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英汉翻译实践报告

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A Report on the E-C Translation Practice of *Principles of Neural Science* (Chapter 35)

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A Report on the E-C Translation Practice of *Principles of Neural Science* (Chapter 35)

Tao Ning

A thesis submitted in conformity with the requirements

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Translation and Interpreting

In English Translation

Supervised by Prof. Tang Xuemei

School of Foreign Studies

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Wuhu

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摘 要

本篇翻译实践报告节选自《神经科学原理》。该文本由诺贝尔奖获得者坎德尔领衔主编，是国际上最权威的神经科学教科书，被称为“神经科学圣经”。译者选择第三十五章《脊髓反射》为本次的翻译任务，该章节主要研究反射产生的原理和反射的功能。

源文本大量使用神经科学领域的术语、被动语态、名词化结构和复杂句,句间逻辑严密,语言精练,表达客观，属于科技英语。根据纽马克的翻译理论，该文本属于信息型文本。本次翻译实践遵守信息型文本翻译标准，采用交际翻译策略。

在翻译过程中译者遇到了一些难点。在词汇层面，专业术语和半专业术语难以确定，以及名词化的翻译。通过参考平行文本，查询线上术语库和词典，确定专业术语和半专业术语；译者将名词化处理成动词和形容词。在句法层面，分析被动语态的转换，长难复杂句的处理，隐含意义的表达；译者通过增加主语和转换主语的方法，将被动语态转换成主动语态，通过分译法和逆译法，翻译长难句，将语句中隐含意义用汉语直接表达出来。语篇层面，语篇的连贯性和逻辑性，通过复原指示代词以及复现信息，建立合理的语言逻辑。

通过本次翻译实践，译者习得了神经科学领域的相关知识，加深了对翻译策略和翻译方法的认知，深化了对源语言和目的语的理解，提高了词汇量和语法掌握程度，提升了翻译速度和准确性，对语言结构和表达有了更明锐的洞察力，除此之外，译者还累积了一定的翻译

经验。希望本篇翻译实践报告能为神经科学领域相关的翻译项目提供参考和借鉴。

关键词：《神经科学原理》；脊髓反射；信息型文本；科技英语

Abstract

This translation practice report excerpted from *Principles of Neural Science*. The text, edited by Nobel laureate Kandel, is the most authoritative international textbook on neuroscience. The author chose Chapter 35 *Spinal Reflex* as the translation task, which mainly introduces the motor reflex response of spinal animals.

The text uses a large number of terms, passive voices, nominalization structures and complex sentences in the field of neuroscience. It is a scientific English with strict logic between sentences, concise language and objective expression. According to Newmark's translation theory, it is originally an informative text. This translation practice adhered to the standards of informative text translation and used communicative translation strategies.

The translator encountered some difficulties during the translation process. At the lexical level, the semantic correspondence of professional terms, the semantic choice of semi-professional terms and the translation of nominalization are discussed. By referring to parallel texts, querying online terminology databases and dictionaries, professional terms and semi-professional terms are determined; the translator processed nominalization into verbs and adjectives. At the syntactic level, it analyzes the conversion of passive voice, the processing of long and complex sentences, and the expression of implicit meaning; the translator transformed the passive voice into the active voice, translated long and difficult sentences through division and reverse translation, and expressed the implied meaning of the sentences directly in Chinese. At the discourse level, the coherence and logic of the discourse establish a reasonable language logic by restoring demonstrative pronouns and reproducing information.

Through this translation, the author has acquired knowledge related to neuroscience, deepened the understanding of translation strategies, and accumulated translation experience. It is hopeful that the report can provide reference and inspiration for translation projects related to neuroscience.

Key Words: *Principles of Neural Science*; Spinal Reflex; informative text; scientific English

Contents

Chapter 1 Task Description

1.1Background of the Practice

Neuroscience is a comprehensive and wide-ranging discipline, and its development not only helps us to deeply understand the structure and function of the nervous system, but also provides important clues for solving many unsolved problems. With the continuous progress of science and technology, neuroscience is bound to play an even more important role in the future. There is a growing demand for neuroscience resources in China, and the requirements for translation standards are bound to be higher than in other fields.

The translator’s tutor has been doing experiments related to neurology. The translator has also participated in experiments and has some knowledge of the field of neurology. When translating, the mentor can also provide some help. The book “*Principles of Neural Science*” is edited by Eric R. Kandel, a Nobel Prize winner. The book is called the “Bible of Neuroscience”. The book has not yet been published in Chinese. The translator's task is Chapter 35, with 10132 words in the source language and 17439 words in the target language, which meets the word count required for the graduation thesis of the master's degree in translation.

1.2 Significance of the Practice

The significance of translating neuroscience books is far-reaching and wide-ranging, as reflected in the following aspects:

Firstly, it promotes the dissemination and exchange of knowledge. Neuroscience, as a science that studies the structure and function of the nervous system, covers many cutting-edge fields, such as brain science, neurological diseases and so on. Translating neuroscience books can transfer these professional knowledge from one language to another, enabling readers in different countries and regions to have access to these valuable scientific resources, thus promoting the global dissemination and exchange of knowledge.

Secondly, it promotes the development of the field of neuroscience. Through translation, scientists and researchers from different cultures can share the latest research results, theories and methods in the field of neuroscience. This cross-cultural communication helps break the geographical limitations and promotes neuroscience research cooperation on a global scale, thus promoting the progress and development of the whole field.

Thirdly, this practice can help author to expand relevant knowledge. This translation practice material is a scientific text in the field of neurology. The original text contains a large number of research results in neuroscience. In the process of translation, the author needs to verify the relevant content in this field and supplement the background knowledge. Therefore, the process of this translation practice is also a learning process of knowledge expansion for the author, which lays a foundation for the author 's future translation of texts in the field of neuroscience.

Fourthly, it can improve author’s translation skills. For the author, this translation practice is long and new. In the process of translation, the author needs to constantly discover problems, record problems, and finally solve problems. In this process, the author has a deep understanding of the syntactic characteristics and language style of the article, and finally consolidated the use of translation strategies and translation skills, such as splitting long and difficult sentences and indicating the manifestation logic of the pronoun reference. True knowledge comes from practice, so translation skills have been improved. In addition, it also provides a feasible solution for others to solve similar translation problems.

1.3 The Source of the Task

The book *Principles of Neural Science* has advanced rapidly from theory to application, covering all fields of biomedicine, and the latest scientific and technological achievements has been made constantly. Since the first edition of this book was published in 1981, the team led by Kandel has made significant contributions to the teaching of this field of neuroscience. As a classic neuroscience textbook, this book comprehensively covers all levels of this science. From the microscopic molecular biology of neurons, the principle of synaptic transmission, to basic perceptual and motor functions, to advanced cognitive functions such as advanced memory, thinking, and language, and to macroscopic nervous system evolution and development, this book describes the fascinating field of neuroscience from multiple angles, providing a wealth of knowledge for all those interested in this discipline and human brain function.

The source text is from the fifth edition of *Principles of Neural Science*, and there is no Chinese version at present. Chapter 35 is mainly about the principles underlying the organization and function of reflexes, focusing on spinal reflexes. It also introduces the adaptability of reflex, muscle stretch, muscle spindle, motor neurons and so on.

Chapter 2 Pre-translation Preparations

2.1 Language Features of Source Text

The main linguistic features of the source text are the following:

Firstly, the use of nominalisation is very frequent in the source text. This reflects a typical feature of scientific and technical English, which is to make expression more concise, objective and accurate through the use of nominalised structures. Since scientific and technical texts need to emphasize the existence of facts and objective information, the nominalised structure can well meet this need. However, in the process of translation, we need to pay attention to the dynamic characteristics of Chinese, and appropriately transform the nominalised structures in English into Chinese verb forms to ensure the fluency and readability of the translation.

Secondly, the use of passive voice in the source text is also more common. Since technical English focuses on objectivity and accuracy, the use of passive voice helps to reduce the involvement of subjective meaning and make the text more persuasive. However, Chinese uses more active voice and first and second person. Therefore, when translating, we need to pay special attention to the conversion of the subject and adopt the complementary method when appropriate to make up for the lack of subject in the original text. At the same time, we also need to ensure the objectivity of the translation and avoid introducing too many subjective factors.

Finally, the source text uses a large number of long and complex sentences. These sentences are compact and logical and are used to express complex concepts and relationships. However, when translating, we need to take into account the expression habits of Chinese and try to avoid using too many long and complex sentences. We can make the translation more in line with Chinese expression habits by splitting sentences and adjusting the word order, while ensuring the completeness and accuracy of the information in the original text.

According to the linguistic features of the source text, the translator can determine that the text belongs to the category of scientific and technical English. The text classification theory of British translation theorist Newmark provides a strong basis. In his classification, scientific and technical English is clearly classified as an informational text, which is because scientific and technical English focuses on the description of objective facts, the use of technical terms and logical and rigorous expression, aiming at conveying specific information and knowledge. Therefore, when translating the source text, the translator should give full consideration to its attributes of informational text to ensure that the translation can accurately and completely convey the information of the original text, while trying to maintain the objectivity and logic of the original text. In the process of translation, we also need to pay attention to the accuracy and consistency of terminology, as well as the clarity and simplicity of language expression, in order to meet the characteristics and requirements of scientific and technical English.

2.2 Translation Tools

Translation tools play an indispensable role in the translation process. Electronic tools and paper dictionaries complement each other and together enhance the efficiency of translation work. Especially when translating scientific and technical English texts, it is often difficult to ensure the accuracy of certain terms by relying only on non-specialized dictionaries. E-tools, on the other hand, are able to quickly search multiple sources of information and provide rich search results with high reference value.

For terminology translation, the translators carefully selected several authoritative resources, such as the *Bilingual Dictionary website of the National Academy of Education*(https://terms.naer.edu.tw/) and the *Termonline* (https://www.termonline.cn/), to ensure that terminology translations were both accurate and exhaustive. In addition to electronic tools, the translator used several paper dictionaries, such as *the New Century English-Chinese Dictionary*, the *Oxford Advanced English-Chinese Dictionary*, which provided detailed explanations of vocabulary and examples of usage.

In order to deeply understand the source text, the translator made full use of library resources and modern electronic network technologies, such as Microsoft Bing, to obtain a large amount of information about the author, the source text and related academic materials through information retrieval. In addition, the translator also collected a large number of parallel texts with the help of academic platforms such as *CNKI*, which provided rich reference materials for the translation work.

During the translation process, translators also employ computer-assisted translation (CAT) tools such as Trados. These CAT tools, as computer-assisted translation software, are capable of generating translation memories and databases for specific fields or disciplines, which greatly saves the time and effort of translators, and at the same time helps to improve the quality and consistency of translations.

To sum up, translation tools play a vital role in the translation process, and they not only improve the efficiency of translation, but also ensure the accuracy and quality of translation.

2.3 Parallel Text

In order to ensure the accuracy and professionalism of the translation, the translator collected and analyzed some parallel texts. The translator searched the Chinese "*spinal reflex*" as a keyword on CNKI, and found a total of 11 papers. Then, the translator searched the English “*spinal reflex*” as a title and keyword, and there were 60 citation papers in ten years. The translator read these 71 papers carefully before translation. The translator also read the book “*The Idea of the Brain: A History*”, which was written by Matthew Cobb in the UK and translated in Chinese by Zhang Jin, a Chinese translation theorist. This book is for learners who have no knowledge of neuroscience at all.

By referring to these parallel texts, the translator gained a deeper understanding of neuroscience and spinal reflexes. Valuable theoretical and practical knowledge has been obtained, which greatly supports the translation work.

2.4 Glossary Building

Create a glossary. The original text contains many neurologic-related terms such as axon, cerebral cortex, collagen, electromyogram. Therefore, the author first listed the terms and entries in the text before translation, and then verified the translation method by means of dictionaries and searching parallel texts. At the same time, the author also discussed with the team members to unify the expression of terms, ensure the consistency and integrity of the translation, and avoid mistranslation. As a result, a list of terms and proper nouns is established, as detailed in the appendix below.

Chapter 3 Case Study

Theory comes from practice. Therefore, successful translation is inseparable from accepted translation theory. According to Catharina Rice's Text Type Theory, the source text is informational text. Informational texts are logical and simple, focusing on content rather than form. In this chapter, the translator mainly expounds the difficulties encountered in the translation process and the solutions to the difficulties through three aspects, including vocabulary, sentence and discourse.

3.1 Disambiguating Vocabulary Meaning

In this part, there are three main difficulties, including terminology, polysemy, and nominalization. Sometimes, it is difficult to get the meaning of professional terms through dictionaries and online database directly. The translator mainly determined its meaning by searching online database and online terminology database. In the process of translation, the translator also encountered some terms that cannot be queried in the online database. The translator chose the Chinese expressions of terms according to the definitions mentioned in the source text. When dealing with polysemous words, the translator mainly selected the meanings of words in biology, neuroscience and other fields, and then retrieved them in the online corpus to see whether the meaning is appropriate in the context of the target language. For the treatment of nominalization, the translator adjusted it according to Chinese language habits and the context in the sentence, and mainly converted it into verbs or adjectives in the translation process.

3.1.1 The Determination of Terminology in Neuroscience

The establishment of terms is the premise of any text translation, and the development of scientific and technological terms is an important basic work for a country to carry out science and technology, culture and economy construction, and the translation of scientific and technological terms is a key issue in the development of science and technology (楚良龙, 2023)**.**

Example 1：

ST: Perhaps the most important-certainly the most studied-spinal reflex is the **stretch reflex**, a lengthening contraction of a muscle.

TT1：脊髓反射是一种**牵拉反射**，即肌肉的拉长收缩，这种反射也许最重要的，当然也是研究最多的。

TT2: 脊髓反射是一种**牵张反射**，即肌肉的拉长收缩，这种反射也许最重要的，当然也是研究最多的。

Analysis: In Example 1, it is difficult to translate the terminology "*stretch reflex*", because its Chinese equivalent expression couldn't be got directly in dictionaries. When the translator searched "*stretch reflex*" in CNKI, there were two different Chinese versions, "*牵拉反射*" and "*牵张反射*". The frequency of the former to be used in CNKI is 32, while that of the latter 19. Therefore, in TT1, the translator translated this term into "*牵拉反射*". However, later the translator looked up this term on the Bilingual Dictionary website of the National Academy of Education and found that "*stretch reflex"* was translated into "*牵张反射*". Furthermore, the translator searched the term on *Termonline,* an online resource library, and found that "*stretch reflex"* was also translated into "牵张反射", which is derived from the book *Chinese Terms in Neurology* published in 2020. Therefore, in TT2, the translator translated this term into "*牵张反射*" in the field of neuroscience.

Example 2：

ST: A third example of adaptability is the conditioning of the **flexion-withdrawal** reflex.

TT1: 适应性的第三个例子是调节屈退反射。

TT2：适应性的第三个例子是调节屈曲反射。

Analysis: In Example 2, it is difficult to translate the terminology "*flexion-withdrawal*", because its Chinese equivalent expression couldn't be got directly in dictionaries and online database. A search on CNKI showed that "*flexion* *withdrawal* " is commonly used, which proves the existence of this phrase. According to the English-Chinese dictionary, in the medicine field, the word "*flexion*" is translated into "*屈曲*" and the word "*withdrawal*" is translated into "*退出，撤退*". Therefore, in TT1, according to its general meaning, the term "*flexion withdrawal*" is translated into "*屈退*". However, later the translator found that the Chinese expression "*屈退*" does not exist in either CNKI or online resource library. Then according to the context, it is very similar to "*flexion reflex*". It is previously mentioned that "*Flexion-withdrawal is a protective reflex in which a discrete stimulus causes all the flexor muscles in that limb to contract coordinately. We know that this is a spinal reflex because it persists after complete transection of the spinal cord.*" The "*flexion reflex*" refers to the flexion reaction of the ipsilateral muscle when the skin is stimulated by injury. The flexors around the joints contract and the extensors are slow. It is a protective reflex. According to definition of the two words, the translator believed that "f*lexion-withdrawal reflex*" is "*flexion reflex*". On the *Termonline*, "*flexion reflex*" is translated into "*屈曲反射*". Therefore, in TT2, "f*lexion-withdrawal*" was translated into "*屈曲*" in the field of neuroscience.

3.1.2 The Selection of Semi Terminology in Neuroscience

Polysemy is a linguistic phenomenon widely existing in natural languages, that is, a word has two or more interrelated meanings. Usually, the form and meaning of a word are not in a one-to-one relationship but in a one-to-many relationship. Accurate translation of polysemous words requires firstly the understanding of the type of the source text, and secondly the choice of meaning according to the context (王俊, 2022).

Example 3:

ST: The **tonic discharge** of both primary and secondary sensory endings signals the steady-state length of the muscle.

TT1：一级和二级感觉末梢的强直放电反映了肌肉的静息长度。

TT2: 一级和二级感觉末梢的紧张性放电反映了肌肉静息长度。

Analysis： In Example 3, it is difficult to translate the word group "*tonic discharge*", because its Chinese equivalent expression couldn't be got directly in dictionaries. The English word "*tonic*" is polysemous. According to *Collins English Dictionary*, "*tonic*" usually means "*强直的，紧张的，强壮的*" in the field of neuroscience. In order to determine the meaning of "*tonic*" in this sentence, the translator firstly retrieved the word "*强直放电*" in the online corpus, and this Chinese expression was found in a paper. On the *Termonline,* the translator searched the phrase "*tonic discharge*" and found the related term "*neuromyotonic discharge*", which means "*神经肌性强直放电*" in Chinese, which comes from the book *Chinese Terms in Neurology* published in 2020. Therefore, in TT1, the term "*tonic discharge*" is translated into "*强直放电*". Then, the translator also retrieved other two Chinese expressions "*紧张放电*" and the "*强壮放电*" in turn in CNKI. It was found that the expression "*紧张性放电*" was used in many papers. Finally, on *Termonline*, translator found that "*tonic discharge*" means "*紧张性放电*" in the field of physiology. Therefore, the word group "*tonic discharge*" is translated into "紧张性放电" in TT2.

Example 4:

ST: The **organization** of reflex pathways in the spinal cord has been established primarily by electrically stimulating the sensory fibers and recording evoked responses in different classes of neurons in the spinal cord.

TT1: 脊髓反射通路的组织，主要是通过电刺激感觉纤维，和记录脊髓中不同类型神经元的诱发反应而建立的。

TT2: 脊髓中的反射通路机制，主要是通过电刺激感觉纤维，和记录脊髓中不同类型神经元的诱发反应而建立的。

Analysis: In Example 4, it is difficult to translate the word "*organization*", because its common Chinese expression appears awkward in the context of this sentence. The meaning of the word "*organization*" in the field of biology is "*组构，组织，结构，机构，机体形成*". When searching for the word in CNKI, the most frequently used Chinese expression is "*组织*". Therefore, in the TT1, the word "*organization*" is translated into "*组织*". However, when reading TT1 as a whole, it was found that is not appropriate in this context. In CNKI and various online resource databases, the expression "*机制*" is commonly used together with the expression "*反射通路*" in the field neuroscience instead of the expression "*组织*". Therefore, the translator translated the word "*organization*" into "*机制*" in TT2.

