

Protons, Electrons, and Morae: Scientific Vocabulary Development in Japanese
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Japanese science and its vocabulary have each gone through stages of development as Japan moved into and out of periods of isolationism. Historically, certain forces such as the import of Chinese characters to write with and the US defeat of Japan in World War II have affected the way Japanese treats scientific vocabulary. This paper begins with an overview of modern Japan and then a general grounding in the mechanics of the language and some explanations of the notation used, then moves on to a breakdown of the three orthographies of Japanese and their origins. This section mostly concentrates on the adoption of Chinese characters and the current divisions of usage between the three orthographies. Next is a discussion of loanwords in Japanese: how they are written, how they are adopted and created, and some quirks found in Japanese loanwords. After this comes an examination of the development of science in Japan, highlighting the main trends for the past several hundred years such as the long period of isolationism lasting to some degree for approximately 300 years which resulted in the Dutch and Portuguese being the main international connections to Western science for Japan. Finally, there is a section on the most common Chinese characters in Japanese scientific vocabulary and some information on the breakdown of overlap between sciences and the tendency toward calques formed because descriptive scientific terms can be translated piecewise from one language to another without impairing meaning.

Introduction

Western civilization has been driven in great part by international competition and strife – wars, colonization races, space races, athletic competitions. The physical proximity of most of Europe allows for a flourishing of collaboration and competition, which led to the wealth of scientific advances in numerous fields the West has seen in the modern age.

Japanese scientific advances, on the other hand, have historically come mainly as one particular field is elevated in the public eye and studied extensively for a period of time – such as the current focus on electronics. The Japanese lexicon bears a vast number of technological terms, as any language does, but given the ideographic nature of one of

the three Japanese orthographies and the habits of development of the sciences in Japan, an examination of the one inevitably delves into the other.

Political-Historical Background

The story of modern Japanese science begins in 1853, though its roots naturally stretch back much further and will be discussed at length later. In 1853, Commodore Matthew Perry sailed into Edo Bay and negotiated the opening of Japan's ports to the US, largely aided by the armaments of his four steam-powered ships -- the Japanese had nothing of the like. After the treaty was finalized Japan entered a new era of industrial and scientific development. The next few decades were marked by a huge influx of foreign ideas and material into Japan -- a high-velocity impact between internal and international affairs. The upheaval of the Meiji Revolution, a cultural shift from being controlled by the warrior classes (the *shogunate*) to the Emperor and a cabinet of ministers, catalyzed industrial development and the founding of the first Japanese universities. While this resulted in an overall progression of Japan's technological level, it also saw the beginning of significant numbers of young people losing touch with the history and traditions of their native country because of the influx of foreign cultures and changes in society. Also, due to the forced nature of Perry's negotiations and the initially backward appearance of the Japanese, for a long time the West did not see Japan as any kind of political player on the world's stage, Japan was thus subject to unequal treaties and blatant, broad-spectrum discrimination.

The beginning of the 20th century saw Japan in little better shape politically, though by then things were looking up: the nation had technologically caught up to the

West and in 1902 signed on to the Anglo-Japanese Alliance with Great Britain. Though seen as a powerful global player during World War I, Japan still faced racism and patronization from America and other Western countries, including legislation such as the Exclusion Act passed by the US Congress prohibiting Japanese immigration into America after 1924, a law that remained on the books for four decades. In addition, the Great Kanto Earthquake of 1923 killed over 140,000 people and the Kanto region – which includes Tokyo and Yokohama – was left in ruins. Six years later, Japan was once again laid low, this time by the Great Depression.

The American occupation of Japan was perhaps the primary and most significant outcome of World War II for the Japanese. Many aspects of Japanese culture faced radical change. For a number of years it was required for signs to be English/Japanese bilingual, and even now Japanese schools require three years of English study. The Japanese were denied the ability to maintain a standing army, instead forced to rely on a “Self-Defense Force” (SDF) with a limited budget and strictly controlled powers. The “Peace Constitution” written (by the US) in 1947 stated that “the Japanese people forever renounce war as a sovereign right of the nation and the threat or use of force as means of settling international disputes.” While Japan does possess an active chemical industry, it is active in weapons of mass destruction nonproliferation and to this day Japan’s technological development does not extend to warfare and the development of new weaponry.

