, we want to make sure of basic facts in biological researches:

(3) *A History of Biology*

1665 Robert Hooke (1635-1703) discovered the *cell*.

1838 Matthias Jakob Schleiden (1804-1881) put forward the *cell theory* on plants.

1839 Theodor Schwann (1810-1882) put forward the *cell theory* on animals.

1842 Karl Wilhelm von Nägeli (1817 -1891) discovered *chromosomes*.

1859 Charles Darwin (1809-1882) put forward the *evolution theory*.

1865 Gregor Mendel (1822-1884) put forward the theory of *genes*[16].

1869 Friedlich Miescher (1844-1895) discovered the *nucleic acid*[17].

1900 Hugo de Vries (1848-1935), Carl Correns (1864-1933), and Erich von Tschermak (1871-1962) *rediscovered* Mendel's genetics[18].

1901 De Vries put forward *mutationism*: an attempt to integrate Mendel's genetics and Darwin's evolution theory.

1902 William Bayliss (1860-1924) and Ernest Starling (1866-1927) discovered *hormone* (concretely, *secretin*).

1913 The first chromosome map was made by Alfred Henry Sturtevant (1891-1970), a disciple of Morgan.

1926 Thomas H. Morgan (1866-1945) identified the locations of genes with *chromosomes* (*chromosome theory*).

1945 George Wells Beadle (1903-1989) and Edward Lawrie Tatum (1909-1975) put forward the *one gene-one enzyme theory*.

1949[19] Linus Pauling (1901-1994) studied the sickle-cell anemia, which contributed to establishing the *one gene-one protein theory*.

1952 Alfred Hershey (1908-1997) and Martha Chase (1927-2003) identified the location of genes with *DNA*.

1952 Maurice Hugh Frederick Wilkins (1916-2004) and Rosalind Elsie Franklin (1920-1958) succeeded in taking *X-ray diffraction photographs of DNA*.

1953 James Watson (1928-) and Francis Crick (1916-2004) put forth the *double helix structure* of DNA[20].

1954 George Gamow (1904-1968), the famous physician, suggested the *triplet theory*.

1958 Crick put forward the *central dogma*, according to which genetic information is transferred from DNA to RNA and further to protein in one direction.

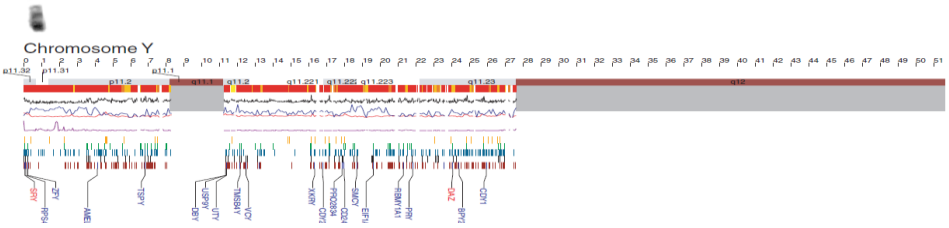
1961[21] François Jacob (1920-2013) and Jacques L. Monod (1910-1976) put forward the *operon theory*.

1961[22] Marshall Warren Nirenberg (1927-2010) *firstly deciphered a base sequence*, that is, how a specific base sequence codes an amino acid.

1965[23] Har Gobind Khorana (1922-2011) deciphered *all of the 64 genetic codes* (base sequences).

2000[24] The draft of *human genome* was published by *International Human Genome Sequencing Consortium*.

Figure: (4) The Draft of Gene Map of Y-Chromosome (IHGSC, 2001)



The genome map could be one goal of modern biology. *Genetics* becomes, in this sense, indispensable for the current argument, too. The *cell theory* was, true, a mile stone. So was the *evolution theory*. But after all, genetics should play the most important role, which matured around 100 years after the discovery of Mendel (see 1865 in *Chron*. (3)).

An Additional Note (6)

What we saw just now is, as it were, the broadest time line of biology. Narrowing it down would lead us to a more detailed course of events concerning sex, our original interest. Let us then move on to that time line:

(5)[25] *An Additional Note*

1890 Geddes & Thompson put forward the *biological determinism* of sex.

1891 Hermann Henking (1858-1942) discovered an enigmatic chromosome, calling it "*X*"[26].

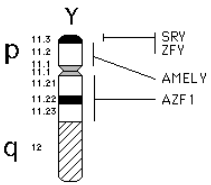
1901 Clarence McClung (1870-1946) suggested that Henking's X-chromosome is nothing but the determinant of sex[27] (but, as we know, this hypothesis is fundamentally wrong).

1905 Nettie Stevens (1861-1912) discovered a tiny partner of the X-chromosome, calling it "*Y*." And she eventually confirmed that the Y-chromosome is the determinant of sex[28].

1947 Alfred Jost (1916–1991) showed that the key organ to sex determination is the *testicle*.

Figure: (6) Sry on Y

(NAO, 2008, p.849)



1990 Andrew H. Sinclair's group discovered *Sry*.

This makes no more than the second half of the relevant history. Study of sex moved that slowly. Besides, they have played second fiddle to biology, so to speak. For example, the discovery of chromosome (see 1842 in *Chron*. (3)) enabled Henking's pursuit (see 1891 in *Chron*. (3)); Khorana's attainment (see 1965 in *Chron*. (3)) motivated Sinclair's group (see 1990 in *Chron*. (5)), and so forth.

However, the history of biological study of sex would have its own course. The pathway to it is probably a *hormone*. It began playing a crucial role after the genetics matured, as we will see later (§§14-15).

A History of Theoretical Chemistry (7)

Let me take a detour for a while, because the preceding formulae in *Fig*. (2) consist of *atoms*, *molecules*, etc., which demands of us the additional knowledge of *theoretical chemistry*:

(7) *A History of Theoretical Chemistry*

1648[29] Jan Baptista van Helmont (1577-1644) discovered *carbon dioxide*.

1660 Robert Boyle (1627-1691) laid down the modern, nonphilosophical concept of *element*.

1766 Henry Cavendish (1731-1810) discovered *hydrogen*.

1772 Daniel Rutherford (1749-1827) discovered *nitrogen*.

1774 Karl Wilhelm Scheele (1742-1786) discovered *chlorine*.

1774[30] Joseph Priestley (1733-1804) discovered *oxygen*.