3.1.3 The Conversion of Nominalization

According to Halliday, nominalization is an important means of constructing grammatical metaphor, which determines its multiple functions in discourse. Nominalization has changed the tediousness of multiple clauses into an effective and concise cohesive device, making the text smoother and more logical. Nominalization structure can get rid of the dynamic subjective world created by spoken language. By nominalizing actions and logical relations, discourse can be considered and organized from abstract concepts such as thoughts and reasons rather than from the perspective of the actor, so as to make the discourse more fair and objective. (肖建安，王志军，2001)

Example 5:

ST: Excitation of one group of muscles and **inhibition** of their antagonists--those that act in the opposite direction-is what Sherrington called reciprocal innervation...

TT1：对一组肌肉的**刺激**和对其反向拮抗肌的**抑制**，就是谢林顿所说的互反神经支配……

TT2: 谢灵顿所说的交互神经支配是指，**刺激**一组肌肉，并**抑制**肌肉中反向运动的拮抗肌……

Analysis: In Example 5, it is difficult to translate the two nominalizations "*excitation*" and "*inhibition*". In TT1, translator adopted literal translation to translate "*excitation*" and "*inhibition*" into Chinese nouns "*刺激*" and "*抑制*" respectively. After reading TT1 again, it was found that these two expressions "*对一组肌肉的刺激*" and *"对其反向拮抗物的抑制"* are not very natural in Chinese because Chinese is a verb-dominant language. The form of "*nominalization + of*" is common in English. According to the book *Scientific Translation*, this English structure could be converted into a Chinese phrase with the verb-object structure. In the TT2, the translator translated the two nouns “*excitation*” and “*inhibition*” into the two verbs “*刺激*” and “*抑制*”. In this way, the nominalization structure in English is transformed into a verb-object structure. This conversion method does not change the meaning of the original text, helps the reader to understand the meaning of the original text, and conforms to the language habits of the target language.

Example 6:

ST: <u>Relaxation</u> of the antagonist muscle during a movement enhances speed and efficiency because the muscles that act as prime movers are not working against the **c<u>ontraction</u>** of opposing muscles.

TT1: 作为原动力的肌肉，不会对抗拮抗肌<u>的收缩</u>，因此在运动期间，拮抗肌的<u>放松</u>能增加运动速度和效率。

TT2：作为原动力的肌肉，不会对抗<u>收缩</u>拮抗肌，因此在运动期间，<u>放松</u>拮抗肌能增加运动速度和效率。

TT3: 作为原动力的肌肉，不会对抗<u>收缩的</u>拮抗肌，因此在运动期间，<u>放松</u>拮抗肌能增加运动速度和效率。

Analysis: In Example 6, it is difficult to translate the two nominalizations “*relaxation*” and “*contraction*”. In TT1, translator translated them into Chinese nouns “*收缩*” and “*放松*” directly. Obviously, it is not fluent and natural with little readability. In order to make the translation be more natural and closer to the target language, the translator used the method of part-of-speech conversion and transformed the English structure of “*nominalization + of*” into the Chinese structure of “*verb + object*”. Then, in TT2, the two nominalizations “*relaxation*” and “*contraction*” are translated into Chinese verbs “*收缩*” and “*放松*” respectively. When proofreading the translation, the translator found that in the first half of TT2 there are two Chinese verbs “对抗” and “收缩” used together, which makes the translation not smooth. After querying the data, the translator knew that the “*prime mover*” should fight against the “*antagonist muscle*”, so the “*antagonist muscle*” should be the object of this sentence, and “*contraction*” should be the state of the “*antagonist muscle*”, so the translator translated the English word "*contraction*" into the Chinese adjective "*收缩的*". After the change, TT3 reads very fluently and conforms to the language habits of the target language.

3.2 Changing Sentence Structures

In scientific English, passive voice is widely used to ensure the objectivity of the article. However, in Chinese, passive sentences are rarely used, especially the word "被", which has a negative meaning in Chinese. Therefore, the translator converts the passive voice into the active voice, or tries to avoid using the word "被". In addition, there are great differences in sentence structures between English and Chinese, which brings great difficulties to translation. The characteristic of English sentences is that each component in the sentence can have modifiers, and each modifier can be very long. One modifier can also be modified by another modifier, so the sentence structure is complex. In Chinese, modifiers are few and short, and sentences are composed of clauses one by one. Therefore, in the process of English-Chinese translation, when dealing with long sentences, the translator splits them into short sentences. In order to avoid repetition and make the article more concise, the source text use widely pronouns and punctuations to connect the context. In order to make the translation easier to understand, the translator clearly points out the meaning of some pronouns in the process of translation, and directly expresses the meaning of some punctuations in Chinese, and restores the omitted parts in the original text.

3.2.1 The Shift of Passive Voice to Active Voice

Both English and Chinese will use the passive voice in the text, but due to the differences in cultural differences and ways of thinking between the East and the West, there are great differences in the use of passive voice between English and Chinese. English and Chinese belong to the Indo-European language family and the Sino-Tibetan language family respectively, with obvious differences. English is a language of 'rule of law', and a prominent feature of language structure and morphology is hypotaxis; Chinese is a language of ‘rule of man’, and a prominent feature of language structure and morphology is parataxis (刘宓庆, 2006). When the subject of the sentence is the recipient or victim of the action, the verb form is in the passive voice. Passive voice is widely used in English, especially English for science and technology (刘明东, 2001).

Example 7:

ST: Thus muscle spindles **<u>are used by</u>** the central nervous system to sense relative positions of the body segments.

TT1: 因此，肌梭<u>被</u>中枢神经系统<u>用来</u>感知身体各部分的相对位置。

TT2: 因此，中枢神经系统<u>利用</u>肌梭来感知身体各部分的相对位置。

Analysis: In Example 7, it is difficult to translate the passive voice. The passive voice in Chinese is realized by lexical means, mainly by words such as “被，由，给，把” and so on. When the word “*use*” is translated into Chinese, it is often combined with the word “*被*”, so the translator translated the passive voice here into “*被…用来…*” in the TT1. However, in Chinese, especially, the word “被”, usually conveys a negative meaning. When there is an obvious recipient and agent in the English passive voice, the agent as the subject and the recipient as the object can be translated into the Chinese active voice. In Example 7, the English expression “*muscle spindle*” is the recipient and “*the central nervous system*” is agent. Therefore, in the TT2 the translator took “*the central nervous system*” as the subject and “*muscle spindles*” as the object, and translated the English passive sentence into the Chinese active sentence, which conforms to the Chinese habits without changing the original meaning.

Example 8:

ST: A subject **<u>is asked</u>** to place the palmar surface of an index finger on an electrode.

TT1: <u>要求</u>受试者将食指的手掌面放在电极上。

TT2: 实验<u>要求</u>受试者将食指的手掌面放在电极上。

Analysis: In Example 8, it is difficult to translate the passive voice, because in this sentence, there is only a recipient and no agent, making it difficult to translate into the active voice of Chinese. As in the previous example, it is not appropriate to adopt a literal translation. In this example, there is no agent, only recipient. Chinese can be without a subject, so the translator translated this sentence into Chinese without a subject in TT2. The translator found the translation is not smooth when she read it. Another translation method is also mentioned in the thesis on passive voice, that is, when the original sentence does not mention the agent and does not express an obvious negative meaning, the subject can be translated according to the specific situation. According to the word "*subject*" and the context of the sentence, this is an experiment, so the translator added the Chinese expression "*实验*" when translating in the TT3. This method of translation converts the passive voice into the active voice, and the translation is very smooth.

3.2.2 The Change of the Structure of Long Sentences

Long sentences in English for Science and Technology are usually several parallel clauses or clauses in a sentence. These clauses are interdependent and mutually restrictive. They can be said to be connected and linked to each other, making the sentences complicated and dazzling. It is difficult to understand their true meaning (余高峰, 2012). Therefore, for science and technology workers, the translation of long sentences in English for science and technology becomes more and more important.

Example 9:

The strength of the electrical stimulus required to activate a sensory fiber is measured relative to the strength required to activate the afferent fibers with the largest diameter because these fibers have the lowest threshold for electrical activation.

TT1: 激活一个感觉纤维所需的电刺激强度是相对于激活直径最大的传入纤维所需的强度来测量的，因为这些纤维具有最低的电激活阈值。

TT2: 直径最大的传入纤维具有最低的电激活阈值，因此根据激活该纤维所需的电刺激强度，来测量感觉纤维所需的电刺激强度。

Analysis: In Example 9, it is difficult to translate the long sentence, because translator should break long sentences into short sentences. Example 9 is a very long and complex sentence, and direct translation is very difficult, so the translator took several steps to translate it. First, determine the structure of the sentence. The expression "*The strength*" is subject, and the expression "*is measured*" is the predicate. Second, translate the subject, predicate, and other part separately. Third, connect the whole sentence. After these three steps of translation, the sentence TT1 is very long and difficult to understand. And the sentence does not conform to Chinese language habits. Chinese generally first shows the reason and then says the result. Therefore, the translator adopted the reverse translation method. First, the reason is mentioned at the beginning of the sentence. In order to avoid repetition, the translator advanced the object in the source language, and added the word "*根据*". After adjusting the expression order, the translation is changed into three short sentences in the TT2, which not only makes the sentences easier to understand, but also conforms to the expression habits of the target language.

Example 10:

ST: These interneurons receive inputs from collaterals of axons descending from neurons in the motor cortex that make direct excitatory connections with spinal motor neurons.

TT1: 这些中间神经元接收来自运动皮层神经元下行轴突的侧支的输入, 与脊髓运动神经元产生直接的兴奋性连接。

TT2: 这些中间神经元接收来自运动皮层神经元下行轴突的侧支的输入，轴突与脊髓运动神经元产生直接的兴奋性连接。

TT3: 这些中间神经元接收下行轴突侧枝的输入，而轴突来自运动皮层神经元，且与脊髓运动神经元产生直接的兴奋性连接。

Analysis: In Example 10, it is difficult to translate the long sentence, because translator should break long sentences into short sentences. The subject and predicate of this sentence are very short, but the object is very long and there is a clause. The translator adopted literal translation to get TT1. The latter part of the translation is very ambiguous, it is not clear what the subject of the clause is. After the translator 's analysis, it is concluded that the clause is an attributive clause, and that refers to the previous word "*axons*". The translator also completed the subject of the attributive clause and translated it into "*轴突*". After reading TT2 several times, the translator believed that the first half can be further optimized and can be simplified or divided into two sentences. In the first half of the sentence, there are many descriptions of the object, and the readability is poor. The translator split the first half of TT2. The split part is the description of the object, so the translator added "*而…且…*" to translate the two parts into parallel sentences in TT3. TT3 is very smooth and easy to read.

Example 11:

ST: Relaxation of the antagonist muscle during a movement enhances speed and efficiency because the muscles that act as prime movers are not working against the contraction of opposing muscles.

TT1: 在运动过程中放松拮抗剂肌可以提高运动速度和效率，因为作为原动力的肌肉不会对抗收缩的拮抗肌。

TT2: 因为作为原动力的肌肉并不会对抗收缩的拮抗肌，所以在运动期间，放松拮抗肌能增加运动速度和效率。

TT3: 原动肌不会对抗收缩的拮抗肌，因此在运动期间，放松拮抗肌能增加运动速度和效率。

Analysis: In Example 11, it is difficult to translate the long sentence, because translator should break long sentences into short sentences. In the TT1, the translator adopted the literal translation method, and the translation was composed of two long sentences, which does not conform to the Chinese language habit. This example consists of a main sentence and an adverbial clause of cause. Because Chinese is used to express the cause first and then the result, the translator put the adverbial clause of cause at the beginning of the sentence in TT2. Then the main sentence can be divided into two parts. The whole sentence is broken up into three short sentences. When translating other original texts, the translator found that there is the expression "*原动肌*" in Chinese, so "*作为原动力的肌肉*" can be simplified to "*原动肌*". And the sentence"*因为…所以…*" can also be shortened to "*因此*". In TT3, the original meaning of the sentence is not changed, but the translation is also simplified. Therefore, the translation TT3 is more appropriate.

3.2.3 The Explicitation of Implicit Meaning

The technique of explicit translation was first proposed by French scholars Vinay and Darbelnet when they compared the stylistic styles of French and English. As an important strategy of stylistic translation, explicit translation refers to the process of making explicit in the target language information that is not explicitly expressed in the original language but can be reasonably inferred from the context or situation (Vinay, Darbelnet, 1995). In translation practice, the translation of punctuation marks is crucial to achieving the effect of explicit translation. Punctuation not only has the basic function of sentence breaks, but also plays an important role in connecting sentences and enhancing semantic expression (苏培成, 1994). This method of translation helps to ensure that the target language readers are able to more accurately understand the intent and connotation of the original text. These are the hidden meanings of punctuation. In Chinese-English translation, through the deconstruction of sentence patterns, we can use these punctuation marks to help connect different cohesion modes, so as to achieve effective information processing (梁丽，王舟, 2001).

Example 12:

ST: Excitation of one group of muscles and inhibition of their antagonists**---those that act in the opposite direction---is what Sherrington called reciprocal innervation,** a key principle of motor organization that is discussed later in this chapter.

TT1: 刺激一组肌肉并抑制它们的拮抗物——那些朝着相反方向运动的拮抗肌——就是谢灵顿所说的交互神经支配，这是运动机制的一个关键原理，本章稍后将对此进行讨论。

TT2: 谢灵顿所说的交互神经支配是指，刺激一组肌肉, 并抑制肌肉中反方向运动的拮抗肌。这是运动机制的一个关键原理，本章稍后将对此进行讨论。

Analysis： In Example 12, it is difficult to translate the two dashes and one comma, because the translation of the sentence retains the original structure, which makes the translation difficult to understand. In theTT1, the translator adopted literal translation. In Chinese scientific discourse, dashes have the functions of emphasis, explanation and supplement. The first dash in the example serves as a supplement, while the second dash serves as an explanation. A literal translation of this example is reasonable in terms of punctuation. However, fluency is one of the most important principles in scientific English translation. When translator read TT1, found that the translation is not smooth. The implicit meaning of both dashes is interpretation. In TT2, the translator clearly translated the hidden meaning of the two dashes. For sentence fluency and to avoid repetition, two sentences before and after the first dash can be combined into "*抑制肌肉中朝着反方向运动的拮抗肌*". The second dash translator removed it and the Chinese expression "*谢灵顿所说的交互神经支配是指*" can be placed at the beginning of the sentence, which increased the emphasis of the sentence and made the whole sentence easier to understand and more readable. In the original text, the translator changed the comma into a period, because the meaning before the comma is very complete, and the content after the comma is a supplement to the whole sentence before. The translation of TT2 is easy to understand and does not change the meaning of the original.

Example 13:

ST: Afferent axons from muscle spindles make excitatory connections on two sets of motor neurons<u>: </u>alpha motor neurons that innervate the same (homonymous) muscle from which they arise and motor neurons that innervate synergist muscles.

TT1: 来自肌梭的传入轴突在两组运动神经元上建立兴奋性连接<u>:</u>支配同一(同名)肌肉的阿尔法运动神经元和支配协同肌的运动神经元。

TT2: 来自肌梭的传入轴突，在两组运动神经元上建立兴奋性连接，<u>这两组神经元分别是，</u>支配同一（同名）肌的阿尔法运动神经元，以及支配协同肌的运动神经元。

Analysis： In Example 13, it is difficult to translate the colon, because it has to be translated according to the context. In the TT1, translator retained the original structure. The sentence is very long and difficult to understand. The meaning of the colon in English is the same as that in Chinese, both of which have the meaning of enumeration and explanation. In this sentence, the contents before and after the colon refer to neurons, so it can be inferred that the colon here indicates enumeration, which is hidden meaning of the colon. Therefore, in TT2, the translator adopted the method of amplification in translation, adding “*这两组神经元分别表示*”, and directly expressed the meaning of the colon in Chinese characters, which made the sentence easier to understand. The sentence after the colon in Example 13 is very long. According to the explanation in *Comparison and Translation Between English and Chinese*, it is a sentence of parallel coordination. To translate such sentences, can use parallel conjunctions or separate them with commas. Chinese often uses short sentences, therefore, when translating the whole sentence, the translator also adopted the segmentation method, using commas to separate the long sentence. Therefore, TT2 does not change the meaning of the original sentence, but also increase the readability of the sentence.

3.3 Strengthening Coherence

The concept of discourse coherence is proposed by Halliday, which refers to the use of implicit or explicit cohesive devices to maintain the consistency and coherence of context semantics within sentences, between sentences, within paragraphs, and between paragraphs (胡壮麟, 1994). Li Yunxing (2001) believes that coherence is the discourse characteristic of words, small sentences, and sentence groups that are conceptually and logically reasonable, and properly connected.

3.3.1 Restoration of Pronouns

English is important in the sentence structure, and the necessary components are indispensable. Although a word has no practical significance in the sentence, it cannot be less. Chinese pays attention to refinement. As long as the meaning is clear and the language is fluent, it does not care about the existence of certain components. Whether it is ancient Chinese or modern Chinese, the frequency of using pronouns is far less than English, or English uses pronouns far more frequently than Chinese. Therefore, experienced translators tend to translate some personal pronouns and demonstrative pronouns in English into the nouns that these pronouns replace, and omit some personal pronouns and possessive pronouns, so as to maintain the normal Chinese version and make the Chinese translation conform to the reading habits of Chinese readers (曹明伦, 2019).

Example 14:

ST: A subject is asked to place the palmar surface of an index finger on an electrode. A mild electrical shock is then paired with an audible tone. As expected, after only a few pairings the tone alone will elicit the withdrawal reflex. **What exactly has been conditioned?** Is **it** the contraction of a fixed group of muscles or the behavioral act that withdraws the finger from the noxious stimulus?

TT1: 实验要求受试者将食指的手掌心放在电极上。然后将温和的然后将温和的电击与可听见的声音配对使用。不出所料，几次实验后，单是听到声音就会引起退缩反射。是什么条件引起的呢？这是一组固定的肌肉收缩，还是将手指从上海性刺激中抽离的行为动作？

TT2: 实验要求受试者将食指的手掌心放在电极上，然后将温和的电击与可听见的声音配对使用。不出所料，几次实验后，单是听到声音就会引起退缩反射。**这种反射**到底是什么条件引起的呢？**这种反射**是一组固定的肌肉收缩，还是将手指从伤害性刺激中抽离的行为动作?

TT3: 实验要求受试者将食指的手掌心放在电极上，然后将温和的电击与可听见的声音配对使用。不出所料，几次实验后，单是听到声音就会引起退缩反射。**这种反射**到底是什么条件引起的呢？是一组固定的肌肉收缩，还是将手指从伤害性刺激中抽离的行为动作?

Analysis: In Example 14, it is difficult to translate two questions, because what the pronoun refers to is unclear. In the TT1, translator adopted a literal translation method. The logic of the translation is not clear, which makes it difficult for readers to understand. The first question has no subject, and the second question has a demonstrative pronoun "*it*". Based on the previous discussion, the translator found that both questions are asking questions about the "*withdrawal reflex*". In the TT2, the translator added the subject of the first question and indicated the pronoun in the second question. When both were clearly translated, the translator found some duplication. In the TT3, the translator removed the subject of the second sentence to avoid duplication. Because the former sentence has clearly translated "*这种反射*" and the subject of the two sentences is the same, deleting the second "*这种反射*" does not affect understanding, but also increases the fluency of the sentence.

Example 15:

ST: Activation of gamma motor neurons causes shortening of the polar regions of the intrafusal fibers. **This** in turn stretches the central region from both ends, leading to an increase in firing rate of the sensory endings or to a greater likelihood that the sensory endings will fire in response to stretch of the muscle.