Japanese have held varying opinions on WWII, though modern trends show that the populace in general feels at fault for the behavior of Japan in the war and the negative aspects of the war’s outcome, but yet take pride in having been defeated so completely.

The reasoning behind this is opaque to me and well-deserving of its own research paper. Nevertheless, although public opinion is moving towards acceptance, the government continues to deny some of Japan's more unethical behaviors during the war, especially in Manchuria.

After being forced open by Perry's armed negotiations, Japan took upon itself the task of outstripping the West in any way it could. Modern Japan is a key player in the field of technological development, particularly in the field of electronics, and the numerous laboratories scattered across the country make it a rich environment for the study of practically any scientific field. Japan produces electronics equipment without peer, and cutting-edge gadgetry has a high chance of coming from Tokyo in the modern age.

The modern Japanese language heard on the streets of Tokyo and throughout the central region of Japan is often heavily populated with loanwords. Speakers make little attempt to avoid using loanwords, and will even take foreign words or roots and create new constructions with uniquely Japanese interpretations.

Technical Introduction to Japanese

A basic knowledge of the structure of Japanese is necessary to a meaningful discussion on how things can change and are changing within the language right now. However, I will be making an attempt to restrict most of my discussion to the written language, only bringing in spoken Japanese to the extent that there are some relevant, useful or enlightening things that can be said about the spoken language in relation to the

way the written language is set down. Hence this discussion of Japanese will also concentrate almost entirely on the written language.

Japanese is written phonetically with 46 basic symbols, each representing either one (C)V unit or, in two special cases, the nasal 'n' or the marker for consonant gemination. This is not truly a syllabic representation but a moraic one. Morae with voiced obstruents are represented by small markings on the corresponding unvoiced obstruent. Syllables where the consonant has a glide are bimoraic and represented by one full-size character which depends on the initial consonant followed by one half-size character which represents the glide and vowel. Further aspects of the Japanese "syllabaries" are discussed below, in the section on notation.

Cases and prepositional phrases in Japanese are indicated by particles. These particles are generally the same for all speakers in all speech act situations, but certain parts of speech, particularly sentence-final particles, change depending on social cues such as the gender of the speaker and the politeness of the dialogue. Politeness level in Japanese has several levels: speaking plainly as if to a confidant or colleague, speaking with common courtesy as if to strangers, particularly humbling oneself, or particularly honoring the conversation partner – see Figure 1. The only reason this bears mentioning is that politeness level can change the conjugation of verbs and the choice of sentence-final particles, but since my studies focus on individual words I won't dwell on sentence-level changes beyond this section.

Fig. 1

私 は 鉛筆 で 手紙 を 書きました。 watashi wa enpitsu de tegami wo ka+kimashita I [topic] pencil [dative] letter [object] write+[polite past] "I wrote a letter in pencil."
私 鉛筆 で 手紙 書いた。 Watashi enpitsu de tegami kaita. I pencil [dat.] letter write+[short past] "I wrote a letter in pencil."
これは 私が 書いた 手紙 です。 Kore wa watashi ga ka + ita tegami desu. This [topic] I [subject] write+[short past] letter [is, polite present] "This is the letter I wrote."
私の 友達 だ。 Watashi no tomodachi da. I [possessive] friend [is, short present] "[This] is my friend."
社長 は お 帰り になりました。 Shachou wa o kaeri + ni narimashita. Director [topic] [honorific] return + [honorific past] "The director has returned." [i.e. home]
お 荷物 を お 持ち します か。 O nimotsu o o+ mochi shimasu ka [honorific] luggage [object] [honorific] carry [humble present] [question] "Shall [I] carry [your] luggage?"

A Note on Notation

In this paper, it will be important at times to make note of what orthography a Japanese word is written in; here the reader may find a guide to the different formatting used to differentiate words in the text.