1803 John Dalton (1766-1844) put forward the *atomic theory*, where also the concept of the *atomic weight* appeared[31].

1811 Amedeo Avogadro (1776-1856) put forward the *molecular theory*.

1813[32] Jöns Jacob Berzelius (1779-1848) put forward the *symbols of element using alphabets* instead of the symbols using pictures suggested by Dolton in 1805.

1827 Robert Brown (1773-1858) discovered *Brownian motion*.

1895[33] Wilhelm Conrad Röntgen (1845-1923) discovered an *X-ray*.

1897 Joseph John Thomson (1856-1940) discovered an *electron*.

1909[34] Jean Baptiste Perrin (1870-1942) researched Brownian motion and decided Avogadro's number, which finally confirmed Dalton's atomic theory.

1912 Max Theodor Felix von Laue (1879-1960) discovered the *X-ray diffraction* with *Laue spots*.

1913 William Henry Bragg (1862-1942) and William Lawrence Bragg (1890-1971) put forward *Bragg's law*, which, together with Laue spots, finally provided the *X-ray crystal structural analysis*, which enabled the researchers including Wilkins and Franklin especially (see 1952 in (3)) to analyze the micro-structures of protein, DNA etc.

1913 Niels Henrik David Bohr (1885-1992) put forward *Bohr's model*, which initially elucidated the structure of the atom.

1916[35] Gilbert Newton Lewis (1875-1946) put forward the idea of the *ionic bond*, and furthermore, of the *covalent bond* with his disciple, Irving Langmuir (1881-1957), the so-called *Lewis-Langmuir theory*, which finally proved the correctness of Avogadro's molecular theory[36].

1919[37] *International Union of Pure and Applied Chemistry* (*IUPAC*) was founded.

Herein, the history of *physics* is also included. This is because the structure of the atom was elucidated in cooperation with physicists. Even with this cooperation, however, the atomic structure as we know it today was established as late as 1910's. It is a bit surprising.

A History of Organic Chemistry (8)

Now that an overall picture was provided, we return to our original question of biology. How and when did biologists acquire the chemical manner of speech?

One landmark is, as mentioned above, the work of Kekulé (§5). We approach this achievement on the basis of the preceding chronologies:

(8) *A History of Organic Chemistry*

1670 With his mentor, Johann Joachim Becher (1635-1682), Georg Ernst Stahl (1659-1734) put forward the *phlogiston theory*. He insisted *vitalism* as well.

1789[38] Antoine-Laurent de Lavoisier (1743-1794) published his *theory of combustion*, which refuted Stahl's *phlogiston theory*.

1807 Jöns Jacob Berzelius (1779-1848) put forward the distinction of *organic* and *inorganic* matter.

1823[39] Michel Eugène Chevreul (1786-1889) published his study of animal fats, which marks the beginning of the study of the *three major nutrients* (sugars, proteins, and fats), not only of *fats*.

1828 Friedrich Wöhler (1800-1882), a disciple of Berzelius, ironically synthesized *urea* $CO(NH_2)_2$,[40] which is regarded as organic matter, from *ammonium cyanate* NH_4OCN, which is regarded as inorganic matter[41]. This result is said to have undermined the vitalism.

1845 Adolph Wilhelm Hermann Kolbe (1818-1884), a disciple of Wöhler, synthesized *acetic acid* CH_3COOH,[42] which is regarded as organic matter, from *carbon disulfide* CS_2, which is regarded as inorganic matter[43]. This result is said to have *finished* vitalism.

1831 Justus von Liebig (1803-1873) devised the *ultimate analysis*[44].

1858[45] Archibald Scott Couper (1831-1892) and Friedrich August Kekulé (1829-1896) each found the theory of the *bond* (or the *valence*).

1861 Aleksandr Mikhailovich Butlerov (1828-1886) put forward the theory of *chemical structure.*

1865 Kekulé put forward the *hexagonal structural formula of benzene*.

1884[46] Emil Fischer (1852-1919) began the study of *sugars*.

1907[47] Fischer succeeded in synthesizing polypeptide constituted of eighteen amino acids, which marked a great progress in study of *proteins*.

1927[48] Heinrich Otto Wieland (1877-1957) received the Novel Prize for the study of *bile acids*.

1928[49] Adolf Otto Reinhold Windaus (1876-1959) received the Novel Prize for the study of *sterols*.

1936 Hermann Staudinger (1881-1965) established the *macromolecular theory*.

Our question was how and when biologists acquired such a chemical manner of speech as we have seen in *Fig.* (2). An initial answer to this question is given in the item of 1858, when Couper and Kekulé each proposed the *chemical bonds*, which enabled the notation like "—OH" in *Fig.* (2). After that, Kekulé put forward the *hexagonal structure* in 1865, which enabled the description of the *steroid ring (nucleus)*[50] as we see it in *Fig.* (2).

These two achievements made the name of Kekulé immortal, while it is a bit surprising that they appeared long before Bohr's model elucidating the internal structure of the atom (see 1913 in *Chron*. (7)).

However, it was not sufficient that Kekulé alone published his researches, actually. See the steroid ring depicted in *Fig*. (2). That part suggests the hormones in *Fig*. (2) are literally *steroids*, a kind of *lipid* like *oils and fats*[51].

The study of those typical "organic" matters went beyond Kekulé's field partially. Chevreul, instead, began the research as early as 1823 with regard to *fats*, a kind of oils and fats (see *Chron*. (8)). Wieland and Windaus each succeeded to his research (see *Chron*. (8)). This is how the structure like *Fig*. (2) was gradually determined (cf. Takeuchi, 1993, p.100).

However, even their researches were not conclusive at all. They made mistakes. After all, researchers needed some concrete observation device to determine the structure. Although the X-ray crystal structural analysis that physicists adopted in 1913 (see *Chron*. (7)) seemed promising, the demands of researchers were not fully met.

It was quite recently (as late as in the second half of the 20th century) that reserchers got the one which they are satisfied with (cf. Takeuchi, 1993, pp.100-101).

A Short Summary of the Preceding Chronologies (9)

The overview of these chronologies tells us how recent products structural formulae like *Fig.* (2) are. At a rough estimate, we should say, biologists acquired the chemical manner of speech in the past 50 years or so.

Now, let us turn our eyes to the matters themselves, not formulae, depicted in *Fig.* (2), namely *sex hormones*. As we can see in *Chron.* (3), Bayliss and Starling discovered a hormone as early as 1902, but it was not a "sex" hormone. Even the word "sex hormone" does not appear in *Chron.* (5), for example. This implies how recent product this conception is.