TT1: 激活伽马运动神经元会导致梭内纤维极区缩短。反过来这则会从两端拉伸中央区域，导致感觉末梢的放电速率增加，或者使感觉末梢为响应肌肉拉伸而放电的可能性增大。

TT2: 激活伽马运动神经元会导致梭内纤维极区缩短。而抑制伽马运动神经元会扩大梭内纤维的中央区域，从而导致感觉末梢的放电速率增加，或使感觉末梢为响应肌肉拉伸而放电的可能性增大。

Analysis: In Example 15, it is difficult to translation the word "*this*", because what the pronoun refers to is unclear. In the TT1, the translator did not clearly translate what "*this*" refers to, so the second sentence is difficult to understand. Compared with the first sentence, the structure of second expression in the original text has changed. Based on the "*in turn*" in the second sentence, the translator can determine that "*this*" refers to something opposite to the previous sentence. In order to make the translation easy to understand, the translator indicated what "*this*" refers to, translated it into "*抑制伽马运动神经元*", and in order to match the first sentence, the translator translated the second sentence in a different way. The translator also added the conjunction "*从而*" before the word "*leading*" to make the sentence more fluid. In the TT2, the translator clearly translated what the pronoun "*this*" refers to, and the logic of the whole sentence is more smooth and reasonable.

3.3.2 Repetition of Previous Information

Hoey believes that cohesion is largely a product of lexical relations rather than grammar. Lexical relation is the only cohesive way that systematically constitutes multiple relations. Lexical cohesion is the main means to create textual structure, accounting for about 40 % of the textual cohesive ties. According to Halliday & Hasan, lexical cohesion can be divided into two categories: recasts and collocations. Recast refers to the repetition of the previous item in the text, including the repeated use of the same word, synonyms, synonyms and so on. Although English and Chinese belong to different language families, human beings live in the same material world, their thinking modes are similar, and their thinking contents also have their commonalities. From the perspective of discourse, the two also have their own similarities in lexical cohesion. Therefore, textual equivalence can be achieved by reproducing the cohesive devices of the source language in English-Chinese translation (李延林, 刘连芳, 2008).

Example 16:

ST: Excited by collaterals of the axons of motor neurons, Renshaw cells make inhibitory synaptic connections with several populations of motor neurons, including the motor neurons that excite them and the Ia inhibitory interneurons. The connections with motor neurons form a negative feedback system that may help stabilize the firing rate of the motor neurons, whereas the connections with the Ia inhibitory interneurons may regulate the strength of inhibition of antagonistic motor neurons.

TT1: 闰绍细胞受运动神经元轴突侧支的刺激，与若干运动神经元群建立抑制性突触连接，包括刺激它们的运动神经元和 Ia 抑制性中间神经元。与运动神经元的连接形成一个负反馈系统，该系统可能有助于稳定运动神经元的放电速率，而

与 Ia 抑制性中间神经元的连接可能有助于调节对抗性运动神经元的抑制强度。

TT2: 闰绍细胞受运动神经元轴突侧支的刺激，与若干运动神经元群建立抑制性突触连接，<u>**这些神经元中**</u>包括刺激他们的运动神经元和 Ia 抑制性中间神经元。<u>**闰绍细胞**</u>与运动神经元的连接形成一个负反馈系统，该系统可能有助于稳定运动神经元的放电速率，连接 Ia 抑制性中间神经元可能有助于调节对抗性运动神经元的抑制强度。

Analysis: In Example 16, it is difficult to clarify the logic of the text, because some information is omitted in the text. In the TT1, the translator adopted literal translation. The translation did not add any information. After reading it several times, the translator found that the logic of the translation was not clear and difficult to understand. According to "*the motor neurons that excite them and the Ia inhibitory interneurons*", this is related to the information "*several populations of motor neurons*". Therefore, in the TT2, the translator added "*这些神经元*" before the word "*包括*". In the second sentence of the translation, the subject is not complete. The two elements can form a connection. According to the previous sentence, the intercalated cells and motor neurons form a connection. Therefore, in order to make the sentence complete, the translator added "*闰绍细胞*". The logic of TT2 is clear and easy for readers to read and understand.

Example 17:

ST: The Ia axons in reflex pathways also provide excitatory inputs to many of the motor neurons innervating synergist muscles (up to 60% of the motor neurons of some synergists). Although widespread, <u>**these connections**</u> are not as strong as the connections to homonymous motor neurons.

TT1: 反射通路中的 Ia 轴突也为支配协同肌的许多运动神经元提供兴奋性输入，其中一些协同肌的运动神经元高达 60%。尽管这些<u>**连接**</u>分布广泛，但他们不如同名运动神经元间的连接性强。

TT2: 反射通路中的 Ia 轴突也为支配协同肌的许多运动神经元提供兴奋性输入，其中一些协同肌的运动神经元高达 60%。尽管<u>**感觉神经元与目标神经元形成的连接**</u>分布广泛，但他们不如同名运动神经元间的连接性强。

Analysis: In Example 17, it is difficult to deal with the word "*connections*", because the information is incomplete. In the TT1, according to the source text content literal translation, but in the process of proofreading found that if literal translation, the reader does not know how to form the connection. The translator found the word "*connections*" in the sentence "*In all reflex pathways in the spinal cord the sensory neurons form divergent connections with a large number of target neurons through extensive branching*". From this sentence, we know that the sensory neurons and target neurons form a connection. This sentence is far from the example sentence in the original text. Readers are likely to have forgotten the previous sentence when they read the latter one. In order to make the sentence more fluent and easier to understand, the translator added "*感觉神经元与目标神经元形成的连接*" here. This makes the logic of TT2 more logical and complete.

Chapter 4 Conclusion

In this translation practice, the translator analyzes the source text according to the differences between English and Chinese languages and the characteristics of scientific English. In translation, the translator mainly adopts the translation strategy of scientific English. In this process, the translator has deepened his understanding of the differences between English and Chinese languages, and mastered the translation methods more skillfully.

4.1 Proofreading

Detailed proofreading is an indispensable part of the translation process. The content of this translation practice is long and contains certain professional fields. Therefore, in the process of translation, there will inevitably be some subjectivity or mistakes. Therefore, after completing the translation, the author has carried out three rounds of proofreading in order to improve the quality of the translation. The specific proofreading process is three rounds of self-proofreading, intra-group proofreading and mentor proofreading.

First of all, self-proofreading is carried out to check whether there are obvious errors in the details of the translation, such as punctuation, font size, mistranslation and omission, and inaccurate verification. Secondly, the group members proofread the translation. In this process, the readability of the translation is emphasized. The group members first do not read the translation through the original text, and the group members mark the incomprehensible places or the places where there is room for modification, and then make translation proofreading according to the original text, brainstorm, discuss translation problems, and improve translation quality. Finally, it is proofread by the mentor, mainly putting forward suggestions for some complex sentence patterns and key and difficult problems, and annotating the problems of the translation. On this basis, the author polishes and perfects the translation, and finally finalizes it through repeated revisions.

4.2 Gains

Translation is a work that needs continuous learning and accumulation. Through this translation practice, the translator has learned a lot of knowledge. First of all, the translator's linguistic skills were improved after this translation practice. The translator gained a lot of knowledge in the field of neuroscience, understood the principles and functions of spinal reflexes, increased her vocabulary in the field of neuroscience, and learnt a lot of specialised vocabulary and English expressions. The linguistic features of scientific English were learnt, and the grammatical structure and syntactic features of the source language were deepened, which will provide a reference for the practice of Chinese-to-English translation thereafter.

Secondly, the translator's logical thinking and reasoning ability is improved. Scientific and technical texts often contain complex logical relationships and technical details, which require the translator to have strong logical thinking and reasoning ability. Through translation practice, translators exercise their logical thinking ability, better understand the meaning and intention of the original text, and accurately convey them to the target language readers.

Thirdly, through this translation practice, the translator's problem-solving ability is also enhanced. During the translation process, the translator encounters a lot of problems and difficulties, and through various enquiries into various materials and revising the translation, the translator's problem-solving ability and patience in dealing with problems are enhanced.

In conclusion, the gains of this translation practice are manifold, which can not only improve the translator's language ability and professionalism, but also enhance the problem-solving ability. These gains are of great significance to translators' personal growth and professional development.

4.3 Limitations

Although this translation practice has been completed, some problems in the translation process cannot be solved. First of all, the translator knows little about neuroscience. When encountering terms that cannot be found in the online database, the translator can only translate them according to the definitions and similar terms mentioned in the original text, and cannot be sure that the translation is completely accurate. The translator reads a small number of neuroscience-related texts, and it is not guaranteed that all the words are in line with the habits of the field of neurology. Because some common words in the field of neurology have similar meanings to those in the general field, but the statements are different.

Secondly, the translator 's translation ability needs to be improved. The translator does not fully grasp the translation skills, and the differences between English and Chinese are not very complete. This requires the translator to accumulate translation experience and learn knowledge constantly.

Third, at present, the teaching of English translation for science and technology only stays at the language level, lacking the combination with practical needs and interdisciplinary cooperation. This makes it difficult for students to acquire a comprehensive knowledge system and comprehensive quality training. Translation teaching should also strengthen the cooperation between schools and enterprises.

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Appendix

Appendix I: Glossary

序号	英文	中文
1	Actin	肌动蛋白
2	Action potential	动作电位
3	Alpha motor neurons	阿尔法运动神经元
4	Amphibian	两栖动物
5	Angular momentum	角动量
6	Angular motion	角[向]运动
7	Antagonistic muscle	拮抗肌
8	Arc	弧线
9	Axon	轴突
10	Ballistic	弹道
11	Beta axon	贝塔轴突
12	Biceps brachii	肱二头肌
13	Binding protein	结合蛋白质
14	Brain stem	脑干
15	Calcium pump	钙泵
16	Central nervous system	中枢神经系统
17	Central neurons	中枢神经元
18	Cerebral cortex	大脑皮层
19	Collagen	胶原蛋白
20	Collateral sprout axon	侧支出芽轴突
21	Corticospinal	皮质脊髓
22	Cranial nerves	颅神经

23	Crossed-extension reflex	对侧伸肌反射
24	Cutaneous receptors	皮肤感受器
25	Dark band	暗带
26	Decerebrate	v.去脑，切除大脑 n.去脑动物
26	Dorsal roots	脊髓根
27	Electromyogram	电机图
29	EMG	肌电图
30	EPSP	兴奋性突触后电位
31	Extensor	伸肌
32	Extrafusal muscle fibers	梭外纤维
33	Flexion-extension	屈伸
34	Flexor	屈肌
35	Gamma motor neurons	伽马运动神经元
36	Gastrocnemius	腓肠肌
37	Golgi tendon organs	高尔基腱器官
38	Hering- Breuer reflex	赫白反射
39	Interneuron	中间神经元
40	Intrafusal fibers	梭内纤维
41	Joint	关节
42	Klippel-Feil syndrome	克利佩尔-费尔综合征
43	Mammal	哺乳动物
44	Monosynaptic Pathway	单突触通路
45	Motor neuron	运动神经元
46	Muscle fiber membrane	肌纤维膜
47	Muscle fibers	肌肉纤维
48	Muscle spindle	肌梭
49	Muscle Spindles	肌梭；肌纺锤
50	Nuclear bag fiber	核袋纤维

51	Nuclear chain fiber	核链纤维
52	Polysynaptic pathway	多突触通路
53	Renshaw cells	闰绍细胞
54	Sensorimotor loop	感觉运动环路
55	Sensorimotor system	感觉运动系统
56	Sensory axons of the peripheral nerve	周围神经感觉轴突
57	Sensory feedback	感觉反馈
58	Sensory Feedback Delays	感觉反馈延迟
59	Sensory nerve endings	感觉神经末梢
60	Sensory signals	感觉信号
61	Servomechanism	伺服系统
62	Soleus	比目鱼肌
63	Spasticity	痉挛
64	Spike-triggered averaging	锋电位触发平均
65	Spinal	脊髓的;脊柱的;脊的
66	Synapse	突触
67	Synaptic current	突触电流
68	Tactile sensations	触觉
69	Tendon jerk	腱反射
70	Tendon reflexes	肌腱反射
71	Tendon-jerk reflex	肌腱抽搐反射
72	Vertebrate	脊椎动物
73	Voluntary movements	自主运动

Appendix II: The Source Text and the Target Text

Source Text	Target Text
Spinal Reflexes	脊髓反射
Reflexes Are Adaptable to Particular Motor Tasks	反射可以适应特定的运动任务
Spinal Reflexes Produce Coordinated Patterns of Muscle Contraction	脊髓反射产生协调的肌肉收缩模式
Cutaneous Reflexes Produce Complex Movements That Serve Protective and Postural Functions	浅反射产生复杂的运动，起到保护和平衡的作用
The Stretch Reflex Resists the Lengthening of a Muscle	牵张反射抵制肌肉拉伸过长
Local Spinal Circuits Contribute to the Coordination of Reflex Responses	局部脊髓回路有助于协调反射反应
The Stretch Reflex Involves a Monosynaptic Pathway	牵张反射包括单突触通路
la Inhibitory Interneurons Coordinate the Muscles Surrounding a Joint	Ia 抑制性中间神经元可协调关节周围的肌肉
Divergence in Reflex Pathways Amplifies Sensory Inputs and Coordinates Muscle Contractions	反射通路的发散会放大感觉输入并协调肌肉收缩
Convergence of Inputs on Ib Interneurons Increases the Flexibility of Reflex Responses	越来越多的输入在 Ib 中间神经元上汇合，能增加了反射反应的灵活性
Central Motor Commands and Cognitive Processes Can Alter Synaptic Transmission in Spinal Reflex Pathways	中枢运动指令和认知过程可以改变脊髓反射通路中的突触传递
Central Neurons Can Regulate the Strength of	中枢神经元能在反射通路的

Spinal Reflexes at Three Sites in the Reflex Pathway	三个部位调节脊髓反射的强度
Gamma Motor Neurons Adjust the Sensitivity of Muscle Spindles	伽马运动神经元调节肌梭的敏感度
Proprioceptive Reflexes Play an Important Role in Regulating Both Voluntary and Automatic Movements	本体感觉反射在调节随意运动和自主运动中起着重要作用
Reflexes Involving Limb Muscles Are Mediated Through Spinal and Supraspinal Pathways	肢体肌肉的反射是通过脊髓和脊髓上的通路来介导的
Stretch Reflexes Reinforce Central Commands for Movements	牵张反射强化了运动的中枢指令
Damage to the Central Nervous System Produces Characteristic Alterations in Reflex Response and Muscle Tone	中枢神经系统的损伤改变反射反应和肌肉张力的特征
Interruption of Descending Pathways to the Spinal Cord Frequently Produces Spasticity	脊髓下行通路中断通常会导致痉挛
Transection of the Spinal Cord in Humans Leads to a Period of Spinal Shock Followed by Hyperreflexia	人类脊髓横断导致脊髓进入休克期，随后出现反射亢进现象
During purposeful movements the central nervous system uses information from a vast array of sensory receptors to ensure that the pattern of muscle activity suits the purpose.	在有目的的运动中，中枢神经系统利用大量来自感觉受体的信息，以确保肌肉活动的模式符合目的。
Without this sensory information movements tend to be imprecise, and tasks requiring fine coordination in the hands, such as buttoning one's shirt, are impossible.	如果没有这种感觉信息，动作往往不精准，而那些需要双手精细协调的动作，比如扣衬衫，就不可能完成。
Charles Sherrington was among the first to	查尔斯·谢灵顿（Charles

recognize the importance of sensory information in regulating movements.	Sherrington）是最早认识到感觉信息在调节运动中具有重要作用的人之一。
In 1906 he proposed that simple reflexes-stereotyped movements elicited by activation of receptors in skin or muscle are the basic units for movement.	1906 年，他提出简单反射，该反射由皮肤或肌肉中的感受器的动作引起的固定运动是运动的基本单位。
He further posited that complex sequences of movements can be produced by combining simple reflexes. This view guided motor physiology for much of the 20th century.	他还进一步提出，复杂的运动序列可以通过结合简单反射而产生。这种观点在 20 世纪的大部分时间里指导着运动生理学。
The view that reflexes are automatic, stereotyped movements in response to stimulation of peripheral receptors arose primarily from laboratory studies of reflexes in animals with central nervous system lesions.	通过对中枢神经受损的动物进行反射实验得出一种结论，反射是指通过刺激周围感受器，肌肉做出的自动、刻板的动作。
Once investigators began to measure reflexes in intact animals engaged in normal behavior, ideas about reflexes changed. We now know that reflexes are flexible, that under normal conditions they can be adapted to a task. The prevalent view today is that reflexes are integrated by centrally generated motor commands into complex adaptive movements.	当研究人员开始研究正常动物的行为反射，关于反射的想法就改变了。我们现在知道反射是灵活的，在正常情况下它们可以适应任务。如今普遍认为，反射是由中枢神经产生的运动指令整合而成的复杂的适应性运动。
In this chapter we consider the principles underlying the organization and function of	在本章中，我们研究的是反射产生的原理和反射的功

reflexes, focusing on spinal reflexes. The sensory stimuli for spinal reflexes arise from receptors in muscles, joints, and skin, and the neural circuitry responsible for the motor response is entirely contained within the spinal cord.	能，重点是脊髓反射。脊髓反射的感觉刺激来自肌肉、关节和皮肤的感受器，负责运动反应的神经回路完全包含在脊髓内。
Reflexes Are Adaptable to Particular Motor Tasks	反射可以适应特定的运动任务
A good example of the adaptability of reflexes is how certain reflexes change in response to stretching the wrist muscles. When a person is kneeling or standing the stretched muscles contract, but muscles in other limbs also contract to prevent a loss of balance. Interestingly, the reflex response of the elbow extensor of the opposite arm depends on how that arm is being used.	这有一个很好的例子，某些反射随着腕部肌肉的伸展而变化。当一个人跪下或站立时，伸展的肌肉会收缩，其他四肢的肌肉也会收缩以防止失去平衡。有趣的是，对侧手臂伸肘肌的反射反应取决于该手臂的使用方式。
If the arm is used to stabilize the body by holding the edge of a table, a large excitatory response in the elbow extensor muscle resists the forward sway of the body. If the arm is instead holding an unsteady object such as a cup of tea, reflex inhibition of the elbow extensors prevents movement of the cup.	如果手臂握着桌子的边缘来稳定身体，肘部伸肌会产生强烈的兴奋反应，以阻止身体的前倾。 如果手臂握着一个不稳定的物体，如一杯茶，肘关节的反射抑制会防止杯子晃动。
Another example of adaptability is the reflex of finger and thumb flexor muscles in response to stretching thumb muscles. If a subject rhythmically taps the tips of the index	适应性的另一个例子是手指和拇指屈肌对拇指伸肌的反应。如果受试者有节奏地互相轻击食指和拇指指尖，并

finger and thumb to each other, and flexion of the thumb is resisted, a short-latency reflex response is produced in both the finger and thumb flexor muscles.	且拇指的屈曲受到抵抗，手指和拇指屈肌会产生一种短潜伏期反射反应。
As a result, the reflex in the finger flexor muscle produces a larger flexion movement of the finger to compensate for the reduced flexion of the thumb and ensure the performance of the intended task. If the subject is simply making rhythmic thumb movements, a reflex response is produced only in the thumb flexor muscle.	因此，手指屈肌中的反射会产生更大的屈曲运动，以弥补拇指屈曲的减少，并确保预期任务的执行。如果受试者只是简单地做有节奏的拇指运动，反射反应只会在拇指屈肌中产生。
Reflex responses are often complex and can change depending on the task.	反射反应通常很复杂，并且会随着任务的不同而变化。
Perturbation of one arm causes an excitatory reflex response in the contralateral elbow extensor muscle when the contra-lateral limb is used to prevent the body from moving forward by grasping a table. The same stimulus produces an inhibitory response in the muscle when the contralateral hand holds a filled cup.	当用对侧肢体抓住桌子防止身体向前移动时，手臂的波动会引起对侧肘关节伸肌的兴奋性反射反应。 当对侧手拿着装满水的杯子时，同样的刺激会在肌肉中产生抑制反应。
Loading the thumb during a rhythmic sequence of finger-to-thumb pinching movements produces a reflex response in the finger muscle as well as the thumb muscle. The additional movement of the finger ensures that the pinching movement remains accurate. The blue area in the electromyogram	在一系列有节奏的捏指运动中，拇指的负荷会在食指肌肉和拇指肌肉中产生反射反应。食指的其他运动确保捏合运动的精确性。肌电图(EMG）记录中的蓝色区域表示反射反应。