Fig. 2

Hepburn Romanization		
教科書	[kɔ:kɔ:kɔ]	<i>kyoukasho</i>
質問	[ʃitsumɔn]	<i>shitsumon</i>
影響	[e:kjɔ:]	<i>eikyou</i>
会社	[kaiʃa]	<i>kaisha</i>
続く	[tsuzukɯ]	<i>tsuzuku</i>

Though there are multiple ways to romanize Japanese – write it with roman characters – I have chosen to work in the Hepburn system (Fig. 2 for examples), which stays faithful to the sounds of

Japanese rather than the underlying syntactic structure, because this paper’s focus is not on syntax, and I feel it better illustrates some of the forced pronunciation changes seen in loanwords. The only exceptions I will take are in the cases of the monomoraic nasal,

written as *N*, and the monomoraic consonant germination marker, written as *Q*.

Consonant gemination is marked by a symbol that appears immediately before the

consonant to be geminated

(See Fig. 3 for examples of

consonant gemination and

nasal).

Sometimes it will

ka.Q.pa	<i>kappa</i>	water goblin
hi.Q.shi	<i>hisshi</i>	frantic
za.Q.shi	<i>zasshi</i>	magazine
ta.su.ka.Q.ta	<i>tasukatta</i>	[someone] helped [someone else]
ge.N.ki	<i>genki</i>	happy/energetic
sha.shi.N	<i>shashin</i>	picture
ha.N.i	<i>hani</i>	range
ha.N.ni.N	<i>hannin</i>	criminal/perpetrator

be important to know what script a word is being represented in. When a romanized

Japanese word is used merely for naming purposes within the paper and not as an

example, as in the examples of the names of the orthographies themselves, *italics* will be

used. When taking care to differentiate script, the following will be used: SMALL CAPS for

kanji, solid underline for *hiragana*, and dotted underline for *katakana*.

Orthography

Written Japanese has three orthographies, or writing systems: the set of characters taken from Chinese, *kanji*, and two “syllabaries” (technically MORARIES, systems of writing that represent each mora with a character – analogous to a syllabary, but whose components are morae instead) adapted from that set, *hiragana* and *katakana*. Japanese can also be represented in roman characters (which can be seen in this paper), but this system is hardly ever used by Japanese except in advertising or a few vocabulary words (such as *T-shatsu* for T-shirt) that contain a roman character.

Until the *kanji* were first adopted from Chinese by scholars, the Japanese were not literate – they did not write their language down. The process of moving from spoken historical Japanese to modern written Japanese was long and arduous.

Around 200 AD, Japanese scholars started importing Chinese vocabulary wholesale, for use as loanwords, with their own unchanged meanings and pronunciations. To write was to write in Chinese. Soon the nature of scholarship changed, this straightforward borrowing shifted, and *kanji* were used to try to express Japanese words and grammar. *Kanji* were used simply as symbols, bearing no real connection to the Japanese language (particularly in the case of *kanji* chosen to represent inflections and particles), representing the words and grammatical inflections of Japanese but losing all ties to the original written Chinese from which they came. As Japanese is not Chinese¹, and each scholar or school used a different notation, this was doomed to never quite work out properly. The isolating nature of Chinese, where symbols represented morphemes, was unsuited to the particles, post-positions, and inflected words of Japanese.

As this became apparent, new ideas for the usage of *kanji* were thought up – instead of *kanji* being either imported from Chinese with Chinese pronunciation and meaning or imported from Chinese and adapted to represent whole lexical items, particles, and grammatical inflections of Japanese, *kanji* were chosen for their approximate sound value (as close as the Japanese could come to the Chinese pronunciation) and used as phonetic representations of Japanese speech. Since the number of *kanji* that become homophonous when expressed in Japanese, whose tone system is completely different

¹ Despite popular opinion, Japanese and Chinese are very distinctly different languages. Mandarin Chinese, the current dominant dialect, is a member of the Sino-Tibetan language family, while Japanese and its related dialects, the Japonic family, are notoriously hard to place genealogically: some dub them Altaic, some tie them to Korean or even Tamil, a Dravidian language, and some place them in their own individual family. Some even believe Japanese is a creole, with Altaic substratum and Austronesian superstratum.

from and much more limited than Chinese, is staggering, this created a large amount of somewhat redundant study for readers, since an author might choose any of over 150 *kanji* with the pronunciation (for example) [ʃu] with the expectation of being understood by readers.