As is well known, sex hormones did not play a central role in the biological study of sex from the beginning. Instead, it was the *Y-chromosome* that played a central role.

Stevens is said to have discovered it as early as 1902 (see *Chron.* (5)). However, here as well, immature observation devices plus knowledge delayed its recognition. Researchers should have recognized her discovery on a *genetic* level (see our arguments below, in §§10-11). Yet it took them another 50 years to attain that. (At least, Bragg family's contribution in 1913 of *Chron.* (7), Morgan's achievement in 1926 of *Chron.* (3), and above all, the work of Watson & Crick in 1953 of *Chron.* (3) were necessary.)

Beyond the Hackneyed Idea (10)

To sum these all up, we can conclude, it is quite recently that the biological study of sex, including its chemical manner of speech, matured. On the other hand, feminists should notice that their familiar talk on sex chromosomes, such as XY, XX, was a thing of the past. Nevertheless, there are still some researchers who stick to this conception:

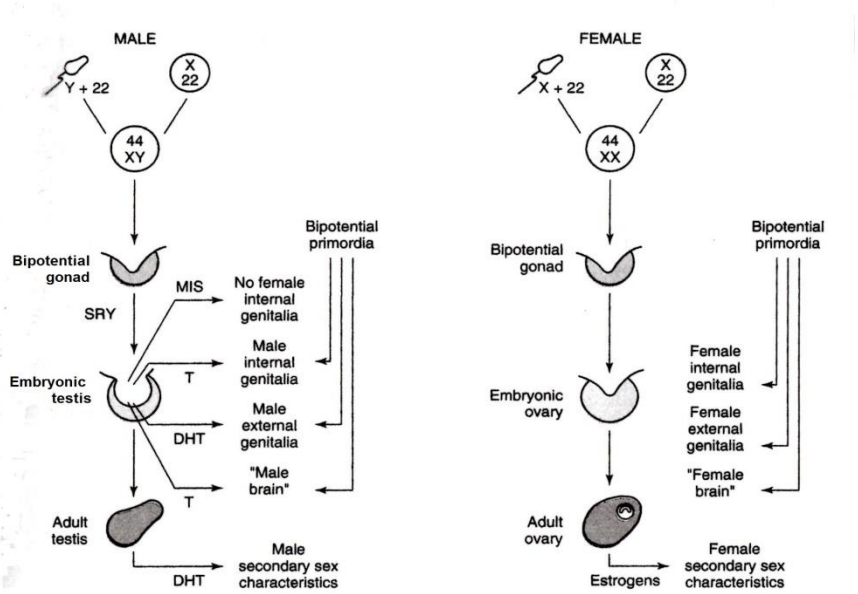
> (9)[52] It has come to be known that the sexual difference [of male and female] is diverse and continuous. […] Think about the sexual difference at a chromosome level. In our high school days, a biology teacher told us that XX chromosomes determine the female whereas XY chromosomes determine the male. However, there is actually a person having [abnormal] chromosomes, such as XXY, XO, and so on; besides, it is undetermined what kind of

> information each chromosome has concerning sex. It is also possible that a Y-chromosome has information concerning the female body and that an X chromosome has information concerning the male body. […] Anyway, we [usually] make a distinction of male and female by reference to babies' external figures of genitalia[, for example]. Nevertheless, there are neutral figures[, as it were], so that we cannot rely on them decisively. […] The predominant view is that not only normative sexual differences such as masculinity and femininity, but also the recognition of his/her own sex—[the so-called] gender identity— as well as which sex one prefers [as his/her partner]—[the so-called] sexual preference— is not determined genetically, but acquired in his/her course of life. (Ehara & Yamada, 2003, pp.20-22)

This is a citation from a book at hand written by sociologists. Certainly, we heard some time in our high school days: "A human being has in total *46 chromosomes*, which are divided into *23 pairs (46=2n)*. One set (or one side) of the 23 pairs is called *human genome*, the least information for the living thing to survive[53]. Among the set (of 23 chromosomes) is X or Y. After the fertilization, either XY or XX appears. XY determines a male. XX determines a female." The cited passage criticizes very much this argument. But chromosomes such as X and Y are already things of the past. Biologists now pursue Sry, which we have seen in *Chron.* (5) above, not chromosomes[54].

See the following figure:

Figure: (10) *The Overview of Sexual Determinatio*n (Ganong, 2005, p.417)



The interest of biologists is currently in the process under "44 XY" (MALE) or "44 XX" (FEMALE). Nevertheless, the preceding citation (i.e. (9)) stuck to the process *before* that, unfortunately.

Biologists are no longer interested in the hackneyed idea of sex chromosomes. Such an old-style thought was gone long before.

Sry (11)

The determinant of sex is no longer sex chromosomes, but *Sry*, which is written as "SRY" above (see *Fig.* (10)), meaning "*sex-determining region on the Y chromosome*" (Bainbridge, 2003, p.18; Ganong, 2005).

This is fairly important. Biologists already know abnormalities, which sociologists proudly mentioned (see (9)), was no longer problematic; it was solved on a genetic level (cf. Bainbridge, 2003, pp.17-18). Contrary to the preceding citation (i.e. (9)), sexual differences are determined genetically. The Y-chromosome is a dummy. We must go into its "sex-determining

region," which means its *genetic* information. The mistake sociologists made was that they stuck to the *chromosome* level.

Let us then go into the genetic level named Sry. We may regard it both as a *gene* and as a *protein*[55]. It is allowable, since Sry is no more than abbreviation. But we introduce two more terminologies to get clear: a *Sry regulatory gene* and a *Sry regulatory protein*.