(EMG)records indicates the reflex response.	
A third example of adaptability is the conditioning of the flexion-withdrawal reflex. Flexion-withdrawal can be associated with an auditory tone by classical conditioning (see Chapter 65). A subject is asked to place the palmar surface of an index finger on an electrode. A mild electrical shock is then paired with an audible tone. As expected, after only a few pairings the tone alone will elicit the withdrawal reflex. What exactly has been conditioned? Is it the contraction of a fixed group of muscles or the behavioral act that with-draws the finger from the noxious stimulus?	适应性的第三个例子是屈曲反射。通过条件反射，可将屈曲与声音联系起来（见第65章）。实验要求受试者将食指的手掌心放在电极上，然后将温和的电击与可听见的声音配对使用。不出所料，几次实验后，单是听到声音就会引起退缩反射。这种反射到底是什么条件引起的呢？是一组固定的肌肉收缩，还是将手指从伤害性刺激中抽离的行为动作?
This question can be answered by having the subject turn his or her hands over after conditioning is complete, so that now the dorsal surface of the finger is in contact with the electrode. Most subjects will withdraw their fingers from the electrode when the tone is played, even though this means that the opposite muscles now contract. Thus, the conditioned response is not merely a stereotyped set of muscle contractions but the elicitation of an appropriate behavior.	可以用下面的方法回答这个问题。受试者在完成上面的试验后，让其翻转双手，使手指的背面与电极接触。当声音响起，大多数受试者会将手指从电极上抽出来，这意味着背面肌肉也会收缩。因此，条件反应不仅仅是一套刻板的肌肉收缩，而是一种适当行为的诱发。
Three important principles are illustrated by these examples. First, neural signaling in reflex pathways is adjusted according to the	这些例子说明了三个重要原则。首先，反射通路中的神经信号会根据运动任务进行

motor task. The state of the reflex pathways for any task is referred to as the functional set. Exactly how a functional set is established for most motor tasks is largely unknown, and unraveling the underlying mechanisms is one of the challenging areas of contemporary research on motor systems.	调整。所有任务的反射通路的状态被称为功能集合。确切地说，大多数运动任务的功能集是如何建立的，这在很大程度上是未知的，而揭示其潜在机制是当代运动系统研究的一个具有挑战性的领域。
Second, sensory input from a localized source generally produces coordinated reflex responses in several muscles at once, some of which may be distant from the stimulus. Third, supraspinal centers play an important role in modulating and adapting spinal reflexes, even to the extent of reversing movements when appropriate.	第二，来自局部的感觉输入，一般会在几块肌肉中同时产生协调的反射反应，其中一些可能离刺激物很远。第三，脊髓上的中枢神经在调节和适应脊髓反射方面发挥着重要作用，甚至在适当的时候可以逆转运动。
To understand the neural basis for reflexes and how they are modified for a particular task, we must first have a thorough knowledge of how reflex path ways are organized in the spinal cord. Although under nor-mal conditions descending central commands directly shape spinal reflexes, many qualitative features of spinal reflexes are maintained after complete transection of the spinal cord, a condition that isolates the spinal circuits from the brain.	为了了解反射的神经基础以及它们是如何为特定的任务而改变的，首先，我们必须全面了解脊髓中的反射通路是如何形成的。在正常情况下，虽然中枢下行指令能直接形成脊髓反射，但在脊髓完全切断后，脊髓反射的许多定性特征得以保留，这使得脊髓圈与大脑分离。
Spinal Reflexes Produce Coordinated Patterns of Muscle Contraction	脊髓反射产生肌肉收缩的协调模式

Cutaneous Reflexes Produce Complex Movements That Serve Protective and Postural Functions	浅反射产生复杂的运动起到保护和平衡的作用
A familiar example of a spinal reflex is the flexion withdrawal reflex, in which a limb is quickly withdrawn from a painful stimulus. Flexion-withdrawal is a protective reflex in which a discrete stimulus causes all the flexor muscles in that limb to contract coordinately. We know that this is a spinal reflex because it persists after complete transection of the spinal cord.	脊髓反射的一个常见例子是屈曲反射，在这种反射中，肢体迅速从痛苦的刺激中抽出。屈曲是一种保护性反射，在这种反射中，一个间断的刺激会导致肢体的所有屈肌协调地收缩。我们知道这是因为脊髓完全被切断后，脊髓反射仍然存在。
The sensory signal activates divergent polysynaptic reflex pathways. One excites motor neurons that innervate flexor muscles of the stimulated limb, whereas another inhibits motor neurons that innervate the limb's extensor muscles (Figure 35-2A). Excitation of one group of muscles and inhibition of their antagonists-those that act in the opposite direction-is what Sherrington called reciprocal innervation, a key principle of motor organization that is discussed later in this chapter.	感觉信号激活了不同的多突触反射通路。一种刺激支配受刺激肢体屈肌的运动神经元，而另一种抑制运动神经元，这种神经元支配肢体的伸肌（图35-2A）。谢灵顿所说的交互神经支配是指，刺激一组肌肉,并抑制肌肉中相反方向运动的拮抗肌。这是运动组织的一个关键原理，本章稍后将对此进行讨论。
The reflex can produce an opposite effect in the contralateral limb, that is, excitation of extensor motor neurons and inhibition of flexor motor neurons. This crossed-extension reflex serves to enhance postural support	反射在对侧肢体可产生相反的作用，即激发伸肌运动神经元，抑制屈肌运动神经元。这种交叉牵张反射的作用在于，当脚从痛苦的刺激中撤

during withdrawal of a foot from a painful stimulus. Activation of the extensor muscles in the opposite leg counteracts the increased load caused by lifting the stimulated limb. Thus, flexion-withdrawal isa complete, albeit simple, motor act.	出时加强姿势支持。激活对侧腿的伸肌可以抵消因抬起受刺激的肢体而增加的负荷。因此，屈曲是一个简单但完整的运动动作
Although flexion reflexes are relatively stereotyped, both the spatial extent and the force of muscle contraction depend on stimulus intensity, Touching a stove that is slightly hot may produce moderately fast withdrawal only at the wrist and elbow, whereas touching a very hot stove invariably leads to a forceful contraction at all joints, leading to a rapid withdrawal of the entire limb. The duration of the reflex usually increases with stimulus intensity, and the contractions produced in a flexion reflex always outlast the stimulus.	虽然屈曲反射相对刻板，但肌肉收缩的空间范围和力量都取决于刺激强度。接触一个微热的炉子可能会产生轻微地快速收缩，但只会在手腕和肘部产生，而接触一个非常热的炉子则会导致所有关节的强力收缩，从而导致整个肢体的快速收缩。反射持续的时间通常随着刺激强度的增加而增加，而屈曲反射产生的收缩总是比刺激持续的时间长。
Because of the similarity of the flexion-withdrawal reflex to stepping, it was once thought that the flexion reflex is important in producing contractions of flexor muscles during walking. We now know, however, that a major component of the neural control system for walking is a set of intrinsic spinal circuits that do not require sensory stimuli (see Chapter 36). Nevertheless, in mammals the intrinsic spinal	由于屈曲反射与走路相似，人们曾一度认为在步行过程中屈肌产生收缩对屈曲反射很重要。然而，我们现在知道，行走的神经控制系统的一个主要组成部分，是一套不需要感觉刺激的固有脊髓回路(见第 36 章)。然而，在哺乳动物中，控制行走的固有脊髓回路共享部分参与屈

circuits that control walking share many of the interneurons that are involved in flexion reflexes.	曲反射的中间神经元。
The Stretch Reflex Resists the Lengthening of a Muscle	牵张反射防止肌肉过度拉长
Perhaps the most important-certainly the most studied-spinal reflex is the stretch reflex, a lengthening contraction of a muscle. Stretch reflexes were originally thought to be an intrinsic property of muscles. But early in the last century Liddell and Sherrington showed that they could be abolished by cutting either the dorsal or the ventral root, thus establishing that these reflexes require sensory input from muscle to spinal cord and a return path to muscle (Figure 35-2B).	脊髓反射是一种牵张反射，即肌肉的拉长收缩，这种反射也许最重要的，当然也是研究最多的。人们最初认为牵张反射是肌肉的固有特性。但是在上个世纪早期，利德尔（Liddell）和谢灵顿（Sherrington）就证明，通过切断背根或腹根，就可以消除这种反射，这一发现也确定了这些反射需要从肌肉到脊髓的感觉输入，以及到肌肉的返回路径(图 35-2B)。
Spinal reflexes involve coordinated contractions of numerous muscles in the limbs.	脊髓反射涉及四肢众多肌肉的协调收缩。
Polysynaptic pathways in the spinal cord mediate flexion and crossed-extension reflexes. One excitatory pathway activates motor neurons that innervate ipsilateral flexor muscles, which withdraw the limb from noxious stimuli. Another pathway simultaneously excites motor neurons that innervate contralateral extensor muscles,	脊髓中的多突触通路介导屈曲和对侧伸肌反射。一种兴奋性通路激活支配同侧屈肌的运动神经元，使肢体远离有害刺激。另一种通路同时刺激支配对侧伸肌的运动神经元，在肢体抽出时提供支持。抑制性中间神经元确保

providing support during withdrawal of the limb. Inhibitory interneurons ensure that the motor neurons supplying antagonist muscles are inactive during the reflex response.	供应拮抗肌的运动神经元在反射反应期间不活跃。
Monosynaptic pathways mediate stretch reflexes. Afferent axons from muscle spindles make excitatory connections on two sets of motor neurons: alpha motor neurons that innervate the same (homonymous) muscle from which they arise and motor neurons that innervate synergist muscles. They also act through interneurons to inhibit the motor neurons that innervate antagonist muscles. When a muscle is stretched by a tap with a reflex hammer, the firing rate in the afferent fiber from the spindle increases.	单突触通路介导牵张反射。来自肌梭的传入轴突，在两组运动神经元上建立兴奋性连接，这两组神经元分别是，支配同一（同名）肌的阿尔法运动神经元，以及支配协同肌的运动神经元。它们还通过中间神经元来抑制支配拮抗肌的运动神经元。使用反射锤敲击肌肉产生肌肉拉伸时，来自肌梭的传入纤维的传导速率增加。
This leads to contraction of the same muscle and its synergists and relaxation of the antagonist. The reflex therefore tends to counteract the stretch. enhancing the spring-like properties of the muscles. The records on the right demonstrate the reflex nature of contractions produced by muscle stretch in a decerebrate cat. When an extensor muscle is stretched it normally produces a large force, but it produces a very small force (dashed line) after the sensory afferents in the dorsal roots have been severed.	这导致了同一肌肉及其协同肌产生收缩，放松了拮抗肌。因此，这种反射往往会抵消拉伸，增强肌肉的弹性。右边的记录显示了有脑损伤的猫肌肉拉伸时产生的反射性收缩。当伸肌拉伸时，它通常会产生一个很大的力，但当背部根的感觉传入被。切断后，它会产生一个很小的力。
We now know that the receptor that senses the	我们现在知道，感知长度变

change of length is the muscle spindle (Box 35-1) and that the type la axon from this receptor makes direct excitatory connections with motor neurons. (The classification and nomenclature of sensory fibers from muscle are discussed in Box 35-2.)	化的感受器是肌梭（框 35-1），该受体的 Ia 型轴突与运动神经元产生直接的兴奋性连接。(方框 35-2 讨论了肌肉感觉纤维的分类和命名。)
The afferent axon also connects to interneurons that inhibit the motor neurons that innervate antagonist muscles, another instance of reciprocal innervation. This inhibition prevents muscle contractions that might otherwise resist the movements produced by the stretch reflexes.	肌梭的传入轴突还连接到中间神经元，这些中间神经元抑制支配拮抗肌的运动神经元，这是交互神经支配的另一个例子。这种抑制作用阻止了肌肉收缩，否则肌肉收缩可能会抵抗牵张反射产生的运动。
Sherrington developed an experimental model for investigating spinal circuitry that is especially valuable in the study of stretch reflexes. He conducted his experiments on cats whose brain stems had been surgically transected at the level of the midbrain, between the superior and inferior colliculi. This is referred to as a decerebrate preparation.	谢灵顿开发了一种用于研究脊髓回路的实验模型，该模型在研究牵张反射方面特别有价值。他在猫身上进行实验，这些猫的脑干进行了外科手术，即从中脑的上丘和下丘之间横切下来。这被称为去脑准备。
The effect of this procedure is to disconnect the rest of the brain from the spinal cord, thus blocking sensations of pain as well as interrupting normal modulation of reflexes by higher brain centers. A decerebrate animal has stereotyped and usually heightened stretch	这一过程是为了将大脑的其余部分与脊髓断开，从而阻断疼痛的感觉，并中断大脑高级中枢正常的反射调节。去脑动物具有刻板的牵张反射，反射的强度通常会增强，

reflexes, making it is easier to examine the factors controlling their expression.	因此更容易检查控制其产生的因素。
Without control by higher brain centers, descending pathways from the brain stem powerfully facilitate the neuronal circuits involved in the stretch reflexes of extensor muscles. This results in a dramatic increase in extensor muscle tone that sometimes suffices to support the animal in a standing position, In normal animals, owing to the balance between facilitation and inhibition, stretch reflexes are weaker and considerably more variable in strength than those in decerebrate animals.	如果没有高级大脑中枢的控制，来自脑干的下行通路会有力地促进涉及伸肌牵张反射的神经元回路。这导致伸肌张力显著增加，有时足以支撑动物站立。在正常动物中，由于促进和抑制之间的平衡，牵张反射比去脑动物更弱，而强度变化比那些没有大脑的动物要大得多。
Box 35-1 Muscle Spindles	框35-1肌梭
Muscle spindles are small encapsulated sensory receptors that have a spindle-like or fusiform shape and are located within the fleshy part of a muscle. Their main function is to signal changes in the length of the muscle within which they reside, Changes in length of muscles are closely associated with changes in the angles of the joints that the muscles cross. Thus muscle spindles are used by the central nervous system to sense relative positions of the body segments.	梭肌是一种小的被包裹的感受器，呈纺锤或梭形，位于肌肉的肉质部分。它们的主要功能是，当其所处的肌肉长度发生变化时，就会发出信号。肌肉长度的变化与肌肉交叉的关节角度的变化密切相关。因此，中枢神经系统利用肌梭来感知身体各个部分的位置。
Each spindle has three main components: (1) a group of specialized intrafusal muscle fibers with central regions that are	每个肌梭有三个主要部件：(1)一组特殊的梭内纤维，其中心区域不收缩；(2)感觉纤

noncontractile;(2)sensory fibers that terminate in the noncontractile central regions of the intrafusal fibers; and (3) motor axons that terminate in the polar con-tractile regions of the intrafusal fibers (Figure 35-3A).	维，其终止于梭内纤维的非收缩中心区域;(3)运动轴突，终止于梭内纤维的极性收缩区域(图 35-3A)。
When the intrafusal fibers are stretched, often referred to as "loading the spindle," the sensory nerve endings are also stretched and increase their firing rate. Because muscle spindles are arranged in parallel with the extrafusal muscle fibers that make up the main body of the muscle, the intrafusal fibers change in length as the whole muscle changes. Thus, when a muscle is stretched, activity in the sensory endings of muscle spindles increases. When a muscle shortens, the spindle is unloaded and the activity decreases.	当血管内纤维遭到拉伸（通常被称为“负荷纺锤体”），感觉神经末梢也会拉伸并增加其放电率。由于肌梭与构成肌肉主体的梭外纤维平行排列，因此梭内纤维的长度随整个肌肉的变化而变化。因此，当肌肉拉伸时，肌梭感觉末梢的活动就会增加。当肌肉缩短时，肌梭失去负荷，活动减少。
The intrafusal muscle fibers are innervated by gamma motor neurons, which have small-diameter myelinated axons, whereas the extrafusal muscle fibers are innervated by alpha motor neurons, with large-diameter myelinated axons. Activation of gamma motor neurons causes shortening of the polar regions of the intrafusal fibers. This in turn stretches the central region from both ends, leading to an increase in firing rate of the sensory endings or to a greater likelihood that	梭内纤维由小直径髓鞘轴突的伽马运动神经元支配，而梭外纤维由大直径髓鞘轴突的阿尔法运动神经元支配。激活伽马运动神经元会导致梭内纤维极区缩短。而抑制伽马运动神经元会扩大梭内纤维的中央区域，从而导致感觉末梢的放电速率增加，或使感觉末梢为响应肌肉拉伸而放电的可能性增大。因

the sensory endings will fire in response to stretch of the muscle. Thus the gamma motor neurons adjust the sensitivity of the muscle spindles, Contraction of the intrafusal muscle fibers does not contribute significantly to the force of muscle contraction.	此伽马运动神经元会调节肌梭的敏感度。而梭内纤维的收缩对肌肉收缩力的影响不大。
The structure and functional behavior of muscle spindles is considerably more complex than this simple description implies. When a muscle is stretched the change in length has two phases: a dynamic phase, the period during which length is changing, and a static or steady-state phase, when the muscle has stabilized at anew length. Structural specializations within each component of the muscle spindles allow spindle afferents to signal aspects of each phase separately.	梭肌的结构和功能行为比描述的要复杂得多。当肌肉拉伸时，长度的变化有两个阶段:一个是动态阶段，即长度变化的时期，另一个是静态或稳态阶段，即肌肉稳定在一个新的阶段。肌梭每个部分结构的特异性允许肌梭传入向每个阶段的各个部分分别发出信号。
There are two types of intrafusal muscle fibers: nuclear bag fibers and nuclear chain fibers. The bag fibers can be divided into two groups, dynamic and static. A typical spindle has two or three bag fibers and a variable number of chain fibers, usually about five. Further-more, the intrafusal fibers receive two types of sensory endings, A single la (large diameter) axon spirals around the central region of all intrafusal muscle fibers and serves as the primary sensory ending (Figure 35-3B). A variable number of type l (medium	梭内纤维有两种类型:核袋纤维和核链纤维。袋式纤维可分为动态和静态两类。一个标准的肌梭有两到三种袋状纤维和数量不定的链状纤维，通常约五种。此外，梭内维有两种感觉末梢。单个 Ia(大直径)轴突是一级感觉末梢，绕着所有梭内的中心区域旋转(图 35-3B)。数量不等的 II 型(中等直径)轴突是二级感觉末梢，位于