This led, unsurprisingly, to the development a set of “preferred” *kanji* which, while still large in number, made functional literacy easier to achieve. For a long time, the list of *kanji* required for fluency in Japanese remained large – prohibitively so. To become a scholar was to devote oneself entirely to the memorization of *kanji*. Around 759 AD, a poetry anthology called the *Manyoushuu* (“Collection of Ten Thousand Leaves”) was created, and the *kanji* used in this anthology were widely regarded as the definitive set of *kanji* fit for use in written Japanese. This set, called the *Manyougana* (“Characters of Ten Thousand Leaves”), was the first successful effort to set the boundaries of a common pool of characters for writing. It was so successful, in fact, that it remained for the most part the country’s yardstick until the 1920s. Certain *kanji* became accepted as the most common representation of a phoneme, and alternate *kanji* became known as *hentaigana*, “strange/different characters.”

The Meiji era (1868-1912) saw the beginning of increased effort by academics and revolutionaries (in the sense that the Meiji era was an era of revolution) to trim the list of officially recognized “important” *kanji* to a manageable level, but it was radical language reform after the end of World War II that resulted in the thousands of *kanji* being trimmed down to the current ~2000 characters, less than a third of what was originally suggested when the ideas of *kanji* reduction began. In addition, some *kanji* were simplified.

Most modern *kanji* have two basic readings: the native Japanese word assigned to the symbol, called the *kunyomi* (lit. ‘native’ reading), and the sound-based reading that came from the Chinese pronunciation of the symbol, called the *onyomi* (lit. sound reading). In addition, *kanji* are classified by structural type: pictographic, ideographic, aggregate, or phonetic ideographic – see Fig. 4. Pictographic *kanji* are stylized depictions of things in the physical world, ideographic *kanji* represent abstract concepts, aggregate *kanji* take pictographic *kanji* or other common *kanji*, in complete or stylized form, and combine them in fairly logical ways to create new concepts, and phonetic ideographic *kanji* use one pre-existing *kanji* or radical to suggest meaning and another as a pronunciation marker, causing the *kanji* to be pronounced the way the word for that concept is pronounced.

Fig. 4

	Character	Meaning	Notes
Pictographic	山	Mountain	
	車	Car/cart	
	川	River	
	小	Small	
Ideographic	上	Above	Comes from a dot above a line.
	下	Below	Comes from a dot below a line.
	一	One	
	三	Three	
Aggregate	森	Forest	“Tree” x3
	鳴	Sing/Ring	“Bird” plus “mouth” – i.e. birdsong
	休む	Rest	“Man” next to “tree”
	泉	Spring	“White” above “Water”
Phonetic Ideographic	伯	Count (title)	Pronounced HAKU from 白 on the right, meaning comes from 人, HITO, “person,” on the left.
	舶	Ship/liner	Pronounced HAKU from 白 on the right, meaning comes from 舟, FUNE, “boat,” on the left.
	線	Line	Pronounced SEN from 泉 on the right, meaning comes from 糸, ITO, “string,” on the left.
	腺	Gland	Pronounced SEN from 泉 on the right, meaning comes from 月, TSUKI, “moon,” on the left.

As a side note, the Japanese *kanji* no longer necessarily match the Chinese character they were originally taken from; the Chinese lexicon has seen modifications and adjustments, but the source of Japanese *kanji* can be seen in the study of classical Chinese, and the structural grouping of *kanji* applies to both Japanese and Chinese. There do exist a few hundred purely Japanese characters, created by the Japanese government for use and called *kokuji* (lit. national characters). Most are obscure, but a few have made it into common usage.