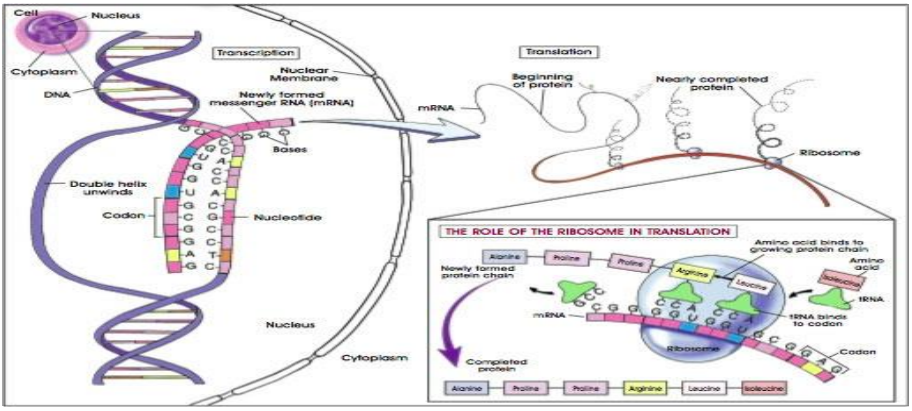
This interpretation reflects the *operon theory* by Jacob & Monod in 1961 (see *Chron.* (3)). According to them, there are two types of gene: genes *directly* affecting our lives, and genes *indirectly* affecting our lives through *regulating* the other genes. This *regulation* is a kernel of the operon theory, and a key to understand the determination of sex as well.

A Normal Function of the Gene (12)

Without the knowledge of the operon theory, we cannot realize how Sry works, either. So we look into the theory, furthermore[56].

A *gene* is normally considered coding[57] that *protein* which *directly* affects our lives. This mechanism was known by researchers around 1940's (see *Chron.* (3)).

Figure (11) An Overview of Genetic Coding[58] (see also Asashima et al., 2012, pp.84-85)



This figure shows how genes work normally; for example, how a digestive enzyme, a protein directly used for our lives, is produced (cf. Shiokawa et al., 2007, p.11).

See the center of *Fig*. (11). There, we can find an *mRNA*[59]. With the help of an *RNA polymerase*[60], the mRNA *transcripts* the information of genes, bringing it out of the nucleus (cf. Asashima et al., 2013, pp.92-97).

What is a "gene," by the way? To tell the truth, not a few researchers avoid answering this question[61]. But we may loosely regard it as a set of *codons*, each of which is a triplet of bases like GCG[62]. Genes are such sequences; and as they get out of the nucleus, there comes a *ribosome*[63].

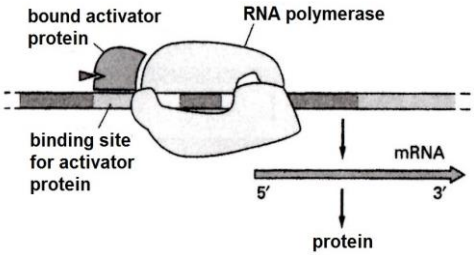
The ribosome *translates* the genetic information (transcribed by the mRNA) by uniting those *amino acids* with each other which *tRNAs*[64] bring successively.

A *protein* is a *polymer* constituted of amino acids as its *monomers* (cf. Takeuchi et al., 2012, pp.262f.)[65]. Thus, when a ribosome translates all the information of mRNA, building up a protein from amino acids prescribed by the mRNA, a normal function of the gene is considered done.

Operon Theory (13)

This is a normal function of the gene. In contrast, Jacob & Monod suggested, in their operon theory, another type of gene which affects the "normal" function. A *Sry regulatory gene* as we mentioned it above (§11) is a typical example. Thus, we focus on that very gene henceforward (because our interest is originally in sexual differentiation).

Figure (12): A Model of Operon Theory (Albert et al., 2003, p.274)



See Fig. (12). There is a striped slender bar drawn horizontally. We regard it as DNA. As is well known, this is shorthand for *deoxyribonucleic acid*, which Hershey & Chase identified with Mendelian genes (see 1952 in *Chron.* (3)).

We have already seen that an mRNA brings out a genetic information with the help of an RNA polymerase (§12). *Fig.* (12) is a close-up of this part. It depicts the RNA polymerase transcribing the genes.

The Sry regulatory gene, which we are talking about, is located outside of this figure, unfortunately. But the "(bound) *activator protein*" coded by the Sry (regulatory gene) appears at the upper left, instead.

The activator protein is a kind of *regulator protein*, which *activates* the RNA polymerase. The meaning of the "activation" is explained in the following way[66].

Although in *Fig.* (12) the RNA polymerase has already bound with the specific region of DNA (colored narrowly in black at the middle of it), which is called a "*promotor*," this part (promoter) is originally so powerless[67] to invite the RNA polymerase that it always needs help. Thus, the regulatory protein comes to help the promotor invite the RNA polymerase.

This is the meaning of "activation." After this activation, the RNA polymerase follows a normal course of transcribing genes. This normal part of DNA is called, in distinction from the regulatory genes, "structural genes." The operon theory centers at this distinction of a "*structural gene* (*gène de structure*)" and a "*regulator gene* (*gene régulateur*)."

MIS (14)

This is an overview of the operon theory, and Sry in its context. Sry is a regulator gene (or a regulator protein); it regulates a function of a specific gene. In the present context, the regulated function is, of course, the *sexual differentiation* (see *Fig.* (10) again).

Now we are getting closer to the true mechanism of sexual differentiation (while the false or misleading one is the superficial understanding of the Y-chromosome, as stated in §10). The function of Sry, which is said to be playing a crucial role on the Y-chromosome, should be concretely explained next.

Veterinarian David Bainbridge (1968-), however, instructs us that it is not so simple. He says:

> (13) The Sry [regulatory] gene [makes the Sry regulatory] protein that switches on the Sox9 [regulatory] gene, and [the] Sox9

> [regulatory gene] then makes [the Sox9 regulatory] protein that switches on [the] MIS [regulatory gene]. [The MIS regulatory gene] is especially important, for [it coordinates] the construction of testicle itself. (Bainbridge, 2003, pp.20-21)

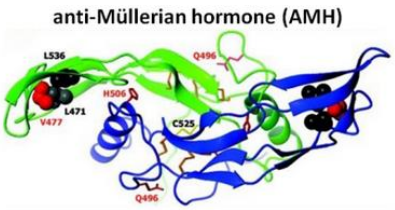
Here, Bainbridge surely has the operon theory in mind. And he summarizes this description in the following way:

(14) Y chromosome → Sry → Sox9 → MIS → testicle[68]. (Bainbridge, 2003)

The noteworthy here is "MIS." We saw it in *Fig.* (10) already.

Bainbridge's usage of this word is, however, a bit vague; he uses it in the sense of a regulatory gene as well. But normally, "MIS" means "Müllerian inhibiting substance" (cf. Ganong, 2005, pp.414f.)[69], which is not a gene but a hormone, as Bainbridge (2003, p.22) admits.