diameter) axons, located adjacent to the central regions of the static bag and chain fibers, serve as secondary sensory endings.	静态袋状纤维和链状纤维的中心区域附近。
The gamma motor neurons can also be divided into two classes: Dynamic gamma motor neurons innervate the dynamic bag fibers, whereas the static gamma motor neurons innervate the static bag fibers and the chain fibers.	伽马运动神经元也可分为两类：动态伽马运动神经元支配动态袋状纤维，静态伽马运动神经元支配静态袋状纤维和链状纤维。
This duality of structure is reflected in a duality of function. <u>The tonic discharge of both primary and secondary sensory endings signals the steady-state length of the muscle.</u> The primary sensory endings are, in addition, highly sensitive to the velocity of stretch, allowing them to provide information about the speed of movements. Because they are highly sensitive to small changes, the primary endings rapidly provide information about sudden unexpected changes in length, which can be used to generate quick corrective reactions.	这种结构的对偶性体现在功能的对偶性中。<u>一级和二级感觉末梢的紧张性放电反映了肌肉静息长度。</u>此外，一级感觉末梢对肌肉伸展的速度高度敏感，因此它们能够提供有关运动速度的信息。它们对微小的变化非常敏感，所以一级末梢能迅速地提供关于长度突然变化的信号，这可以产生快速的纠正反应。
Increases in the firing rate of dynamic gamma motor neurons increase the dynamic sensitivity of primary sensory endings but have no influence on secondary sensory endings. Increases in the firing rate of static gamma motor neurons increase the tonic level of activity in both primary and secondary	增加动态伽玛运动神经元放电率可提高一级感觉末梢的动态敏感度，但对二级感觉末梢无影响。提高静态伽玛运动神经元放电率会增加一级和二级感觉末梢的紧张性活动水平，降低一级末梢的

sensory endings, decrease the dynamic sensitivity of primary endings (Figure 35-3C), and can prevent the silencing of primary endings when a muscle is released from stretch. Thus the central nervous system can independently adjust the dynamic and static sensitivity of the different sensory endings in muscle spindles.	动态敏感性（图 35-3C），并可以防止肌肉拉伸后一级末梢变得不活跃。因此中枢神经系统可以独立调节肌梭中不同感觉末梢的动态和静态敏感度。
Figure 35-3 The muscle spindle detects changes in muscle length.	图 35-3 肌梭检测肌肉长度的变化。
The main components of the muscle spindle are intrafusal muscle fibers, afferent sensory endings, and efferent motor endings. The intrafusal fibers are specialized muscle fibers with central regions that are not contractile. Gamma motor neurons innervate the contractile polar regions of the intrafusal fibers. Contraction of the polar regions pulls on the central regions of the intrafusal fiber from both ends. The sensory endings spiral around the central regions of the intrafusal fibers and are responsive to stretch of these fibers.	肌梭的主要成分是梭内纤维、传入感觉末梢和传出运动末梢。梭内纤维是一种特殊的肌肉纤维，其中心区域不能收缩。伽玛运动神经元支配梭内纤维的极性区域收缩。极性区域的收缩从两端拉动梭内纤维的中心区域。感觉末梢在梭内纤维的中心区域盘旋，并对这些纤维的拉伸做出反应。
The muscle spindle contains three types of intrafusal fibers: dynamic nuclear bag, static nuclear bag, and nuclear chain fibers. A single la sensory axon innervates all three types of fibers, forming a primary sensory ending. Type ll sensory axons innervate the nuclear	肌梭包括三种梭内纤维：动态核袋纤维，静态核袋纤维，核链纤维。单个 la 感觉轴突支配这三种类型的纤维，形成一级感觉末梢。II 型感觉轴突支配核链纤维和静态核

chain fibers and static bag fibers, forming a secondary sensory ending. Two types of motor neurons innervate different intrafusal fibers. Dynamic gamma motor neurons innervate only dynamic bag fibers; static gamma motor neurons innervate various combinations of chain and static bag fibers.	袋纤维，形成二级感觉末梢。两种类型的运动神经元支配不同的梭内纤维。动态伽马运动神经元只支配动态核袋纤维；静态伽马运动神经元支配核链纤维和静态核袋纤维的各种组合。
Selective stimulation of the two types of gamma motor neurons has different effects on the firing of the la fibers from the spindle. Without gamma stimulation the la fiber shows a small dynamic response to muscle stretch and a modest increase in steady-state firing. When a static gamma motor neuron is stimulated, the steady-state response of the la fiber increases, but there is a decrease in the dynamic response. When a dynamic gamma motor neuron is stimulated, the dynamic response of the la fiber is markedly enhanced, but the steady-state response gradually returns to its original level.	两种类型的伽马运动神经元的选择性刺激，对纺锤体 1a 纤维的放电有不同的影响。在伽马运动神经元没有受到刺激的情况下，1a 纤维对肌肉拉伸表现出较小的动态反应，稳态放电适度增加。当静态伽马运动神经元受到刺激时，1a 纤维的稳态响应增加，但动态响应减少。当动态伽马运动神经元受到刺激时，1a 纤维的动态响应显著增强，但稳态响应逐渐恢复到其原始水平。
Box 35-2 Classification of Sensory Fibers from Muscle	框 35-2 肌肉感觉纤维的分类
Sensory fibers are classified according to their diameter. Axons with larger diameters conduct action potentials more rapidly than do fibers of smaller diameters. Because each class of sensory receptors is innervated by fibers with diameters within a restricted	感觉纤维根据其直径进行分类。直径大的轴突比直径小的轴突传导动作电位更快。由于每一类感觉感受器都由直径在一定范围内的纤维支配，这种分类方法在一定程

range, this method of classification distinguishes to some extent the fibers that arise from the different types of receptor organs. The main groups of sensory fibers from muscle are listed in Table 35-1.	度上区分了产生于不同类型感受器器官的纤维。表 35-1 中列出了来自肌肉的主要感觉纤维群。
The organization of reflex pathways in the spinal cord has been established primarily by electrically stimulating the sensory fibers and recording evoked responses in different classes of neurons in the spinal cord. This method of activation has three advantages over natural stimulation. The timing of afferent input can be precisely established; the responses evoked in motor neurons and other neurons by different classes of sensory fibers can be assessed by grading the strength of the electrical stimulus; and certain classes of receptors can be selectively activated.	脊髓中的反射通路机制，主要是通过电刺激感觉纤维，和记录脊髓中不同类型神经元的诱发反应而建立的。与自然刺激相比，这种激活方法有三个优点。 一，可以精确地确定传入的时间；二，通过对电刺激的强度进行分级，可以评估不同类别的感觉纤维在运动神经元和其他神经元中诱发的反应；三，某些类别的受体可以选择性地激活。
The strength of the electrical stimulus required to activate a sensory fiber is measured relative to the strength required to activate the afferent fibers with the largest diameter because these fibers have the lowest threshold for electrical activation. The threshold of type I fibers is usually one to two times that of the largest afferents (with la fibers having, on average, a slightly lower threshold than Ib fibers). For most type II fibers the threshold is 2 to 5 times higher,	直径最大的传入纤维具有最低的电激活阈值，因此根据激活该纤维所需的电刺激强度，来测量感觉纤维所需的电刺激强度。I 型纤维的阈值通常是最大传入纤维的一倍（Ia 纤维的平均阈值略低于 Ib 纤维）。 对于大多数 II 型纤维，阈值是最大传入纤维的 2 – 5 倍，而 III 型和 IV 型的阈值是最

whereas type ll and IV have thresholds in the range of 10 to 50 times that of the largest afferents.	大传入纤维的 10 – 50 倍。
Local Spinal Circuits Contribute to the Coordination of Reflex Responses	局部脊髓回路有助于协调反射反应
The Stretch Reflex Involves a Monosynaptic Pathway	牵张反射涉及单突触路
The neural circuit responsible for the stretch reflex was one of the first reflex pathways to be examined in detail. The physiological basis of this reflex was examined by measuring the latency of the response in ventral roots to electrical stimulation of dorsal roots.	负责牵张反射的神经回路是最先受到详细检查的反射通路之一。通过测量腹根对背根电刺激反应的潜伏期，来研究这种反射的生理基础。
When the Ia sensory axons innervating the muscle spindles were selectively activated, the reflex latency through the spinal cord was less than 1 ms. This demonstrated that the la fibers make direct connections on the alpha motor neurons, for the delay at a single synapse is typically 0.5 ms to 0.9 ms (Figure 35-4B).	当支配肌肉主轴的 Ia 感觉轴突被选择性地激活时，穿过脊髓的反射潜伏期小于 1 毫秒。这表明 Ia 纤维直接连接阿尔法运动神经元，因为单个突触的延迟通常为 0.5 毫秒到 0.9 毫秒（图 35-4B）。
The pattern of connections of la fibers to motor neurons can be shown directly by intracellular recording. la fibers from a muscle excite not only the motor neurons innervating the same(homonymous) muscle, but also those innervating other (heteronymous) muscles with a similar mechanical action. The la fibers also form	Ia 纤维与运动神经元的连接模式可以通过细胞内记录直接显示出来。肌肉中的 Ia 纤维不仅刺激支配同一（同名的）肌肉的运动神经元，而且也刺激支配其他（相关而异名的）肌肉的运动神经元，使其产生类似的机械动作。

inhibitory connections with the alpha motor neurons innervating antagonistic muscles through the Ia inhibitory interneurons. This disynaptic inhibitory pathway is the basis for reciprocal innervation: When a muscle is stretched, its antagonists relax.	Ia 纤维还通过 Ia 抑制中间神经元与支配拮抗肌的阿尔法运动神经元形成抑制连接。这种双突触性的抑制途径是互感神经的基础： 当肌肉被拉伸时，其拮抗肌就会放松。
Figure 35-4 The number of synapses in a reflex pathway can be inferred from intracellular recordings.	图 35-4 反射通路中突触的数量可以从细胞内记录推断出来。
An intracellular recording electrode is inserted into the cell body of a spinal motor neuron that innervates an extensor muscle. Stimulation of la sensory fibers from flexor or extensor muscles produces a volley of action potentials at the dorsal root.	将细胞内记录电极插入支配伸肌的脊髓运动神经元的细胞体中。屈肌或伸肌中，受到刺激的 Ia 感觉纤维在背根产生一连串的动作电位。
Left: When la fibers from an extensor muscle are stimulated the latency between the recording of the afferent volley and the excitatory postsynaptic potential in the motor neuron is only0.7 ms. Because this is approximately equal to the duration of signal transmission across a single synapse, it can be inferred that the excitatory action of the stretch reflex pathway is monosynaptic.	左：当伸肌的 la 纤维被刺激时，传入截击的记录与运动神经元兴奋性突触后电位之间的潜伏期仅为 0.7 毫秒。这与信号通过单个突触传递的持续时间大约相同，因此可以推断出牵张反射通路的兴奋作用是单突触的。
Right: When la fibers from an antagonist flexor muscle are stimulated, the latency between the recording of the afferent volley and the inhibitory postsynaptic potential in	右：当来自拮抗屈肌的 la 纤维受到刺激时，传入截击的记录与运动神经元抑制性突触后电位之间的潜伏期为

the motor neuron is 1.6 ms. Because this is approximately twice the duration of signal transmission across a single synapse, it can be inferred that the inhibitory action of the stretch reflex pathway is disynaptic.	1.6 毫秒。这大约是通过单个突触的信号传输时间的两倍，因此可以推断出牵张反射通路的抑制作用是双突触的。
Ia Inhibitory Interneurons Coordinate the Muscles Surrounding a Joint	Ia 抑制性中间神经元协调关节周围的肌肉
Reciprocal innervation is useful not only in stretch reflexes but also in voluntary movements. Relaxation of the antagonist muscle during a movement enhances speed and efficiency because the muscles that act as prime movers are not working against the contraction of opposing muscles.	交互神经支配不仅适用于牵张反射，也适用于自主运动。原动肌不会对抗收缩的拮抗肌，因此在运动期间，放松拮抗肌能增加运动速度和效率。
The la inhibitory interneurons involved in the stretch reflex are also used to coordinate muscle contraction during voluntary movements. These interneurons receive inputs from collaterals of axons descending from neurons in the motor cortex that make direct excitatory connections with spinal motor neurons. This organizational feature simplifies the control of voluntary movements, for higher centers do not have to send separate commands to the opposing muscles.	参与牵张反射的 Ia 抑制性中间神经元也用于协调自主运动过程中的肌肉收缩。这些中间神经元接收下行轴突侧枝的输入，而轴突来自运动皮层神经元，且与脊髓运动神经元产生直接的兴奋性连接。这种组织特征简化了对自主运动的控制，因为高级中枢不需要向拮抗肌发出单独的指令。
Sometimes it is advantageous to contract the prime mover and the antagonist at the same time. Such co-contraction has the effect of	有时，同时收缩原动肌和拮抗肌是有好处的。这种同时收缩具有加固关节的作用，

stiffening the joint and is most useful when precision and joint stabilization are critical. An example of this phenomenon is the co-con-traction of flexor and extensor muscles of the elbow immediately before catching a ball. The la inhibitory interneurons receive both excitatory and inhibitory signals from all of the major descending pathways (Figure 35-5A). By changing the balance of excitatory and inhibitory inputs onto these interneurons, supraspinal centers can reduce reciprocal inhibition of muscles and enable co-contraction, thus control-ling the relative amount of joint stiffness to meet the requirements of the motor act.	在精度和关节稳定性至关重要的情况下最有用。肘部屈肌和伸肌在接球之前的联合收缩就是这种现象。Ia 抑制性中间神经元同时接收来自所有主要下行通路的兴奋性和抑制性信号(图 35-5A)。通过改变这些中间神经元的兴奋和抑制输入的平衡，椎管上中枢可以减少肌肉的相互抑制，使肌肉协同收缩，从而控制关节的相对硬度，以满足运动行为的需求。
The activity of spinal motor neurons is also regulated by another important class of inhibitory interneurons, the Renshaw cells. Excited by collaterals of the axons of motor neurons, Renshaw cells make inhibitory synaptic connections with several populations of motor neurons, including the motor neurons that excite them and the Ia inhibitory neurons that excite them and the Ia inhibitory interneurons (Figure 35-5B).	脊髓运动神经元的活动也受到另一类重要的抑制中间神经元，即闰绍细胞的调节。闰绍细胞受运动神经元轴突侧支的刺激，与若干运动神经元群建立抑制性突触连接，这些神经元中包括刺激他们的运动神经元和 Ia 抑制性中间神经元。（图 35-5B）
The connections with motor neurons form a negative feedback system that may help stabilize the firing rate of the motor neurons, whereas the connections with the la inhibitory interneurons may regulate the strength of	闰绍细胞与运动神经元的连接形成一个负反馈系统，该系统可能有助于稳定运动神经元的放电速率，连接 Ia 抑制性中间神经元可能有助于

inhibition of antagonistic motor neurons. In addition, Renshaw cells also receive significant synaptic input from descending pathways and distribute inhibition to task-related groups of motor neurons and Ia interneurons. It is therefore likely that Renshaw cells help establish the pattern of signaling in divergent la sensory pathways according to the motor task.	调节对抗性运动神经元的抑制强度。此外，闰绍细胞也从下行通路接收到明显的突触输入，并将抑制作用分布到与任务相关的运动神经元和 Ia 中间神经元组。因此，根据运动任务，闰绍细胞会帮助建立不同的 Ia 感觉通路的信号传导模式。
Figure 35-5 Inhibitory spinal interneurons coordinate reflex actions.	图 35-5 抑制性脊髓中间神经元协调反射作用。
The la inhibitory interneuron regulates contraction in antagonist muscles in stretch-reflex circuits through its divergent contacts with motor neurons. In addition, the interneuron receives excitatory and inhibitory inputs from corticospinal and other descending pathways. A change in the balance of these supraspinal signals allows the interneuron to coordinate co-contractions in antagonist muscles at a joint.	Ia 抑制性中间神经元通过与运动神经元的发散接触，调节牵张反射回路中收缩的拮抗肌。此外，中间神经元接受来自皮质脊髓和其他下行通路的兴奋性和抑制性输入。这些椎管上信号平衡的改变使中间神经元能够协调关节处拮抗肌的协同收缩。
Renshaw cells are spinal interneurons that produce recurrent inhibition of motor neurons. These interneurons are excited by collaterals from motor neurons and inhibit those same motor neurons. This negative feedback system regulates motor neuron excitability and stabilizes firing rates. Renshaw cells also send col-laterals to	闰绍细胞是脊髓中间神经元，会对运动神经元产生反复抑制。这些中间神经元被来自运动神经元的侧枝刺激，并抑制这些运动神经元。这个负反馈系统调节运动神经元的兴奋性，稳定放电率。闰绍细胞也向协同作用的运

synergist motor neurons (not shown) and la inhibitory interneurons that synapse on antagonist motor neurons. Thus, descending inputs that modulate the excitability of the Renshaw cells adjust the excitability of all the motor neurons around a joint.	动神经元(未显示)和Ia抑制的中间神经元发送侧支，这些中间神经元与拮抗的运动神经元突触相连。因此，调节闰绍细胞兴奋性的下行输入，会调节关节周围所有运动神经元的兴奋性。
Divergence in Reflex Pathways Amplifies Sensory Inputs and Coordinates Muscle Contractions	反射通路的差异可放大感觉输入，并协调肌肉收缩
In all reflex pathways in the spinal cord the sensory neurons form divergent connections with a large number of target neurons through extensive axonal branching. The flexion-withdrawal reflex, for example involves extensive divergence within the spinal cord. Stimulation of a small number of sensory axons from a small area of skin is sufficient to cause contractions of widely distributed muscles and thus to produce a coordinated motor pattern.	在脊髓的所有反射通路中，通过广泛的轴突分支，感觉神经元与大量目标神经元形成发散性连接。例如，屈曲反射涉及脊髓内的广泛发散。在一小块皮肤上刺激少量的感觉轴突，就足以引起广泛分布的肌肉的收缩，从而产生一种协调的运动模式。
Lorne Mendell and Elwood Henneman used a computer enhancement technique called spike-triggered averaging to determine the extent to which the action potentials in single la fibers are transmitted to a population of spinal motor neurons. They found that individual la axons make excitatory synapses with all homonymous motor neurons	洛恩·孟德尔（Lorne Mendell）和埃尔伍德·海勒曼（Elwood Henneman）使用一种称为锋电位触发平均法的计算机提升技术，来确定单个Ia纤维中的动作电位传递到一组脊髓运动神经元的程度。他们发现，单个的Ia

innervating the medial gastrocnemius of the cat. This widespread divergence effectively amplifies the signals of individual la fibers, leading to a strong excitatory drive to the muscle from which they originate (autogenic excitation).	轴突与支配猫腓肠肌内侧的所有同名运动神经元会产生兴奋性突触。这种广泛的发散有效地放大了单个Ia纤维的信号，导致肌肉产生强烈的兴奋性驱动（自发性兴奋）。
The Ia axons in reflex pathways also provide excitatory inputs to many of the motor neurons innervating synergist muscles (up to 60% of the motor neurons of some synergists). Although widespread, these connections are not as strong as the connections to homonymous motor neurons. The strength of these connections varies from muscle to muscle in a complex way according to the similarity of the mechanical actions of the synergists. We have already noted that, in the control of voluntary movements, descending path-ways make use of reciprocal inhibition of antagonists in the stretch reflex. A similar convergence principle holds for the activation of motor neurons innervating synergist muscles. Thus stretch reflex pathways provide a principal mechanism by which the contractions of different muscles can be linked in voluntary as well as reflex actions.	反射通路中的Ia轴突也为支配协同肌的许多运动神经元提供兴奋性输入，其中一些协同肌的运动神经元高达60%。尽管感觉神经元与目标神经元形成的连接分布广泛，但他们不如同名运动神经元间的连接性强。根据协同肌机械作用的相似性，这些连接的强度因肌肉而异，其方式很复杂。我们已经注意到，在自主运动的控制中，下行通路利用了牵张反射中拮抗肌的相互抑制。类似的汇聚原理也适用于激活支配协同肌的运动神经元。因此，牵张反射通路提供了一种主要机制，通过该机制，不同肌肉的收缩可以在自主动作和反射动作中联系起来。
Convergence of Inputs on Ib Interneurons	Ib间神经元输入的汇聚增加