Hiragana was the first of the uniquely Japanese phonetic orthographies to come into usage in Japan. It started as a simplified, cursive depiction of a given *kanji* used most frequently by women, leading to the term (女手, ONNADE) “woman’s hand.” Women were considered incapable of the *kanji*-based writing because of the heavy study burden – in fact, they were not even allowed to become scholars of Chinese. Also popular for artistic endeavors such as calligraphy, poetry, and art, it is thought that the rigid structure of the Imperial court, at that time ruled by the Fujiwara clan, helped ensure a coalescence of one single writing system for this shorthand (Crowley, 1968).

Next to develop was the *katakana* system. Where the *hiragana* syllabary consisted of stylized representations of entire *kanji*, the *katakana* syllabary was constructed by picking out part of a *kanji* and stylizing it (if necessary). This system originated from the desire to have a purely phonetic system to write out Chinese Buddhist scriptures.

The three writing systems were actually used arbitrarily until the reform movements of 1925 standardized not only the commonly-used *kanji*, but also the proper usage of the *kana* systems – see Fig. 5 for comparison chart of orthographies. Some of

the most famous works of Japanese literature were written by women entirely or almost entirely in *hiragana*, with only actual Chinese loanwords written in *kanji*. As for *katakana*, in official documents until the reforms it was used to express the grammatical inflections of *kanji* stems.

NAME	KANJI (Chinese characters)	HIRAGANA	KATAKANA
Type	Ideograms	Syllabary	Syllabary
Usage	Used for the base concepts of expressions: nouns, adjective and verb stems, etc.	Used for grammatical inflections and all grammatical markers; also (in text) used when the kanji for a term is deemed too difficult	Used for loanwords; also (in text) used for emphasis.
Appearance	All full-scale characters	Full-scale and half-scale characters	Full-scale and half-scale characters
Examples	木 KI 'tree' 中 NA.KA 'middle' 猫 NE.KO 'cat'	き <u>ki</u> しゅ <u>shu</u> (<u>shi+yu</u>) あ <u>a</u>	テ <u>te</u> ズ <u>zu</u> (<u>su</u> with voicing marker) リヨ <u>ryo</u> (<u>ri+yo</u>)

The 1925 reformation consisted of a suggested list of “*Kanji* for Everyday Use” and suggestions for the standardization of *katakana* and *hiragana* usage, which were not supported enough to be put into effect by the government and populace until after World War II. Initial reactions to the war were so violent that a fairly popular move to abolish all *kanji* to be more like the Americans started, although to this day Japanese continues the use of *kanji* and the number of supporters of such a drastic measure has decreased. 1946 saw the publishing of the first official *Touyou* (“Daily Use”) list, some 1,850 *kanji* deemed a suitable coverage of those needed in everyday life, which was later updated to become the current *Jouyou* (“Habitual/Common Use”) list of 1,945 characters.

Kanji, *hiragana* and *katakana* now serve distinct and different functions in Japanese writing. The *kanji* form the core concepts of the sentence: nouns, pronouns,

adjective and verb roots, generally all the semantics, with the notable exception of adverbs. *Hiragana* are used to show grammatical inflections, particles and the phonetic representation of words composed of *kanji* outside the *Jouyou* list or those the writer simply cannot remember (but only in the case of handwriting, which is becoming drastically less frequent in Japan's busy cities as the Japanese increasingly rely on cellphones). *Katakana* are used for foreign words and the vast collection of mimetic reduplicative phrases for sounds, actions, physical appearances, and more – this collection, though fascinating, is a separate matter and does not necessitate further note here. Other uses for *katakana* include emphasis, similar to italics in roman alphabets, and pronunciation guides (called RUBY, an archaic English term for a certain kind of small typeface, or *furigana*, lit. “appearance characters”) when the author is trying to express a foreign word with *kanji*. This can perhaps be most frequently seen in *manga*, Japanese serial comics.

Which orthography is used for writing to some degree depends on the writer.

Many words, particularly adjectives, can be expressed either with a single *kanji* and

multiple modifying *hiragana* or with a two-

kanji compound and a single *hiragana* particle.