Figure (15) *MIS* (*also AMH*)



Sexual Differentiation (15)

Not only is MIS a hormone but also it is a sex hormone. This is strikingly important, because it means now we come to the second stage of sex differentiation where sex hormones, such as MIS, play a central role instead of genes, such as Sry.

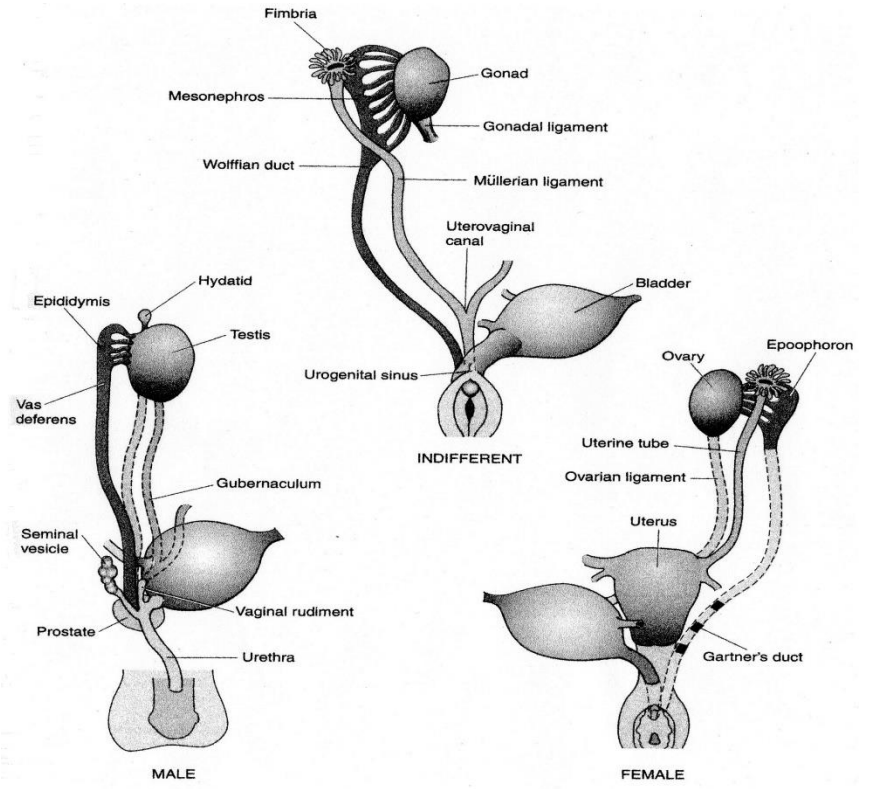
See *Fig.* (10) again, focusing on its left side (concerning "MALE") alone[70]. It can be divided into two parts. One is the process from "Bipotential gonad" to "Embryonic testis," which Bainbridge calls "the first half of the chain" (2003, p.17, pp.20-21) and the whole process of which we saw in *Chart* (14). The other is the process from "Embryonic testis" to "Adult testis," which Bainbridge calls "the second half of the chain" (2003, p.17, pp.21-24).

The former process is governed by genes like Sry, as we saw in *Chart* (14). In contrast, the latter is governed by sex hormones, which is our target below.

In the first place, as Bainbridge (2003, pp.21-25) tells us, we must classify three types of sex hormone forming the testicle: the *Müllerian inhibiting substance*, the *insulin-like-hormone-3*, and the *androgens*. The androgens are a group of hormones including the famous *testosterone* (see *Fig*. (2)).

We can map the function of each sex hormone on the following picture:

Figure (16): The Differentiations of Internal Genitalia (Ganong, 2005, p.415)



Focus on “Gonad,” “Wolffian duct,” “Vas deferens,” “Gubernaculum,” and “Müllerian ligament.” In addition, imagine there is a short strap tying

the gonad to the kidney, named "the suspensory ligament" (Bainbridge, 2003, p.23).

A series of events occurs, as follows. First, the testicle secretes, thanks to the MIS gene, the Müllerian inhibiting substance, which destroys the *Müllerian ligament* necessary to form the female genitalia (cf. Bainbridge, 2003, p.23), and develops the *Wollfian duct* into the *vas deferens* which will carry sperm from the testicle to the penis (cf. Bainbridge, 2003, p.22). After that, the testicle successively secretes the insulin-like-hormone-3, which strengthens the *gubernaculum* so that it can pull the male gonad away from the original position (next to the kidney) (cf. Bainbridge, 2003, pp.23-24). Finally, the testicle secrets the *androgens*, which weaken the suspensory ligament so that the male gonad can pop out of the abdomen to be ventilated (cf. Bainbridge, 2003, p.24)[71].

Conclusion (16)

In this way, sex hormones play a key role in the second stage of sex differentiation.

It is not, however, so important to understand the description precisely, although we gave it, of course, with great care. The point is, rather, to realize that the modern biologists tackle their issue on this level. The Y-chromosome is a thing of the past. Researchers are now working on the functions of genes inside the chromosome, and, as we have just seen, on those of sex hormones, the Müllerian inhibiting substance, the insulin-like-hormone-3, and the androgens.

Understanding like (10) was left far way behind. Feminists should not look away from this fact.

Sokal Affair threw doubt on the conventional studies of feminism, unfortunately (Sokal, 1996).

Nevertheless, we could say, it was a turning point for gender studies. Now feminists should refrain from intricate reference to quantum physics, for example.

Instead, the biological study of sex would appear on their agenda, once again. We have pursued this alternative mainly from a historical viewpoint. If feminists follow up their researches with exact knowledge of this kind, the day will soon come when scientists also recognize the significance of gender studies. I hope this research will be useful for that very purpose.

Notes

[1] This paper is based on my lecture at Chiba University (2014-2015).
[2] As for Mikkola's article (2011), we use section numbers instead of page numbers.
[3] We may include in these feminists Judith Butler (e.g. 1988), Luce Irigaray (e.g. 1985), Julia Kristeva (e.g. 2006) and so on. Unfortunately, some of them were criticized for the lack of knowledge of science in the famous *Sokal Affair* (Sokal, 1996).
[4] We assign a section number (x) to each heading for the later references. The sign "§" is then put in front of it like "§2".
[5] See the description by Mikkola (2011, 1.1) as well.
[6] On account of space, we cannot treat this masterpiece of Darwin's, so we give a short commentary in this footnote. This is important, because not a few biologists, such as Richard Dawkins (1941-), regard Darwin as the most important figure in the history of biology (cf. Dawkins, 1989).