Increases the Flexibility of Reflex Responses	了反射反应的灵活性
Thus far we have considered reflex pathways as though each included only one type of sensory fiber. But an enormous diversity of sensory information converges on interneurons in the spinal cord.	到目前为止，我们认为每条反射通路似乎只包括一种类型的感觉纤维。但大量不同的感觉信息汇聚在脊髓的中间神经元上。
The lb inhibitory interneuron is one of the best-studied interneurons that receive extensive convergent input. Its principal input is from Golgi tendon organs, sensory receptors that signal the tension in a muscle (Box 35-3), and it makes inhibitory connections with homonymous motor neurons. As one might expect from this connectivity, stimulation of tendon organs or their Ib afferent fibers in passive animals produces disynaptic inhibition of homonymous motor neurons (autogenic inhibition). However, stimulation of Ib afferents in active animals does not always inhibit homonymous motor neurons. Indeed, we shall see in the next section that stimulation of tendon organs may in certain conditions excite homonymous motor neurons.	Ib抑制性中间神经元接收广泛的聚合输入，且是目前研究得最透彻的中间神经元之一。它的主要输入来自高尔基肌腱器官，即发出肌肉张力信号的感觉受体(Box 35-3)，并与同名运动神经元产生抑制连接。正如人们预期的那样，在不活跃的动物中，刺激肌腱器官或其Ib传入纤维会产生同名运动神经元的非突触抑制(自发抑制)。然而，在活跃的动物中，受刺激的Ib传入神经并不总是抑制同名运动神经元。的确，我们将在下一节中看到，在某些条件下，对肌腱器官的刺激可能会刺激同名的运动神经元。
One reason that the reflex actions of the sensory axons from tendon organs are complex in natural situations is that the Ib inhibitory interneurons also receive input	在一般情况下，来自肌腱器官的感觉轴突的反射作用是复杂的，原因之一是Ib抑制性中间神经元也接收来自肌

from the muscle spindles, cutaneous receptors and joints (Figure 35-7A). In addition, they receive both excitatory and inhibitory input from various descending pathways.	肉轴突、皮肤感受器和关节的输入（图35-7A）。此外，它们接收各种来自下行通路的兴奋性和抑制性输入。
Golgi tendon organs were first thought to have a protective function, preventing damage to muscle, for it was assumed that they always inhibited homonymous motor neurons and that they fired only when tension in the muscle was high. But we now know that these receptors signal minute changes in muscle tension, thus providing the nervous system with precise information about the state of a muscle's contraction.	最初，人们认为高尔基腱器官具有保护功能，能够防止肌肉损伤，因为人们认为高尔基腱器官总是能抑制同名的运动神经元，而且它们只在肌肉紧张程度高时才会被激活。但我们现在知道，当肌肉的张力产生变化时，这些受体会发出信号，从而为神经系统提供有关肌肉收缩状态的精确信息。
The convergence of sensory input from tendon organs, cutaneous receptors, and joint receptors onto interneurons that inhibit motor neurons may allow for precise spinal control of muscle force in activities such as grasping a delicate object. Additional input from cutaneous receptors may facilitate activity in the Ib inhibitory interneurons when the hand reaches an object, thus reducing the level of muscle contraction and permitting a soft grasp.	来自肌腱器官、皮肤感受器和关节感受器的感觉输入，会聚到抑制运动神经元的中间神经元上，这可能会让脊髓在抓取精细物体等活动中，对肌肉力量进行精确控制。当手接触到物体时，皮肤受体的额外输入可能会促进lb抑制性中间神经元的活动，从而降低肌肉收缩水平，允许柔软的抓握。
Finally, like the la fibers from muscle spindles, the Ib fibers from tendon organs form widespread connections with motor	最后，就像来自肌梭的Ia纤维一样，来自肌腱器官的lb纤维与运动神经元会形成广

neurons that innervate muscles acting at different joints. Therefore, the connections of the afferent fibers from tendon organs with the Ib inhibitory interneurons are part of spinal reflex networks that regulate movements of whole limbs.	泛的连接，这些运动神经元支配着不同关节的肌肉。因此，来自肌腱器官的传入纤维与lb抑制性中间神经元的连接，是调节整个肢体运动的脊髓反射网络的一部分。
Central Motor Commands and Cognitive Processes Can Alter Synaptic Transmission in Spinal Reflex Pathways	中央运动指令和认知过程可以改变脊髓反射通路中的突触传递
Both the strength and the sign of synaptic transmission in spinal reflex pathways can be altered during behavioral acts, For example, in humans the strength of the monosynaptic reflex declines as we progress from standing to walking to running. It does so because stiffness increases naturally as muscle force increases and thus reflexes are not needed.	在行为活动中，脊髓反射通路的突触传递强度和信号都会发生改变。例如，在人类中，单突触反射的强度随着我们从站立到走路再到跑步的过程而下降。这是因为随着肌肉力量的增加，硬度自然增加，因此不需要反射。
Another example of a change in sign occurs in the activity of Ib sensory axons during walking. As we have seen, in passive animals the lb fibers from extensor muscles have an inhibitory effect on homonymous motor neurons. During locomotion they produce an excitatory effect on those same motor neurons because transmission in the disynaptic inhibitory pathway is depressed (Figure 35-7B). This phenomenon is called	走路时，Ib感觉轴突的活动是信号发生变化的另一例子。正如我们所看到的，在不活跃的动物中，伸肌的Ib纤维对同名运动神经元有抑制作用。在运动过程中，它们对这些相同的运动神经元产生兴奋作用，因为双突触性抑制通路的传递受到抑制（图35-7B）。这种现象被称

state-dependent reflex reversal.	为依赖性反射逆转。
Transmission in spinal reflex pathways can also be modified in association with higher cognitive functions. Examples are increases in the tendon jerk reflex in the soleus muscle of humans while imagining pressing a foot pedal, and modulation of the Hoffmann reflex in arm and leg muscles when subjects observe grasping and walking movements, respectively. The latter findings indicate that the mirror-neuron system identified in cortical networks (see Chapter 38) influences neuronal systems in the spinal cord.	脊髓反射通路的传输也会随着高级认知功能的改变而改变。例如，当受试者想象踩踏板时，比目鱼肌中的腱反射增加，当受试者分别观察抓握和行走动作时，手臂和腿部肌肉中的霍夫曼反射发生改变。后一项发现表明，在皮质网络中发现的镜像神经元系统（见第38章）会影响脊髓中的神经元系统。
Furthermore, intracellular recordings from monkeys engaged in normal behavior have demonstrated that the intention to make a movement modifies activity in interneurons in the spinal cord and alters the transmission in spinal reflex pathways.	此外，猴子正常行为的细胞内记录表明，进行运动的意图会改变脊髓中中间神经元的活动，并改变脊髓反射通路的传递。
Box 35-3 Golgi Tendon Organs	框35-3 高尔基肌腱器官
Golgi tendon organs are slender encapsulated structures approximately 1 mm long and 0.1 mm in diameter located at the junction between skeletal muscle fibers and tendon. Each capsule encloses several braided colla-gen fibers connected in series to a group of muscle fibers.	高尔基肌腱器官是一种细长的囊状结构，长约1毫米，直径0.1 毫米，位于骨骼肌纤维与肌腱的交界处。每个胶囊包含若干条编织的胶原纤维，这些胶原纤维串联在一组肌肉纤维上。
Each tendon organ is innervated by a single Ib	每个肌腱器官都由一个Ib轴

axon that branches into many fine endings inside the capsule; these endings become intertwined with the collagen fascicles (Figure 35-6A).	突支配，该轴突在囊内分支成许多细末梢；这些末梢与胶原蛋白束交织在一起（图35-6A）。
Stretching of the tendon organ straightens the collagen fibers, thus compressing the Ib nerve endings and causing them to fire. Because the nerve endings are so closely associated with the collagen fibers, even very small stretches of the tendons can compress the nerve endings.	肌腱器官的拉伸使胶原纤维变直，从而压迫Ib神经末梢并使其放电。由于神经末梢与胶原纤维紧密相连，即使是很小的肌腱拉伸也会压迫神经末梢。
Whereas muscle spindles are most sensitive to changes in length of a muscle, tendon organs are most sensitive to changes in muscle tension. Contraction of the muscle fibers connected to the collagen fiber bundle containing the receptor is a particularly potent stimulus to a tendon organ. The tendon organs are thus readily activated during normal movements. This has been demonstrated by recordings from single Ib axons in humans making voluntary finger movements and in cats walking normally.	而肌梭对肌肉长度的变化最为敏感， 肌腱器官则对肌肉张力的变化最为敏感。肌肉纤维与含有受体的胶原纤维束相连，这种肌肉纤维的收缩对肌腱器官是一种特别有效的刺激。因此，肌腱器官在正常运动期间很容易被激活。通过人类自主手指运动和猫正常行走的单个 Ib 轴突的记录，这一点已经得到了证明。
Studies in anesthetized animal preparations have shown that the average level of activity in the population of tendon organs in a muscle is a good index of the total force in a	麻醉动物制剂的研究表明，肌肉中肌腱器官群活动的平均水平是衡量收缩肌肉总力量的良好指标(图35-6B)。这

contracting muscle (Figure 35-6B). This close agreement between firing frequency and force is consistent with the view that the tendon organs continuously measure the force in a contracting muscle.	种放电频率和力之间的密切一致性与肌腱器官在收缩肌肉中连续测量力的观点一致。
Figure 35-6A When the Golgi tendon organ is stretched (usually because of contraction of the muscle), the Ib afferent axon is compressed by collagen fibers (see inset) and its rate of firing increases.	图 35-6A 当拉伸高尔基腱器官时（通常是因为肌肉收缩），Ib传入轴突会被胶原纤维压缩（见插图），且发电率增加。
Figure 35-6B The discharge rate of a population of Golgi tendon organs signals the force in a muscle. Linear regression lines show the relationship between discharge rate and force for Golgi tendon organs of the soleus muscle of the cat.	图 35-6B 一组高尔基腱器官的放电速率显示出肌肉中的力。线性回归线显示了猫的比目鱼肌的高尔基腱器官的放电率和力之间的关系。
Figure 35-7 The reflex actions of lb afferent fibers from Golgi tendon organs.	图35-7 来自Golgi腱器官的Ib传入纤维的反射作用。
The lb inhibitory interneuron receives input from tendon organs, muscle spindles (not shown), joint and cutaneous receptors, and descending pathways.	Ib抑制性中间神经元接收来自肌腱器官、肌梭(未显示)、关节和皮肤受体以及下行通路的输入。
The action of Ib sensory fibers on extensor motor neurons is reversed from inhibition to excitation when walking is initiated. When the animal is resting, stimulation of Ib fibers from the ankle extensor muscle inhibits ankle extensor motor neurons through lb inhibitory interneurons, as shown by the	开始行走时，Ib感觉纤维对伸肌运动神经元的作用由抑制逆转为刺激。动物休息时，踝伸肌中，受到刺激的Ib纤维通过Ib抑制性中间神经元抑制踝伸肌运动神经元，如记录中的超极化所示。在行

hyperpolarization in the record. During walking the lb inhibitory interneurons are inhibited while excitatory interneurons that receive input from lb sensory fibers are facilitated by the command system for walking, thus opening a lb excitatory pathway from the Golgi tendon organs to motor neurons.	走过程中，Ib抑制性中间神经元受到抑制，而接受Ib感觉纤维输入的兴奋性中间神经元则被行走的指挥系统所促进，从而打开了一条从高尔基体肌腱器官到运动神经元的Ib兴奋性通路。
Central Neurons Can Regulate the Strength of Spinal Reflexes at Three Sites in the Reflex Pathway	中枢神经元能在反射通路的三个部位中调节脊髓反射的强度
As noted earlier, the force of a reflex can vary, although the sensory stimulus remains constant. This variability in reflex strength is possible because synaptic transmission in spinal reflex pathways can be modified at three possible sites: alpha motor neurons, interneurons in all reflex circuits except monosynaptic pathways with la afferent fibers, and the presynaptic terminals of the afferent fibers (Figure 35-8A).	如前所述，虽然感官刺激保持不变，但反射的强度是不同的。反射强度发生改变是可能的，因为脊髓反射通路中的突触传递在以下三个位置可能发生改变:阿尔法运动神经元，所有反射回路中的中间神经元（除Ia传入纤维的单突触通路外），以及传入纤维的突触前末梢(图35-8A)。
All three sites receive inputs from neurons in motor centers in the brain stem and cerebral cortex as well as other regions of the spinal cord. Signals from these higher-level neurons regulate the strength of reflexes by changing the background (tonic) level of activity at any	这三个部位都接受来自脑干、大脑皮层和脊髓其他区域的运动中间神经元的输入。来自这些高级神经元的信号通过改变脊髓反射通路中三个部位中任何一个部位

of the three sites in the spinal reflex pathway, For example, an increase in tonic excitatory input to the alpha motor neurons moves the membrane potential of these cells closer to threshold so that even the slightest reflex input will more easily activate the motor neurons (Figure 35-8B).	的背景（紧张）活动水平，来调节反射强度。例如，α运动神经元的紧张性兴奋输入的增加会使这些细胞的膜电位更接近阈值，因此即使是最轻微的反射输入也会更容易激活运动神经元（图35-8B）。
Another mechanism for modulating the strength of reflexes is to change the physiological properties of motor neurons and perhaps interneurons. Activity in descending monoaminergic systems can alter the properties of motor neurons so they either discharge at a much higher rate in response to the same synaptic input or remain active following a brief excitatory input (see Chapter 34).	调节反射强度的另一种机制是改变运动神经元的生理特性，也许还会改变中间神经元。下行单胺能系统的活动可以改变运动神经元的性质，因此它们要么对相同的突触输入做出更高的放电反应，要么在短暂的兴奋性输入后保持活跃（见第34章）。
Reflex strength can be changed quickly to adapt to the requirements of specific tasks. Intracellular recordings suggest that presynaptic inhibition of the la fibers from muscle spindles is particularly important for producing these changes. For example, during locomotion the level of presynaptic inhibition is rhythmically modulated; this action presumably modulates the strength of reflexes during the different phases ofthe gait cycle (see Chapter 36).	反射强度可以迅速改变，以适应特定任务的要求。细胞内记录表明，肌梭的Ia纤维的突触前抑制对产生这些变化尤为重要。例如，在运动过程中，突触前抑制水平是有节奏地调节的；这个动作可能会在步态周期的不同阶段调节反射的强度（见第36章）。

Figure 35-8 The strength of a spinal reflex can be modulated by changes in synaptic transmission in the reflex pathway.	脊髓反射的强度可以通过改变反射通路中的突触传递来调节
A reflex pathway can be modified at three sites: alpha motor neurons (1), interneurons in polysynaptic pathways (2), and afferent axon terminals (3) Transmitter release from the primary afferent fibers is regulated by presynaptic inhibition (see Figure12-16).	在以下三个位点可以改变反射通路:阿尔法运动神经元(1)，多突触通路中的中间神经元(2)， 和传入轴突终末(3)。释放初级传入纤维的递质会受到突触前抑制的调节(见图12-16)
An increase in tonic (background) excitatory input to a motor neuron depolarizes the neuron to a level that enables an otherwise ineffective reflex input(left) to initiate action potentials. The reflex input is represented by a series of excitatory postsynaptic potentials.	增加运动神经元的紧张性(背景)兴奋输入，会使神经元去极化到一个水平，使原本无效的反射输入(左)能够启动动作电位。反射输入由一系列兴奋性突触后电位表示。
Gamma Motor Neurons Adjust the Sensitivity of Muscle Spindles	伽马运动神经元调节肌梭的敏感度
Activity of muscle spindles may be modulated by changing the level of activity in the gamma motor neurons, which innervate the intrafusal muscle fibers of muscle spindles (see Box 35-1). This function of gamma motor neurons, often referred to as the fusimotor system, can be demonstrated by selectively stimulating the alpha and gamma motor neurons under experimental conditions.	通过改变伽马运动神经元的活动水平，可以调节肌梭的活动敏感度，而伽马运动神经元支配能肌梭的灌注肌纤维(见框35-1)。伽马运动神经元的这种功能，通常称为肌梭运动系统，可以通过实验来证明，在实验中选择性地刺激阿尔法和伽马运动神经元。

When only alpha motor neurons are stimulated, the firing of the la fiber from the muscle spindle pauses during contraction of the muscle because the muscle is shortening and therefore unloading (slackening) the spindle. However, if gamma motor neurons are activated at the same time as alpha motor neurons, the pause is eliminated. The contraction of the intrafusal fibers by the gamma motor neurons keeps the spindle under tension, thus maintaining the firing rate of the la fibers within an optimal range for signaling changes in length, whatever the actual length of the muscle (Figure 35-9). This alpha-gamma co-activation thus stabilizes the sensitivity of the muscle spindles and is used in many voluntary movements.	当只刺激阿尔法运动神经元时，肌梭的Ia纤维在肌肉收缩期间停止放电，因为肌肉正在缩短，从而放松(松弛)肌梭。然而，如果同时激活伽马运动神经元与阿尔法运动神经元，就不会停止放电。伽马运动神经元对梭内肌纤维的收缩会使肌梭保持张力，因此无论肌肉的实际长度如何，Ia纤维的放电率都保持在最佳的长度变化范围内(图35-9)。因此，同时激活阿尔法和伽马可以稳定肌梭的敏感度，并用于许多自主运动。
In addition to the axons of gamma motor neurons, axon collaterals of alpha motor neurons sometimes innervate the intrafusal fibers. Axons that innervate both intrafusal and extrafusal muscle fibers are referred toas beta axons. Beta axon collaterals provide the equivalent of alpha-gamma coactivation. Beta innervation in spindles exists in both cats and humans, although it is unquantified for most muscles.	除了伽马运动神经元的轴突外，阿尔法运动神经元的轴突侧支有时也会支配梭内肌纤维。支配梭内和梭外肌纤维的轴突称为贝塔轴突。激活贝塔轴突侧枝相当于同时激活阿尔法和伽马运动神经元。肌梭中的贝塔神经支配功能存在于猫和人身上，尽管大多数肌肉的神经支配还没有量化。