危ない <i>abunai</i>	危険な <i>kiken na</i>	dangerous
忙しい <i>isogashii</i>	多忙な <i>tabou na</i>	busy
折り紙	折紙	Origami
引き出す	引出す	<i>Hikidasu</i> , withdraw
撃ち殺す	撃殺す	<i>uchikorosu</i> , shoot to death

Such *kanji*-heavy writing is considered more

erudite and professional. Similarly, there are

some compounds which can be written and

understood with or without one or more

accompanying *hiragana*, which are usually left out in more formal or professional

settings – see Fig. 6. Names often contain less-common *kanji* (from a large list of

approved name *kanji*) in an effort to be unique, or a name may be written purposefully in *hiragana*. This practice is common among young women who may think the *hiragana* are “prettier” or “cuter” than the corresponding *kanji*. Alternate *kanji* with the same reading but different composition may also be used in writing as an expression of personality or as creative license, lending nuance to a word.

Loanwords in Japanese

Japanese is an extremely loanword-friendly language, particularly with regard to English. Stores all over the country feature roman characters on clothing, bags, accessories, and more, with varying degrees of success in the grammaticality of constructions. In speech, too, loanwords are frequent, and speakers may very well choose to use a loanword instead of a native word simply because they prefer the sound or because it may be “fashionable.”

The process of converting a loanword to Japanese is a fairly straightforward and well-documented process, so, although it is discussed here, it is not the main focus of the paper. Loanwords are expressed as close to the original as they can be, given the pronunciation rules of Japanese. Because consonant clusters do not occur in Japanese, loanwords often become lengthened by one or more extra vowels, adding to the syllabic length of a word. After being added, vowels may be suppressed (that is, devoiced), but lingering or unsuppressed vowels are perhaps the biggest reason non-native speakers of Japanese run the risk of not even recognizing a word from their native language when they first come across it. The default vowel to add into a loanword is [ɯ] (an unrounded [u]), since it is so often suppressed in Japanese already.

For example, the restaurant chain “McDonald’s:” simply adding in extra vowels creates マクドナルヅズ, “makudonaruduzu”, but because of a phonetic rule changing /du/ to [zu], the pluralization is abandoned (*makudonaruzuzu* has moved too far from the original word, but Japanese does not use the English -s for possessive, so it can be dropped) and the [ɔ] is chosen as the expanding vowel instead of [u], resulting in “makudonarudo.” The fast-spoken Japanese are hardly ever heard saying the entire name anyway, however – it is almost universally shortened to *makudo* or even *maku*.

[ɔ] is the vowel used for syllable addition in loanwords when phonetic rules change consonant sounds beyond what native speakers will consider close enough. In other cases, however, a vowel replacement isn’t feasible even if the vowel is suppressed. In cases like this, a relatively recent development has been to use half-scale bare vowel characters as well as the standard small “ya,” “yu,” “yo” used in creating bimoraic syllables. For example, my own name, “Phoebe:” [ɸibi]. Japanese lacks the differentiation between [h] and [ɸ] necessary to distinguish my name from, for example, HIBI (days). So an extra vowel is added in – [u], as expected for an added vowel – creating the character *fu*, [hu], which is then modified by a half-scale *i*. The second syllable of my name has no problems and is directly converted to *bi*, [bi]. All together the name “Phoebe” is written フェイビ, *fibi*.

There are two general classes of loans in Japanese: the standard adoption of a word and its meaning from another language, and the creative wordplay that results in words and phrases made up of loans but bearing a meaning often opaque or completely novel to a speaker of the loaning language.

For example, ホットドッグ (ho.Q.to.do.Q.gu, ‘hotdog’) is a perfectly ordinary loan, but サラダドッグ (sa.ra.da.do.Q.gu, ‘salad dog,’ salad in a hot dog bun) is a Japanese creation. ‘Friendship’ is a common word in English, but the Japanese created the related term スキンシップ (su.ki.N.shi.Q.pu, ‘skinship,’ a touchy or physically close relationship).

Japanese Scientific Vocabulary

Why change a word from *katakana* to *kanji*?