What catches our eyes on reading *The Origin* is the section titled "Sexual Selection" of Chap. IV, in which Darwin argued as follows:

> [Sexual selection] depends not on a struggle for existence in relation to other organic beings or to external conditions, but on a struggle between the individuals of one sex, generally the males, for the possession of the other sex. The result is not death to the unsuccessful competitor, but few or no offspring. Sexual selection is, therefore, less rigorous than natural selection. Generally, the most vigorous males, those which are best fitted for their places in nature, will leave most progeny. But in many cases, victory depends not so much on general vigor, as on having special weapons, confined to the male sex. […W]hen the males and females of any animal have the same general habits of life, but differ in structure, colour, or ornament, such differences have been mainly caused by sexual selection: that is, by individual males having had, in successive generations, some slight advantage over other males, in their weapons […] which they have transmitted to their male offspring alone. (Darwin, 1859, pp.84-86)

Here, Darwin relates his notion of "sexual selection" with something like the Mendelian genetics. But the sexual selection as he stated it is mainly concerned with "one sex," while our interest is in the between two sexes. So we can tentatively this argument of Darwin's aside.
[7] For the later references, we assign a number within parentheses to each of the citations, the figures, the chronologies, and so on in order.
[8] In accordance with Lynn Margulis' *Five-Kingdom Classification* (cf. Shiokawa, 2007, pp.176f.), the protozoan is that protist which is a unicellular organism, has no chloroplast, and eats another organism: e.g. amebae, paramecia, etc. (cf. Shiokawa, 2007, p.180).
[9] This term implies that they noticed the so-called *first-wave feminism* (cf. Geddes & Thompson, 1890, pp.268-269), which contributed to the improvement of political rights of women (cf. Kaneko, 2009).
[10] Catabolism or Dissimilation: the metabolism to *consume* or *release* energy. With some omissions, we can represent this process by the well-known formula of *aerobic respiration*: $C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O + 38ATP$. Here, the glucose formulated as "$C_6H_{12}O_6$" stands for energy, while "38ATP," being chemicals (of 38 mol) named

adenosine triphosphate, represents the energy of 2800kJ (Takeuchi et al., 2007, pp.231-232), which is consumed in each organization of the body. See the description by Shiokawa et al. (2007, pp.30-32).

[11] Anabolism or Assimilation: the metabolism to *produce* and *reserve* energy. Although women are not plants, for simplicity, we can represent this process, with some omissions, by the well-known formula of *photosynthesis*: $6CO_2 + 12H_2O + E \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$. Here, E stands for the solar energy of 2800kJ (Takeuchi et al., 2007, p.233). And "$C_6H_{12}O_6$" is the product of the energy absorption. See the description by Shiokawa et al. (2007, pp.36-45).

[12] Even if many researchers admire Darwin's achievement (e.g. Dawkins, 1989; Yokoyama, 1997).

[13] In detail, see the explanation by Kaneko (2009), for example.

[14] *Life science*, one of the most popular genres in contemporary biology, is also said to have marked its birth at the moment of Watson & Crick's achievement (cf. Takeuchi et al., 2007, p.221).

[15] We owe the chronology, which eventually divides itself into four parts (i.e. (3), (5), (7) and (8)), to a series of scientific publications (Asashima et al. 2012; Asashima et al. 2013; Kawashima et al. 2006; Kubo et al. 1987; NAO 2008; Shiokawa, 2007; Takeuchi, 1993; Takeuchi et al. 2006; Takeuchi et al., 2007; Takeuchi et al. 2011; Takeuchi et al. 2012; Urabe 2013; Yokoyama 1997).

[16] Needless to say, an epoch-making affair. Let me cite his German original:

> Bezeichnet *A* das eine der beiden constanten Merkmale, z.B. das domini[e]rende, *a* das recessive, und *Aa* die Hybridform, in welcher beide vereinigt sind, so ergibt der Ausdruck:
>
> $$A[A] + 2Aa + a[a]$$
>
> Die Entwicklungsreihe für die Nachkommen der Hybriden je zweier differi[e]render Merkmale.
> (Mendel, 1866, p.17)

As we can see here, Mendel himself used the term "*das constant differi[e]rende Merkmal*" instead of "gene" (see also Mendel, 1866, p.5).

[17] As is well known, he called it "Nuclein" (cf. Shiokawa et al., 2007, p.69).

[18] According to Yokoyama (1997), there remains some doubt that Tschermak is to be counted.

[19] As for this, see: http://www.news-medical.net/health/Sickle-Cell-Disease-History.aspx

[20] See their article (Watson & Crick, 1953).

[21] See their article (Jacob et al., 1960).

[22] See the description of Shiokawa et al (2007, p.87).

[23] See the description of Shiokawa et al (2007, p.88).

[24] See their article (IHGSC, 2001).

[25] See the description of Bainbridge's (2003, pp.183f.).

[26] See the description of Bainbridge's (2003, pp.3-5).

[27] See the description of Bainbridge's (2003, pp.11-13).

[28] See the description of Bainbridge's (2003, pp.13-14).

[29] According to the works published after his death (cf. Kawashima et al., 2006, p.271).