The beta fusimotor system's forced linkage of extrafusal and intrafusal contraction highlights the importance of the independent fusimotor system (the gamma motor neurons). Indeed, in lower vertebrates, such as amphibians, beta efferents are the only source of intrafusal innervation. Mammals have evolved a mechanism that frees muscle spindles from complete dependence on the behavior of their parent muscles. In principle this uncoupling allows greater flexibility in controlling spindle sensitivity for different types of motor tasks.	贝塔肌梭运动系统对梭内和梭外收缩的强制联系突出了独立肌梭运动系统（伽马运动神经元）的重要性。事实上，在低等脊椎动物中，如两栖动物，贝塔传出神经是梭内神经支配的唯一来源。哺乳动物已经进化出一种机制，该机制能让肌梭摆脱其对母体肌肉行为的完全依赖。原则上，这种去耦合机制可以更灵活地控制肌梭灵敏度，从而完成不同类型的运动任务。
This conclusion is supported by recordings in spindle sensory afferents during a variety of natural movements in cats. The amount and type of activity in gamma motor neurons are set at steady levels, which vary according to the specific task or context. In general, activity levels in both static and dynamic gamma motor neurons (see Figure 35-3B) are set at progressively higher levels as the speed and difficulty of the movement increase.	通过记录猫的自然运动过程，肌梭的感觉传入，这一结论得到了支持。伽马运动神经元的活动量和类型设定在稳定的水平，根据具体的任务或环境而变化。一般来说，随着运动速度和难度的增加，静态和动态伽马运动神经元（见图35-3B）的活动水平都会逐渐升高。
Unpredictable conditions, such as when the cat is picked up or handled, lead to marked increases in activity in dynamic gamma motor neurons and thus increased spindle responsiveness when muscles are stretched.	在不可预测的情况下，例如当猫被抱起或被操纵时，会导致动态伽马运动神经元的活跃性明显增加，在肌肉拉伸时，肌梭的反应也会增加。

When an animal is performing a difficult task, such as walking across a narrow beam, both static and dynamic gamma activation are at high levels (Figure 35-10).	当动物执行一项困难的任务时，如走过一条狭窄的横梁上，静态和动态伽马运动神经元的活跃度都十分高（图35-10）。
Thus the nervous system uses the fusimotor system to fine-tune muscle spindles so that the ensemble output of the spindles provides information most appropriate for a task. The task conditions under which independent control of alpha and gamma motor neurons occurs in humans have not yet been clearly established.	因此，神经系统利用肌梭运动系统对肌梭进行微调，使肌梭的集体输出能提供最适合于某项任务的信息。在人类活动中，独立控制阿尔法和伽马运动神经元的任务条件还没有确定。
Figure 35-9 Activation of gamma motor neurons during active muscle contraction maintains muscle spindle sensitivity to muscle length.	图35-9 在活跃的肌肉收缩中，激活的伽马运动神经元保持了肌梭对肌肉长度的敏感度。
Sustained tension elicits steady firing in the la sensory fiber from the muscle spindle (the two muscle fibers are shown separately for illustration only).	持续的张力引起肌梭中的Ia感觉纤维的稳定放电（两条肌纤维单独显示仅用于说明）。
A characteristic pause occurs in the discharge of the la fiber when the alpha motor neuron is stimulated, causing a brief contraction of the muscle. The la fiber stops firing because the spindle is unloaded by the contraction.	阿尔法运动神经元受到刺激时，放电的Ia纤维会出现特征性的停顿，导致肌肉短暂收缩。Ia纤维停止放电是因为肌梭因收缩而卸下负载。
Gamma motor neurons innervate the contractile polar regions of the intrafusal fibers of muscle spindles (see Figure35-3A).	伽马运动神经元支配肌梭内纤维的收缩极区（见图35-3A）。如果伽马运动神经

If a gamma motor neuron is stimulated at the same time as the alpha motor neuron, the spindle is not unloaded during the contraction. As a result, the pause in discharge of the la sensory fiber that occurs when only the alpha motor neuron is stimulated is "filled in" by the response of the fiber to stimulation of the gamma motor neuron.	元与阿尔法运动神经元同时受到刺激，肌梭在收缩期间不会卸下负载。因此，当只有阿尔法运动神经元受到刺激时，受到刺激的伽马运动神经元的纤维反应会〞填补〞暂停放电的Ia感觉纤维。
Figure 35-10 The level of activity in the fusimotor system varies with the type of behavior. Only static gamma motor neurons are active during activities in which muscle length changes slowly and predictably. Dynamic gamma motor neurons are activated during behaviors in which muscle length may change rapidly and unpredictably.	图35-10 肌梭运动系统的活动水平随行为的类型而变化。在肌肉长度变化缓慢且可预测的活动中，只能激活静态伽马运动神经元。在肌肉长度可能快速且不可预测地变化过程中，会激活动态伽马运动神经元。
Proprioceptive Reflexes Play an Important Role in Regulating Both Voluntary and Automatic Movements	本体反射在调节自主和自动运动中发挥着重要作用
All movements activate receptors in muscles, joints, and skin. Sensory signals generated by the body's own movements were termed proprioceptive by Sherrington, who proposed that they control important aspects of normal movements. A good example is the Hering Breuer reflex, which regulates the amplitude of inspiration. Stretch receptors in the lungs are activated during inspiration, and the Hering-Breuer reflex eventually triggers the	所有运动都会激活肌肉、关节和皮肤中的受体。由身体自身运动产生的感觉信号被谢灵顿称为本体感受信号，他提出它们能控制正常运动的重要部分。赫白反射就是一个很好的例子，它可以调节吸气的幅度。吸气时肺部的拉伸感受器激活，当肺部扩张时，赫白反射最终引发

transition from inspiration to expiration when the lungs are expanded.	了从吸气到呼气的过渡。
A similar situation exists in the walking systems of many animals; sensory signals generated near the end of the stance phase initiate the onset of the swing phase (see Chapter 36).	许多动物的行走系统中也存在类似的情况，站立结束时，产生的感觉信号会启动摆动期（见第 36 章）。
Proprioceptive signals can also contribute to the regulation of motor activity during voluntary movements, as has been shown in recent studies of individuals with sensory neuropathy of the arms. These patients display abnormal reaching movements and have difficulty in positioning the limb accurately because the lack of proprioception results in a failure to compensate for the complex inertial properties of the human arm.	近期，根据对手臂感觉神经病患者的研究表明，本体感受信号也有助于调节自主运动期间的运动。这些患者表现出异常的伸展运动，并且难以确定肢体的位置，因为缺乏本体感觉，导致无法弥补人体手臂的复杂惯性。
Therefore, a primary function of proprioceptive reflexes in regulating voluntary movements is to adjust the motor output according to the changing biomechanical state of the body and limbs. This adjustment ensures a coordinated pattern of motor activity during an evolving movement and compensates for the intrinsic variability of motor output.	因此，本体感觉反射在调节自主运动中的主要功能是根据身体和四肢不断变化的生物力学状态，来调节运动输出。这种调整确保了在不断发展的运动中，运动活动的协调模式，并弥补了运动输出的内在可变性
Reflexes Involving Limb Muscles Are Mediated Through Spinal and Supraspinal Pathways	涉及肢体肌肉的反射是通过脊髓和脊髓上通路传导的

Reflexes involving the limbs are mediated by multiple pathways acting in parallel through spinal and supraspinal pathways, Consider the response evoked by a sudden stretch of a flexor muscle of the thumb. This response has two discrete components. The first, the Ml response, is generated by the monosynaptic connection of muscle spindle afferents to the spinal motor neurons. The second, the M2 response, is also are flex because its latency is shorter than the voluntary reaction time (Figure 35-11A).	涉及四肢的反射是由多条通路通过脊髓和脊髓上通路的平行作用传导的。想象一下拇指屈肌突然拉伸引起的反应。该反应有两个独立的成分。第一，M1反应，是由肌梭传入纤维与脊髓运动神经元的单突触连接产生。第二种，M2反应，也是一种反射，因为它的潜伏期比自主反应时间短（图35-11A）。
The M2 response has been observed in virtually all limb muscles. In the distal muscles the M2 responses are mediated by pathways that include the motor cortex, as shown in studies of patients with Klippel-Feilsyndrome. In this unusual condition axons descending from neurons in the motor cortex bifurcate and make connections to homologous motor neurons on both sides of the body.	M2反应几乎在所有的肢体肌肉中都能观察到。如对克利佩尔-费尔综合征患者的研究所示，在远端肌肉中，M2反应由包括运动皮层在内的通路传导。在这种不寻常的情况下，从运动皮层的神经元下来的轴突会分叉，并与身体两侧的同源运动神经元建立联系。
Thus, when the individual voluntarily moves the fingers of one hand, these movements are mirrored by movements of the fingers of the other (Figure 35-11B). Similarly, when the M2 component is evoked by stretching muscles of one hand, a response with the same latency is evoked in the corresponding	因此，当一个人自主地移动一只手的手指时，这些运动会通过另一只手指的运动反映出来（图35-11B）。同样，当通过拉伸一只手的肌肉来诱发 M2 成分时，即使另一只手没有发生 M1反应，也会

muscle of the other hand, even though no M1 response has occurred in the other hand. The reflex pathway responsible for the M2 response must there-fore traverse the motor cortex (Figure 35-11B).	在另一只手的相应肌肉中诱发具有相同潜伏期的反应。因此，负责 M2 反应的反射通路必须穿过运动皮层（图35-11B）。
Figure 35-11 Reflexes of the limbs are mediated by spinal reflex pathways and long-loop pathways that involve the motor cortex.	图35-11 四肢的反射是由脊髓反射通路和涉及运动皮层的长环通路传导的。
In normal individuals a brief stretch of a thumb muscle produces a response that has two components. A short-latency response (M1) in the stretched muscle is controlled by the spinal reflex pathway, the monosynaptic connection between muscle spindle afferents and spinal motor neurons. This is followed by a long-latency response (M2) controlled by a pathway that loops through the motor cortex.	在正常人中，拇指肌肉的短暂拉伸产生的反应有两个部分。拉伸的肌肉中的短潜伏期反应（M1）由脊髓反射通路控制，该通路是肌梭传入纤维和脊髓运动神经元之间的单突触连接。随后是由循环通过运动皮层的通路控制的长潜伏期反应 (M2)。
In individuals with Klippel-Feil syndrome the M2 response is evoked bilaterally because neurons in the motor cortex activate motor neurons bilaterally.	在患有克利佩尔-费尔综合征的个体中，M2反应是双侧诱发的，因为运动皮层中的神经元会激活双侧运动神经元。
Reflex responses mediated through the motor cortex and other supraspinal structures, the long-loop reflexes, have been investigated in numerous muscles in humans and other animals. The general conclusion is that long loop reflexes via the cortex are of primary	通过运动皮层和其他脊髓上结构传导的反射反应，即长环反射，已经在人类和其他动物的许多肌肉中进行了研究。结论是，通过大脑皮层的长环反射对调节收缩的远

importance in regulating contractions in distal muscles, whereas subcortical reflex pathways are largely responsible for regulating the contractions of proximal muscles.	端肌肉具有重要意义，而皮层下反射通路主要负责调节收缩的近端肌肉。
This type of organization is related to functional demands, any tasks involving distal muscles require precise regulation by voluntary commands. By trans-mitting sensory signals to regions of cortex most involved in controlling voluntary movements, motor commands can be quickly adapted to the evolving needs of a task. More automatic motor functions, such as maintaining balance and producing gross bodily movements, can be efficiently executed largely through subcortical and spinal pathways.	这种结构与功能需求有关。许多涉及远端肌肉的任务需要通过自主指令进行精确调节。通过将感觉信号传递到与控制自主运动有关的皮层区域，运动指令可以迅速适应任务的不断发展的需求。更多的自动运动功能，例如保持平衡和产生全身运动，可以通过皮层下和脊髓通路有效地执行。
Pioneering studies by Edward Evarts in the 1960srevealed that activity in approximately 50% of neurons in the motor cortex is modified in response to loading muscles during the voluntary maintenance of wrist position and during simple movements at the wrist. This early finding was initially interpreted as evidence that long-loop cortical reflexes are involved in compensating for change in loading conditions by functioning as online negative feedback controllers.	爱德华·埃瓦茨(Edward Evarts)在20世纪60年代进行的开创性研究表明，运动皮层中大约50%的神经元的活动在自主保持手腕位置和进行手腕简单运动时，会对肌肉负荷做出反应。人们最初认为，这一发现是证明长环皮层反射通过充当在线负反馈控制器，来补偿负载条件变化的证据。
However, subsequent studies on multi joint movements revealed complex response	然而，随后对多关节运动的研究发现，皮层神经元的反

patterns in cortical neurons, many of which are not consistent with this concept. Moreover, the long delays in transmission in long-loop reflexes make these reflexes inappropriate for a direct role in load compensation because the potential delays would create instabilities.	应模式很复杂，其中许多模式与这个概念不一致。此外，长回路反射中传输的长延迟使得这些反射不适合直接在负载补偿中发挥作用，因为潜在的延迟会产生不稳定性。
Currently the function of proprioceptive input to the motor cortex in the volitional control of movement remains a puzzle. One contemporary notion is that proprioceptive input is integrated into internal models for estimating the state of the system (see Chapter 33).	目前，运动皮层的本体感受输入在运动的意志控制中的功能仍然是一个谜。当前一个概念认为应将本体感觉输入整合到内部模型中，用于评估系统的状态（见第33章）。
Another hypothesis is that proprioceptive inputs play a key role in motor cortical circuits that function as optimal feedback controllers, which use only those sensory signals that are required for attaining a specific goal.	另一种假设是，本体感受输入在运动皮层回路中起着关键作用。运动皮层回路作为最佳反馈控制器，只使用那些特定目标所需的感觉信号。
Stretch Reflexes Reinforce Central Commands for Movements	牵张反射会强化运动的中央指令
Stretch-reflex pathways can contribute to regulation of motor neurons during voluntary movements and maintenance of posture because they form closed feedback loops.	牵张反射通路在自主运动和保持姿势期间能调节运动神经元，因为它们能形成闭合反馈回路
For example, stretching a muscle increases activity in spindle sensory afferents, leading to muscle contraction and consequent	例如，拉伸肌肉会增加肌梭感觉传入的活动，导致肌肉收缩，从而使肌肉缩短。肌

shortening of the muscle. Muscle shortening in turn leads to decreased activity in spindle afferents, reduction of muscle contraction, and lengthening of the muscle.	肉缩短反而会导致肌梭传入神经活动减少、肌肉收缩减少、肌肉延长。
The stretch reflex loop thus acts continuously --the output of the system, a change in muscle length, becomes the input--tending to keep the muscle close to a desired or reference length. The stretch reflex is a negative feedback system, or servomechanism, because it tends to counteract or reduce deviations from the reference value of the regulated variable.	因此，牵张反射环路会持续发挥作用，即让系统的输出（肌肉长度的变化）成为输入，使肌肉接近所需长度或参考长度。牵张反射是一种负反馈系统或伺服系统，因为它倾向于抵消或减少与调节变量参考值的偏差。
In 1963 Ragnar Granit proposed that the reference value in voluntary movements is set by descending signals that act on both alpha and gamma motor neurons. The rate of firing of alpha motor neurons is set to produce the desired shortening of the muscle, and the rate of firing of gamma motor neurons is set to produce an equivalent shortening of the intrafusal fibers of the muscle spindle.	1963 年，拉格纳•格拉尼特（Ragnar Granit）提出，自主运动的参考值由作用于阿尔法和伽马运动神经元的下降信号设定。阿尔法运动神经元的放电频率设定为产生所需的肌肉缩短量，伽马运动神经元的放电频率设定为产生等量的肌梭梭内纤维缩短量。
If the shortening of the whole muscle is less than that required by a task, as when the load is greater than anticipated, the sensory fibers increase their firing rate because the contracting intrafusal fibers are stretched (loaded) by the relatively greater length of the	如果整个肌肉的缩短小于任务所需，例如当负荷大于预期时，感觉纤维会增加它们的发电率，因为收缩的梭内纤维被相对较长的整个肌肉拉长（负荷）。如果缩短的

whole muscle. If shortening is greater than necessary, the sensory fibers decrease their firing rate because the intrafusal fibers are relatively slackened(unloaded) (Figure 35-12A).	时间大于必要的时间，感觉纤维就会降低其发电率，因为梭内纤维相对松弛（无负荷）（图35-12A）。
In theory this mechanism could permit the nervous system to produce a movement of a given distance without having to know in advance the actual load or weight being moved. In practice, however, the stretch-reflex pathways do not have sufficient control over motor neurons to overcome large unexpected loads. This is immediately obvious if we consider what hap-pens when we attempt to lift a heavy suitcase that we believe to be empty.	在理论上，这种机制允许神经系统产生一定距离的运动，而不必事先知道被移动的实际负荷或重量。然而，在实践中，牵张反射通路对运动神经元没有足够的控制力来克服巨大的意外负荷。思考一下，当我们试图提起一个我们认为是空的，但实际上很重的手提箱时会发生什么，这一点立即显而易见。
Automatic compensation for the greater-than-anticipated load does not occur. Instead, we have to pause briefly to plan a new movement with much greater muscle activation. Thus, rather than providing compensation for large unexpected loads, monosynaptic and long-loop stretch reflex pathways may compensate for small changes in load and intrinsic irregularities in the muscle contraction, with the relative contribution of each pathway dependent on the muscle and the task.	对大于预期负荷的自动补偿并不会发生。相反，我们必须短暂停顿，以计划一个新的动作，激发出肌肉更大的力量。因此，单突触和长环牵张反射通路可以补偿负荷的微小变化和肌肉收缩的内在不规则性，而不会为大的意外负荷提供补偿，每条通路的相对分布取决于肌肉和任务。
Strong evidence that alpha and gamma motor	强有力的证据表明，在人类

neurons are coactivated during voluntary human movement has come from direct measurements of the activity of muscle spindles. In the late 1960s Ãke Vallbo and Karl-Erik Hagbarth developed micro neurography, a technique for recording from the largest afferent fibers in peripheral nerves.	自主运动过程中，阿尔法和伽马运动神经元是同时激活的，该证据来源于对肌梭活动的直接测量。20世纪60年代末，埃克·沃伯（Ake Vallbo）和卡尔·埃里克·哈巴特（Karl-Erik Hagbarth）开发了微神经电图，这是一种记录周围最大传入纤维的技术。
Vallbo later showed that during slow movements of the fingers the large-diameter la fibers from spindles in the contracting muscles increase their rate of firing even when the muscle shortens as it contracts (Figure 35-12B). This occurs because the gamma motor neurons, which have direct excitatory connections with spindles, are co-activated with alpha motor neurons.	沃伯后来表明，在手指缓慢运动期间，即使肌肉缩短，收缩肌肉中肌梭的大直径Ia纤维会增加肌肉的放电率（图 3S-12B）。这是因为同时激活了与肌梭有直接兴奋联系的伽马运动神经元与阿尔法运动神经元。
Furthermore, when subjects attempt to make slow movements at a constant velocity, the firing of the la fibers mirrors small deviations in velocity in the trajectory of the movements (sometimes the muscle shortens quickly and other times more slowly).	此外，当受试者试图以恒定的速度做慢速运动时，发电的Ia纤维反映了运动轨迹中速度的微小偏差（有时肌肉短促，有时则更慢）。
When the velocity of flexion increases transiently, the rate of firing in the fibers decreases because the muscle is shortening more rapidly and therefore exerts less tension	当屈曲速度瞬时增加时，纤维中的发电率降低，因为肌肉缩短得更快，因此对梭内纤维施加的张力较小。当速