Even though Japanese is such a loanword-friendly language, when it comes to scientific fields the forgiving nature of the common language comes up against the desires of academia and researchers to work with a native lexicon instead of foreign words. It is neither feasible nor productive to fill textbooks with hard-to-pronounce loanwords that offer the reader just a pronunciation, when the alternative is to translate the word and give the reader helpful and/or familiar ideographs instead. Many English scientific terms are aimed at suggesting in some way the nature of their meaning, even if it is by using Greek or Latin roots – though in the past two decades, scientists have been moving toward less formal, more creative vocabulary in disciplines such as physics (Van Dyke 1992). The realms of chemistry and biology remain very consistent, with strictly organized lexicons, whereas physics has co-opted everyday English words left and right. “Color,” for example, no longer simply names the physical color of an object, it also now applies to which of three possible groups a quark is classified as.

Some countries form government-related or independent entities to help guide and control the language, usually in the interests of keeping it “pure.” In the case of French,

the language is controlled and measures are taken by L'Académie Française, a group of forty intellectuals determined to keep the French language pure. However, their successes have been limited. The Japanese also have an official body shaping the Japanese language as times change, and though the nature of the Japanese language itself works against them (the loanword-friendliness), the communal nature of Japanese society is an asset.

Japanese Science Background

Japanese science has tended to develop in one or a few areas at a time, historically because outside interaction spurred research. This trend can be seen as far back as the 1500s, when the Japanese first interacted with the Portuguese in 1543. Before that time, the Japanese had never seen guns, nor had they experienced much in the way of missionary activity, or even any Christian society at all. For about a century, the Japanese were active in the fields of navigation, shipbuilding, astronomy, and medicine thanks to *namban bunka* (lit. "Culture of [the] southern barbarians"), the science and missionary work of the Iberian Peninsula. However, due to increased friction between the Japanese government and Christianity, for some time *namban bunka* was anathema, and Japanese science once again proceeded down a largely isolated road.

One country of the West that Japan maintained contact with was Holland. In 1600, a Dutch ship landed on Japanese shores and from there the Dutch East India company began trade relations with the shogunate government. The Dutch and the Chinese were the only two countries exempted from the isolationist decrees of the government in the 1630s, and due to the Dutch's heavy focus on medicine and natural science, Japan

enjoyed a period of concentrated medical study. Other sciences also trickled into Japan from the West, but for the most part medicine was key.

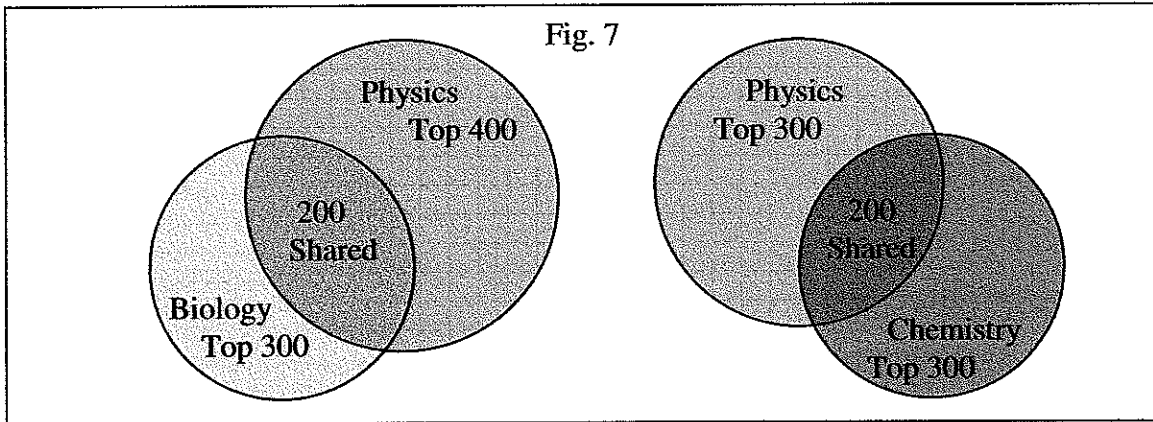
Though Japanese science was not as developed as Dutch, it was not far behind, as evidenced by the Japanese ability to take the Dutch knowledge and develop it further (Numata 1964). From the late 17th century for about a century the Japanese enjoyed a flourishing of science, inspired partly by the logic-based *Shushigaku* school of Confucianism and its successor *kogaku*. Both encouraged empirical science. Partly this flourishing was also due to the eighth shogun, Yoshimune, who was a personal supporter of the sciences, especially those that could benefit the country, such as agricultural science. Yoshimune had a fondness for the Dutch and Western science reminiscent of Peter the Great, and like Peter he spent a great deal of effort encouraging his country to import Western science and technology.