[30] Although he himself did not publish it, Karl Wilhelm Scheele (1742-1786) also discovered oxygen in 1772 (Takeuchi, 1993, p.24).
[31] As for the history of the decision of atomic weights, see the description of Takeuchi (1993, pp.46-48).
[32] See the descriptions by Takeuchi (1993, pp.36-38) and Takeuchi et al. (2011, p.40).
[33] This belongs to the history of physics. However, as we shall see soon (in the item of 1913), it contributes to the invention of the X-ray crystal structural analysis.
[34] For detail, see the description of Takeuchi (1993, pp.39-42).
[35] See the description by Takeuchi (1993, pp.170-171).
[36] Avogadro's theory itself is said to have been admitted in 1860 at the Karlsruhe International Congress (Takuechi, 1993, p.48).
[37] See the descriptions by Takeuchi (1993, pp.125-126).
[38] Although Lavoisier's *combustion theory* (in 1789) appears irrelevant to our concern, it actually refuted the unenlightened thought of Stahl's vitalism (in 1670), opening up the path to modern organic chemistry, which would lead researchers, sooner or later, to handle "organic" matters (see Berzelius' proposal in 1807) without the mysterious notion of "vitality" (cf. Takeuchi, 1993, p.27).
[39] See the description by Takeuchi (1993, p.50) and AOCS (2010).
[40] The so-called *rational formula* (cf. Takeuchi et al., 2012, p.191). In the case of "$CO(NH_2)_2$," this formula clearly shows two *amino groups* "NH_2" and one *ketone group* "CO" (cf. Takeuchi et al., 2012, p.191).
[41] This chemical reaction is simply formulated as follows (Takeuchi et al., 2006, p.226): $NH_4OCN \rightarrow (NH_2)_2CO$.
[42] The rational formula indicating one *carboxyl group* "COOH" (cf. Takeuchi et al., 2012, p.191).
[43] As for this chemical reaction, see the description of Takeuchi (1993, p.50).
[44] Thanks to this analysis, chemists got able to know the *composition* (*compositional formula*) of the organic matter in question, such as CH_2O. Furthermore, by considering its *molecular weight* (mol) successively, they got able to decide the *molecular formula*, such as $C_2H_4O_2$, too (cf. Takeuchi et al., 2006, p.52, p.235; Takeuchi et al. 2011, p.60, p.66). This is so amazing a discovery in the history of biology.

As for the molecular weight (mol), by the way, the following procedures were applied (cf. Urabe 2013, p.493; see also Takeuchi, 1993, pp.83f., p.104):

If the material is volatile, then *the equation of state for the gas* is utilized (cf. Takeuchi et al. 2012, pp.13-14).

If the material is fixed (not volatile), then *the freezing point depression* is utilized (cf. Takeuchi et al. 2012, pp.29-30).

If the material is acid, then *the neutralization titration* is utilized (cf. Takeuchi et al. 2011, pp.124-125).

If the material is a macromolecular compound, then the *osmotic pressure* is utilized (cf. Takeuchi et al. 2012, pp.30-31).

But today (after WWII), mainly *the infrared absorption spectrometry* (*IR*) or *the nuclear magnetic resonance spectrometry* (*NMR*) is applied (cf. Urabe, 2013, pp.494-496; Takeuchi, 1993, pp.158f.).
[45] Before that, Edward Frankland (1829-1889) had already pioneered this theory, according to Takeuchi (1993, pp.52f.).

[46] We refer to this year only as symbolic (cf. Takeuchi, 1993, p.94). In detail, see Fischer's bibliography (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1902/fischer-bio.html).
[47] We refer to this year only as symbolic (cf. Takeuchi, 1993, p.96).
[48] See the website of the Novel Prize (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1927/wieland-facts.html).
[49] See the website of the Novel Prize (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1928/windaus-facts.html).
[50] The partial structure constituted of three *six-membered rings* and one *five-membered ring*. Overall, an *alicyclic hydrocarbon* having this structure (steroid ring) is called a *steroid*.

The steroid is the representative of the *nonhydrolyzable lipid* while the well-known *oils and fats* are *hydrolysable lipids*.
The representative of the steroid is *cholesterol* $C_{27}H_{45}OH$, from which hormones are made in specific organs. In detail, see the descriptions of Urabe (2013, pp.718-720).
[51] See the previous note.
[52] Translations are made by the author arbitrarily.
[53] See the description by Kawashima et al. (2006, p.54) and that by Asashima et al. (2012, p.51).Sometimes the entire genes in all the chromosomes are called the *genome* (cf. Kawashima et al., 2006, p.54; Asashima et al., 2012, p.48).
[54] See the description of Bainbridge's; according to him, such abnormalities of sex chromosomes as sociologists took up were overcome long before (Bainbridge, 2003, pp.16-19).
[55] This is partially due to the vague terminology of researchers talking about it. On one hand, for example, Bainbridge (2003, p.18) clearly regards Sry as a (regulatory) gene. On the other hand, Ganong (2005, p.411) regards Sry as a regulatory protein. This may be ascribable to vagueness of the word "gene," as we shall see later (§12).
[56] See their paper (Jacob et al., 1960). See also the explanation by Shiokawa et al. (2007, pp.100f.) and that by Asashima et al. (2013, pp.110f.). Nagano's essay (1978) is also instructive.
[57] "Code" here means such a prescription as the base sequence UUU prescribing Phe (phenylalanine). The collection of those prescriptions is called the *genetic code* (cf. Asashima et al., 2013, p.98; Alberts et al., 2003, p.244).
[58] Available: http://stemcells.nih.gov/info/scireport/pages/appendixa.aspx
This being merely an image, it is desirable to look into individual textbooks (e.g. Asashima et al., 2013, pp.84-85; Shiokawa et al., 2007, pp.84-85).
[59] The abbreviation of a nucleic acid termed "*messenger RNA*."
[60] A kind of enzyme (cf. Asashima et al., 2013, pp.92f.).
[61] See the arguments of Dawkins (1989, pp.28f.) and of Bainbridge (2003, pp.18f.).
[62] See the triplet theory in 1954 of *Chron*. (3).
[63] An *organelle* functioning as an *enzyme* synthesizing a protein (Asashima et al., 2013, p.100; Alberts et al., 2003, pp.250f.). The protein produced by a ribosome is referred to as "Completed protein" in *Fig*. (11).
[64] See the lower right rectangle in *Fig*. (11). On the right, you can find tRNA, which is shorthand of a *transfer ribonucleic acid* (cf. Asashima et al., 2013, p.95). This is a nucleic acid bringing an amino acid corresponding to a codon, i.e. a triad of base sequences, prescribed by an mRNA. "Bringing" is a bit misleading. In reality, what "brings" an amino acid is not tRNA but a ribosome. See the description of Albert et al. (2003, pp.248f.).