on the intrafusal fibers. When the velocity decreases, firing increases because the muscle is shortening more slowly, and therefore the relative tension on the intrafusal fibers increases. This information can be used by the nervous system to compensate for irregularities in the movement trajectory by exciting the alpha motor neurons.	度降低时，发电率增加，因为肌肉缩短得更慢，因此梭内纤维上的相对张力增加。利用这些信息，神经系统可以通过刺激阿尔法运动神经元来补偿运动轨迹的不规则性。
Figure 35-12 Alpha and gamma motor neurons are co-activated during voluntary movements.	图35-12 阿尔法和伽马运动神经元在自主运动中同时激活。
A. Alpha-gamma co-activation reinforces alpha motor activity	同时激活阿尔法-伽马运动神经元会加强阿尔法运动活动
Spindle activity increases during muscle shortening	肌肉缩短时肌梭活动增加
Co-activation of alpha and gamma motor neurons by a cortical motor command allows feedback from muscle spindles to reinforce activation in the alpha motor neurons. Because any disturbance during a movement alters the length of the muscle and changes the activity in the muscle spindles, altering the spindle input to the alpha motor neuron compensates for the disturbance.	皮质运动指令同时激活阿尔法和伽马运动神经元，使肌肉主轴的反馈加强了阿尔法运动神经元的激活。因为在运动过程中的任何干扰都会改变肌肉的长度，并改变肌梭的活动，改变肌梭对阿尔法运动神经元的输入可以补偿干扰。
The discharge rate in the la sensory fiber of a spindle increases during slow flexion of a finger. This increase depends on	在手指缓慢弯曲时，肌梭的Ia感觉纤维的放电率增加。这种增加取决于被同时激活

alpha-gamma co-activation. If the gamma motor neurons were not active, the spindle would slacken, and its discharge rate would decrease as the muscle shortened (see Figure 35-9C).	的阿尔法和伽马运动神经元。如果伽马运动神经元不活跃，肌梭就会松弛，其放电率会随着肌肉缩短而降低（见图35-9C）。
Damage to the Central Nervous System Produces Characteristic Alterations in Reflex Response and Muscle Tone	中枢神经系统的损伤会改变反射反应和肌肉张力的特征性
Stretch reflexes can be evoked in many muscles throughout the body and are routinely used in clinical examinations of patients with neurological disorders. They are typically elicited by sharply tapping the tendon of a muscle with a reflex hammer.	许多肌肉都能引起牵张反射，并且经常用于神经系统疾病患者的临床检查。它们通常是通过用反射锤尖锐地敲击肌肉的肌腱而引起的。
Although the responses are often called tendon reflexes or tendon jerks, the receptor that is stimulated, the muscle spindle, actually lies in the muscle rather than the tendon. Only the primary sensory fibers in the spindle participate in the tendon reflex, for these are selectively activated by a rapid stretch of the muscle produced by the tendon tap. An electrical analog of the tendon jerk is the Hoffmann reflex (Box 35-4).	虽然这种反应通常称为肌腱反射或肌腱抽搐，但受到刺激的受体，即肌梭，实际上位于肌肉而不是肌腱中。只有肌梭中的初级感觉纤维参与肌腱反射，因为这些纤维是通过肌腱端产生的肌肉快速牵拉而被选择性激活的。腱肌反射的电学模拟是霍夫曼反射(框35 – 4)。
Measuring alterations in the strength of the stretch reflex can assist in the diagnosis of certain conditions and in localizing injury or disease in the central nervous system. Absent	测量牵张反射强度的变化可以帮助诊断某些情况，并对中枢神经系统的损伤或疾病进行定位。牵张反射缺失或

or hypoactive stretch reflexes often indicate a disorder of one or more of the components of the peripheral reflex pathway: sensory or motor axons, the cell bodies of motor neurons, or the muscle itself.	活动减退通常表明外周反射通路的一种或多种成分存在障碍，比如，感觉或运动轴突、运动神经元的细胞体或肌肉本身。
Nevertheless, because the excitability of motor neurons is dependent on descending excitatory and inhibitory signals, absent or hypoactive stretch reflexes can also result from lesions of the central nervous system. Hyperactive stretch reflexes, conversely, always indicate that the lesion is in the central nervous system.	然而，由于运动神经元的兴奋性取决于下行通路的兴奋性和抑制性信号，中枢神经系统的病变也会导致牵张反射的缺失或减退。而过度活跃的牵张反射则表明中枢神经系统有病变。
Box 35-4 The Hoffmann Reflex	框35-4 霍夫曼反射
The characteristics of the monosynaptic connections from la sensory fibers to spinal motor neurons in humans can be studied using an important technique introduced in the 1950s and based on early work by Paul Hoffmann. This technique involves electrically stimulating the la fibers in a peripheral nerve and recording the reflex response in the homonymous muscle. The response is known as the Hoffmann reflex, or H-reflex (Figure 35-13A).	人类从Ia感觉纤维到脊髓运动神经元的单突触连接的特征，可以通过一项在20世纪50年代引入的重要技术来研究，这项技术是基于保罗•霍夫曼（Paul Hoffmann）的早期研究。这种技术是用电刺激周围神经中的Ia纤维，并记录同侧肌肉的反射反应。这种反应被称为霍夫曼反射，或H反射（图35-13A）。
The H-reflex is readily measured in the soleus muscle, an ankle extensor, The la fibers from the soleus and its synergists are excited by an electrode placed above the tibial nerve behind	H反射很容易在比目鱼肌中测出，比目鱼肌是一种踝关节伸展肌。来自比目鱼肌的Ia纤维及协同者由膝盖后面

the knee. The response recorded from the soleus muscle depends on stimulus strength. At low stimulus strengths a pure H-reflex is evoked, for the threshold for activation of the la fibers is lower than the threshold for motor axons. Increasing the stimulus strength excites the motor axons innervating the soleus producing two successive responses.	胫骨神经上方的电极激发。比目鱼肌记录的反应取决于刺激强度。在低强度的刺激下，会诱发纯粹的H反射，因为Ia纤维激活的阈值低于运动轴突的阈值。增加刺激强度，刺激支配比目鱼肌的运动轴突，能产生两个连续的反应。
The first results from direct activation of the motor axons, and the second is the H-reflex evoked by stimulation of the la fibers (Figure 35-13B). These two com-ponents of the evoked electromyogram are called the M-wave and H-wave. The H-wave occurs later because it results from signals that travel to the spinal cord, across a synapse, and back again to the muscle. The M-wave. In contrast, results from direct stimulation of the motor axon innervating the muscle.	第一种是直接激活运动轴突，第二种是Ia纤维刺激诱发的H反射（图35-13B）。诱发肌电图的这两个组成部分被称为M波和H波。H波出现的时间较晚，因为它是由传递到脊髓、穿过突触并再次返回肌肉的信号产生的。而M波是由支配肌肉的运动轴突的直接刺激引起的。
As the stimulus strength is increased still further, the M-wave continues to become larger and the H-wave progressively declines (Figure 35-13C). The decline in the H-wave amplitude occurs because action potentials in the motor axons propagate toward the cell body (antidromic conduction) and cancel reflexively evoked action potentials in the same motor axons. At very high stimulus	随着刺激强度的进一步增加，M波继续变大，H波逐渐变小（图35-13C）。H波振幅下降是因为运动轴突中的动作电位向细胞体传播（逆向传导），并抵消同一运动轴突中反射诱发的动作电位。在非常高的刺激强度下，只有M波持续存在。

strengths only the M-wave persists.	
An interesting feature of the H-reflex is that its magnitude depends on motor experience. For example, it is low in highly trained ballet dancers and varies among different kinds of athletes. This strongly suggests that modification of spinal reflexes is an important process in learning motor skills.	H反射有一个有趣的特点，它的大小取决于运动经验。例如，高强度训练的芭蕾舞者中，H反射很小，不同种类的运动员之间也有差异。这有力地表明，脊髓反射的变化是学习运动技能的一个重要过程。
Extensive studies of humans, monkeys, and rats by Jonathan Wolpaw and his colleagues have demonstrated that H-reflexes can be operantly conditioned to either increase or decrease. The mechanisms underlying these changes are complex and involve alterations at multiple sites including changes in motor neuron properties. For down-conditioning they are dependent on corticospinal signals.	乔纳森·沃尔帕（Jonathan Wolpaw）和他的同事对人类、猴子和老鼠进行的广泛研究表明，通过操作可以增加或减少H反射。这些变化背后的机制十分复杂，涉及多个部位的改变，包括运动神经元特性的改变。对于下行调节，它们依赖于皮质脊髓信号。
Figure 35-13 The Hoffmann reflex	图35-13霍夫曼反射
The Hoffmann reflex (H-reflex) is evoked by electrically stimulating la sensory fibers from muscle spindles inmixed nerves. The sensory fibers excite alpha motor neurons, which in turn activate the muscle. Muscle activation is detected by the electromyogram (EMG).	霍夫曼反射（H反射）是通过电刺激混合神经中肌梭的Ia感觉纤维而诱发的。感觉纤维激活阿尔法运动神经元，它又反过来激活肌肉。肌肉的激活是由肌电图（EMG）检测出来的。
At intermediate stimulus strengths motor axons in the mixed nerve are excited in addition to the spindle afferents. Excitation of	在中等刺激强度下，除肌梭外，混合神经中的运动轴突也受到刺激。在肌电图中，

the motor neurons produces an M-wave that precedes the H-wave (H-reflex) in the EMG.	运动神经元的兴奋产生一个M波，该波先于H波。
At low stimulus strengths only an H-wave is produced because only the spindle afferents are excited. As the stimulus strength increases, the magnitude of the H-reflex also increases, then declines, because the orthodromic motor signals generated reflexively by the spindle afferents are cancelled by antidromic signals initiated by the electrical stimulus in the same motor axons. At very high stimulus strengths only an M-wave is evoked.	在低刺激强度下，只有H波产生，因为只有肌梭传入纤维受到刺激。随着刺激强度的增加，H反射的幅度也会增加，然后下降，因为由肌梭条件反射地产生的顺向传导的运动信号，被同一运动轴突中由电刺激引发的反向传导运动信号所抵消。在很高的刺激强度下，只能诱发M波。
Interruption of Descending Pathways to the Spinal Cord Frequently Produces Spasticity	中断的脊髓下行通路经常产生痉挛现象
Muscle tone, the force with which a muscle resists being lengthened, depends on the muscle's intrinsic elasticity, or stiffness. Because a muscle has elastic elements in series and parallel that resist lengthening, it behaves like a spring. However, there is also a neural contribution to muscle tone; the feedback loop inherent in the stretch reflex pathway acts to resist lengthening of the muscle. The local neural circuits responsible for stretch reflexes provide the brain with a mechanism for adjusting muscle tone to suit different circumstances.	肌肉张力，即肌肉抵抗拉伸的力量，取决于肌肉的固有弹性或硬度。因为肌肉有串联和并联的弹性元件，可以抵制拉长，所以它的行为就像一个弹簧。然而，肌肉张力也与神经有关；牵张反射通路固有的反馈回路能起到抵抗肌肉延长的作用。负责牵张反射的局部神经回路为大脑提供了一种调节肌肉张力的机制, 以适应不同情况。
Because the strength of stretch reflexes is	由于牵张反射的强度是由大

control-led by higher brain centers, disorders of muscle tone are frequently associated with lesions of the motor system, especially those that interfere with descending motor pathways. These conditions may involve either an abnormal increase in tone (hypertonus) or a decrease(hypotonus).	脑高级中心控制的，所以紊乱的肌张力经常与运动系统的损伤有关，特别是那些干扰下行运动通路的损伤。这些情况可能包括张力异常升高（高张力）或降低（低张力）。
The most common form of hypertonus is spasticity, which is characterized by hyperactive tendon jerks and an increase in resistance to rapid stretching of the muscle. A slowly applied stretch in a patient with spasticity elicits little resistance; as the speed of the stretch is increased, resistance to the stretch also rises progressively.	肌张力过高最常见的形式是痉挛，其特点是肌腱抽搐过度，对肌肉快速拉伸的阻力增加。患有痉挛的病人缓慢地进行拉伸，引起的阻力很小；随着拉伸速度的增加，对拉伸的阻力也逐渐上升。
Thus spasticity is primarily a phasic phenomenon. An active reflex contraction occurs only during a rapid stretch; when the muscle is held in a lengthened position the reflex contraction subsides. In some patients, however, the hypertonus also has a tonic component; that is, the reflex contraction continues even after the muscle is no longer being lengthened.	因此，痉挛主要是一种阶段性的现象。只有在快速拉伸时才会发生主动的反射性收缩；当肌肉长度保持在一个的位置时，反射性收缩就会消退。然而，在一些患者中，张力过强也有紧张成分；也就是说，即使肌肉不再延长，反射收缩仍在继续。
The pathophysiology of spasticity is still unclear. It was long thought that hyperactivity of stretch reflexes in spasticity resulted from overactivity of the gamma motor neurons. Recent experiments have cast doubt on this	痉挛的病理机制尚不清楚。长期以来，人们认为痉挛的牵张反射的过度活跃是由伽马运动神经元的过度活跃所致。最近的实验对这一解释

explanation. Although gamma motor neurons may be overactive in some cases, changes in the background activity of alpha motor neurons and interneurons are probably more important. Especially important may be modifications in the properties of motor neurons that enable sustained firing in response to brief excitatory input (see Chapter 34).	提出了质疑。虽然在某些情况下，伽马运动神经元可能过度活跃，但阿尔法运动神经元和中间神经元活动的变化可能更重要。运动神经元特性的变化可能特别重要，这些神经元能够对短暂的兴奋性输入做出持续的放电反应(见第34章)。
Whatever the precise mechanism that produce spasticity, the effect is a strong facilitation of synaptic transmission in the la sensory fibers in the monosynaptic reflex pathway. Indeed, this can provide a mechanism for treatment. A common therapeutic procedure today is to mimic presynaptic inhibition in the terminals of the la fibers by intrathecally administering the drug baclofen to the spinal cord.	无论产生痉挛的确切机制是什么，其作用都是在单突触反射通路中强烈促进感觉纤维的突触传递。事实上，这可以为治疗提供一种机制。目前一种常见的治疗方法，是通过在鞘内注射巴氯芬到脊髓来模拟Ia纤维末梢的突触前抑制。
Baclofen is an agonist of GABA: (y-aminobutyric acid) receptors; binding of the drug to these receptors decreases the influx of Ca2+ into presynaptic terminals, reducing transmitter release.	巴氯芬是GABAB（伽马-氨基丁酸）受体的刺激剂；该药与这些受体结合后，会减少Ca^{2+}流入突触前终端，减少递质释放。
Transection of the Spinal Cord in Humans Leads to a Period of Spinal Shock Followed by Hyperreflexia	人类脊髓横断导致脊髓进入休克期，随后出现反射亢进现象
Damage to the spinal cord can cause large changes in the strength of spinal reflexes.	脊髓的损伤会导致脊髓反射强度产生巨大变化。每年约

Each year approximately 11,000 Americans sustain spinal cord injuries. More than half of these injuries produce permanent disability, including impairment of motor and sensory functions and loss of voluntary bowel and bladder control. Approximately 250,000 people in the United States today have some permanent disability from spinal cord injury.	有11,000名美国人会遭受脊髓损伤。这些损伤中有一半以上会产生永久性残疾，包括运动和感觉功能的损害，以及丧失对肠道和膀胱的自主控制。如今，美国约有25万人因脊髓损伤而出现永久性残疾。
When the spinal cord is completely transected, there is usually a period immediately after the injury when all spinal reflexes below the level of the transection are reduced or completely suppressed. This condition is known as spinal shock. During the course of weeks and months spinal reflexes gradually return, often greatly exaggerated. For example, a light touch to the skin of the foot may elicit strong flexion withdrawal of the leg.	当脊髓完全横断，通常在受伤后的一段时间内，横断水平以下的所有脊髓反射都会减少或完全被抑制。这种情况被称为脊髓休克。在几周和几个月的修复过程中，脊髓反射逐渐恢复，过程通常非常夸张。例如，轻轻触摸对脚部皮肤可能会引起腿部强烈的屈曲反射。
The mechanisms underlying spinal shock and recovery are poorly understood. The initial shock is thought to result from the sudden withdrawal of tonic facilitatory influence from the brain. Several mechanisms may contribute to the recovery, including sprouting of afferent sensory terminals and denervation super sensitivity owing to increased numbers of postsynaptic receptors.	脊髓休克和恢复的机制还不甚明了。最初的休克被认为是由于大脑的紧张性促进作用突然消失。有几种机制可能有助于恢复，其中包括传入感觉终端的萌发和由于突触后受体数量减少而导致的去神经超敏性。
Interestingly, the period of recovery from	有趣的是，动物脊髓休克恢

spinal shock is much shorter in animals than in humans. In nonhuman primates the recovery period is rarely more than a week; in cats and dogs it is only a few hours. The longer recovery period for humans presumably reflects the greater influence of supraspinal centers on spinal reflex circuits.	复的时间比人类短得多。在非人类的灵长类动物中，恢复期很少超过一小时；在猫和狗中，恢复期只有几小时。人类的恢复期越长，可能反映了脊髓上中枢对脊髓反射回路的影响越大。
This may in turn reflect the increased complexity of upright bipedal locomotion. Indeed, as we shall see in the next chapter, in humans with spinal cord injury the recovery of automatic locomotor patterns is slight compared with that of quadrupedal mammals.	这可能反映了直立双足运动的复杂性。事实上，我们将在下一章看到，与四足哺乳动物相比，人类脊髓损伤后的自动运动模式的恢复得很慢。
An Overall View	总结
Reflexes are coordinated, involuntary motor responses initiated by a stimulus applied to peripheral receptors. Some reflexes initiate movements to avoid potentially hazardous situations, whereas others automatically adapt motor patterns to achieve or maintain a behavioral goal.	反射是由施加在周围受体上的刺激引起的协调，且非自愿的运动反应。一些反射发起运动以避免潜在的危险情况，而另一些反射则自动调整运动模式，以实现或保持行为目标。
The actual response evoked by a reflex depends on mechanisms that set the strength and pattern of responses according to the task and the behavioral state, or functional set. We know little about the details of these mechanisms, except that modification of synaptic transmission in spinal reflex pathways by descending signals from the	由反射引起的实际反应取决于反应强度和反应模式的机制，而该机制是根据任务和行为状态或功能设定的。除了认为来自大脑的下行信号对改变脊髓反射通路的突触传递，是一个重要因素以外，我们对这些机制的细节知之

brain is thought to be an important factor.	甚少。
Many groups of interneurons in spinal reflex pathways are also involved in producing complex movements such as walking and transmitting voluntary commands from the brain. In addition, some components of reflex responses, particularly those involving the limbs, are mediated by supraspinal centers, such as brain stem nuclei, the cerebellum, and the motor cortex.	脊髓反射通路中的许多中间神经元群也参与了复杂的运动，如行走和传递来自大脑的自主命令。此外，一些反射反应的组成部分，特别是涉及肢体的反射，是由脊上中枢传导的，如脑干细胞核、小脑和运动皮层。
Reflexes can be smoothly integrated into centrally generated motor commands because of the convergence of sensory signals onto spinal and supraspinal interneuronal systems involved in initiating movements. Establishing the details of these integrative events is one of the major challenges of contemporary research on reflex regulation of movement.	由于感觉信号汇聚到参与发起运动的脊髓和脊髓上神经元间的系统，反射可以顺利地整合到中央产生的运动命令中。确立这些整合事件的细节是当代运动反射性调节研究的主要挑战之一。
Because of the role of supraspinal centers in spinal reflex pathways, injury to or disease of the central nervous system often results in significant alterations in the strength of spinal reflexes. The pattern of changes provides an important aid to diagnosis of patients with neurological disorders.	由于脊髓上中枢在脊髓反射通路中的作用，中枢神经系统的损伤或疾病常常导致脊髓反射的强度发生明显的变化。变化的模式在诊断神经系统疾病的病人时起到了重要的作用。

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