Currently Japan is in the midst of a technology boom in the field of electronics. Cell phones, processor chips, laptop computers – the fastest and the smallest come from Japan.

The Top 500 *Kanji*

Much like the set of general-use *kanji*, a small number of *kanji* figure in a significant percentage of scientific terms in Japanese. Approximately 500 *kanji* account for 75% of the most frequently-appearing scientific terms, and *kanji* tend to cross the borders between disciplines quite readily. 2/3rds of the top 300 *kanji* in biology are contained in the 400 most common *kanji* in physics, and 2/3rds of the top 300 *kanji* in chemistry are contained in the top 300 in physics (Daub 1995) – See Fig. 7. Of course,

one can see a certain amount of overlap in these fields and their terminology even in English, but this definitely reflects the general trend of *kanji* to be used very flexibly.



Compared to the general Japanese lexicon, scientific vocabulary contains a much higher percentage of non-English loanwords –this is probably partly a result of the tendencies of scientific vocabulary to stay in one language even when borrowed into another, such as inventors’ names, units of measurement, etc. Some units of measurement have had *kanji* chosen for them, but many more remain consistent with global standards.

An easy way to convert a word from one language to another is to create a calque – a direct piecemeal translation of the word. As word compounds can be somewhat idiomatic, this is usually not without its drawbacks. However, when dealing with scientific terminology, physics in particular, creating a calque can be the best or even the only feasible way to go about loan translation, as

Fig. 8

Word	Japanese	English
反応物 <i>hannoubutsu</i>	<i>hannou</i> , “reaction,” plus <i>butsu</i> , “thing”	Reactant, “react”, plus “-ant,” a material agent
炭化水素 <i>tankasuiso</i>	<i>Tanka</i> , “carbon+change,” carbonize, plus <i>suiso</i> , “hydrogen”	Hydrocarbon, “hydro-“ water and “carbon,” carbon.
光子 <i>koushi</i>	<i>Kou</i> , “light” plus <i>shi</i> , “child/small thing”	Photon, “photo,” light, plus “-on,” marking an elementary particle
過熱する <i>kanetsu suru</i>	<i>Ka</i> , “exceed/pass” plus <i>netsu</i> , “heat” (<i>suru</i> is the general “to do” verb)	To superheat, “super,” above/beyond, plus “heat,” heat
四面体 <i>shimentai</i>	<i>Shi</i> , “four,” plus <i>men</i> , “face,” plus <i>tai</i> , “body/object”	Tetrahedron, from Greek “four-sided”

hopefully any other approach to translation would come up with a similar word anyway – see Fig. 8 for examples. The problem with this approach comes when words are translated that piecewise bear no relationship to the overall meaning, such as some of the more recent and creative terms in the realm of physics. Japanese does contain a large number of partial or total calques, but logically so. Again, it is in the realm of creative terminology that the creation of a calque can be dangerous.

Conclusion

Although modern Japanese provides a mechanism for foreign word adoption, in large part this orthography is not used in the fields of science nearly as much as I had expected. Japanese scientific terms, coming from the *Jouyou kanji* list, tend to share characters with each other, which means they also share sounds. Science is perhaps one realm of Japanese which should most firmly resist movements away from *kanji* usage, since differentiating scientific terms is so key to understanding. At the same time, Japanese scientific terms are linked by the *kanji* they use. Similar processes may share a *kanji*, terms involving the same type of radiation or behavior may share a *kanji*.

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