[65] Although there is no convenient general formula for a protein, such as $(C_6H_{10}O_5)_n$ for a polysaccharide (cf. Takeuchi et al., 2012, p.257).
[66] In the original article, Jacob & Monod mainly considered its opposite function (of the regulatory gene) under the name of "repression" (Jacob et al. 1960).
[67] In words of Alberts et al. (2003, p.274), "marginally functional."
[68] "Testicle" is a synonym of "testis" (cf. Sakamoto & Hashimoto, 2012, pp.206-207). But in the present article, we identify "testicle" in this chart of Bainbridge's with "Embryonic testis" in *Fig*. (10) above.
[69] The figure on the right side is from: https://infertilechemist.wordpress.com/2013/04/08/test-results/
As stated in footnote 65, proteins, which include hormones, have basically no general formula, because they consist of various amino acids differentiating themselves from each other by (*chemical*) *side chains* (cf. Shiokawa et al., 2007, pp.11f.; Asashima et al., 2013, pp.17f.). Therefore, in most cases, proteins are depicted graphically as *Fig*. (15) shows. MIS (or AMH) is said to consist of 536 amino acids (Ganong, 2005, p.414). To express so complex a structure, researchers customarily use structural notations, such as *α-helices* or *β-sheets* (see Alberts et al., 2003, pp.132-133).
[70] In the following, we focus on the development of the male genitalia alone, although there are interesting topics on the female genitalia as well (cf. Bainbridge, 2003, pp.25f.).
[71] Teleologically speaking, this ventilation cools the male gonad (the testicle) so that it can produce healthy sperm (cf. Bainbridge, 2003, p.23).

References

Alberts, B. et al. (2003). *Essential Cell Biology* (2nd ed.). NY: Garland Science.

AOCS. (2010). *Michel Eugène Chevreul*. Retrieved from http://lipidlibrary.aocs.org/history/Chevreul/index.htm

Asashima, M. et al. (2012). *Elementary Biology [Seibutsu Kiso]*. Tokyo: Tokyo Shoseki. (Japanese)

Asashima, M. et al. (2013). *Biology [Seibutsu]*. Tokyo: Tokyo Shoseki. (Japanese)

Bainbridge, D. (2003). *The X in Sex: How the X chromosome controls our lives*. MA: Harvard U.P.

Beauvoir, S.de. (1949). *Le Deuxième Sexe*, Tome I, II. Paris: Gallimard.

Butler, J. (1988). Performative Acts and Gender Constitution: An Essay in Phenomenology and Feminist Theory. *Theatre Journal, 4*(4), 519-531.

Dawkins, R. (1989). *The Selfish Gene* (2nd ed.). Oxford: Oxford U.P.

Darwin, C. (1859). *The Origin of Species by means of Natural Selection of the Preservation of Favoured Races in the Struggle for Life*. NY: Signet Classics.

Ehara, Y. & Yamada, M. (2003). *Sociology of Gender (revised edition). Housou Daigaku Shuppankai*. (Japanese)

Ganong, W. (2005). *Review of Medical Physiology* (22nd ed.). NY: McGraw-Hill.

Geddes, P. & Thompson, J. (1890). *The Evolution of Sex*. NY: Scriber&Welford.

IHGSC. (2001). Initial sequencing and analysis of the human genome. Nature, 409(6822), 860-921. (IHGSC= International Human Genome Sequencing Consortium.)

Irigaray, L. (1985). *Is the Subject of Science Sexed?* Cultural Critique, 1, 73-88.

Jacob, F. et al. (1960). L'opéron : groupe de gènes à expression coordonnée par un opérateur. *Comptes rendus hebdomadaires des seances de l'Academie des sciences, 250*, 1727-1729.

Kaneko, Y. (2009). Modern Philosophy and Gender. *Philosophical Studies, 27*, 84-97. The University of Tokyo. (Japanese)

Kawashima, S. et al. (2006). *Biology I [Seibutsu I]*. Tokyo: Suken Shuppan. (Japanese)

Kristeva, J. (2006). *A Father is Beaten to Death*. In A Two-Day Internatuonal Symposium at Columbia University. Retrieved from http://www.kristeva.fr/father.html

Kubo, R. et al. (1987). *A Dictionary of Physics and Chemistry [Rikagaku Jiten]*. Tokyo: Iwanami Shoten. (Japanese)

Mendel, G. (1866): *Versuche über Pflanzen-Hybriden*. In: Verhandlungen des Naturforschenden Vereines, Band 4, 3-47.

Mikkola, M. (2011). *Feminist Perspectives on Sex and Gender*. CA: Stanford Encyclopedia of Philosophy. Retrieved from http://plato.stanford.edu/entries/feminism-gender/

Mill, J.S. (1869). *The Subjection of Women*. IN: Hackett Publishing Company.

Nagano, K. (1978). *Monod. 109 Persons of Contemporary Thought [Gendai Shisou no 109 nin]*. Tokyo: Seido Sya. (Japanese)

NAO (2008). *Chronological Scientific Tables [Rika Nenpyo]*. Tokyo: Maruzen. (Japanese)

Sakai, T. & Hashimoto, H. (2012). *An Anatomical Chart [Zintai Kaibou Zu]*. Tokyo: Seibido Shuppan. (Japanese)

Sokal, A. (1996). Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity. *Social Text, No. 46/47*. Retrieved from http://www.physics.nyu.edu/faculty/sokal/transgress_v2_noafterword.pdf

Shiokawa, K. et al. (2007). *Biology II [Seibutsu II]*. Tokyo: Suken Shuppan. (Japanese)

Takeuchi, H. (1993). *A History of Chemistry*. Tokyo: Housoudaigaku Syuppankai. (Japanese)

Takeuchi, H. et al. (2006). *Chemistry I [Kagaku I]*. Tokyo: Tokyo Shoseki. (Japanese)

Takeuchi, H. et al. (2007). *Chemistry II [Kagaku II]*. Tokyo: Tokyo Shoseki. (Japanese)

Takeuchi, H. et al. (2011). *Elementary Chemistry [Kagaku Kiso]*. Tokyo: Tokyo Shoseki. (Japanese)

Takeuchi, H. et al. (2012). *Chemistry [Kagaku]*. Tokyo: Tokyo Shoseki. (Japanese)

Urabe, Y. (2013). *A Commentary on Chemistry [Kagaku no shin kenkyu]*. Tokyo: Sanseido. (Japanese)

Yokoyama, T. (1997). *The History of Biology [Seibutsugaku no Rekishi]*. Tokyo: Housoudaigaku Syuppankai. (Japanese)

Watson, J. & Crick, F. (1953). Molecular Structure of Nucleic Acid. *Narure, 171*(4356), 737-738.

Yusuke Kaneko, Part-time Lecturer

Contact address: Meiji University, 1 Chome-1 Kanda Surugadai, Chiyoda, Tokyo 101-8301, Japan.

E-mail address: kyaunueskuok_e@yahoo.co.jp