Introduction

"*Bian Zhuang Lun Zhi*" (Differentiating Appearance to Determine Quality): The essence of experience-based Chinese medicinal identification

Authentication is fundamental for the standardization and globalization of Chinese medicinal materials. Macroscopic identification is an essential foundation for practitioners dedicated to authentication and herbal pharmacy, and represents a simple and convenient method that relies on using the naked senses to identify authenticity and quality. In macroscopic identification, the external features of medicinal materials are assessed by looking, smelling, touching and tasting, complemented by techniques known as fire and water testing. As these methods are based on experience accumulated by practitioners over the course of history, macroscopic identification is also known as "experience-based" differentiation.

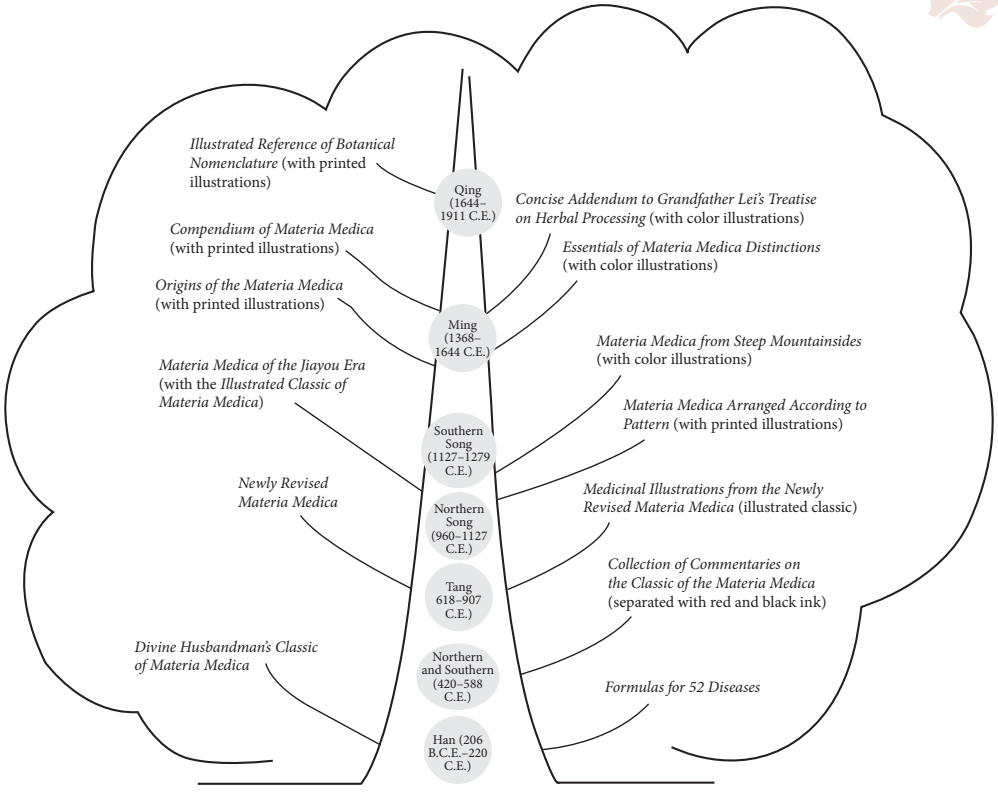
Historical Literature on Medicinal Materials

According to ancient Chinese tradition, the mythological founder of Chinese herbal medicine, *Shen Nong* (the "Divine Husbandman"), was said to have "tried the hundred herbs by tasting them, encountering 70 toxicities within a day." This description of *Shen Nong* was recorded in the early Western Han Dynasty in the ancient text *The Philosophers of Huainan* (*Huai Nan Zi*, ca. 200 B.C.E.), and it reflects the importance of directly assessing medicinals based on organoleptic features such as taste and the mouth's associated sensory response. Valuable experiences accumulated through ancient human trial and error have been passed down from generation to generation in a rich oral and literary history, and the myth of *Shen Nong* honors the countless unknown individuals that dedicated their lives to discovering the effects of the botanicals around them.

The broad genre of Chinese materia medica texts is often referred to as "*ben cao*" literature. This term, which literally means "rooted in herbs," reflects the fact that most Chinese medicinal materials are derived from botanical sources. Materia medica (*ben cao*) literature primarily consists of records related to three different categories: the medicinal material itself, its medicinal effects, and its medicinal nature.

Shen Nong, the "Divine Husbandman"

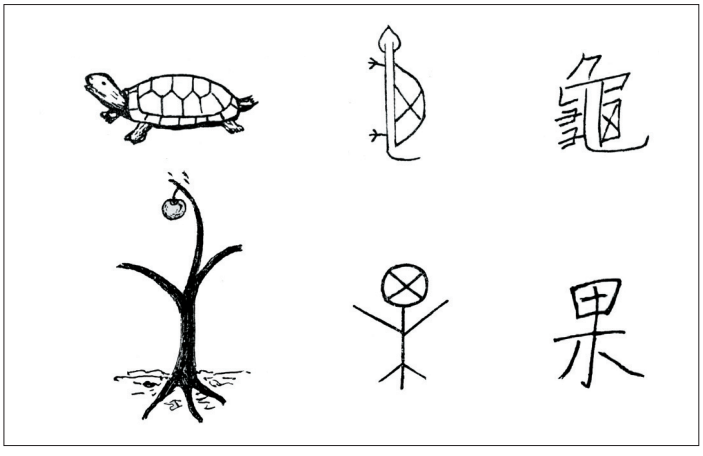
In discussions about the medicinal material itself, *ben cao* literature primarily emphasizes topics such as nomenclature, appearance, production regions, harvesting and post-harvest handling, and medicinal processing (*pao zhi*). Discussions on medicinal effects primarily discuss the therapeutic effects of a medicinal on the body, while discussions of its medicinal nature primarily focus on the theoretical explanation behind these effects, such as nature and flavor, entering channels, and its ascending, descending, floating or sinking nature.



Key historical materia medica texts dedicated to medicinal differentiation

Early Records

The use of medicinal substances in China has been documented for over 3000 years, dating back to China's earliest written records. The Chinese written language evolved gradually from pictographic representations of objects into characters, and the precise line between ancient writing and ancient drawing is shrouded by the mystery of time. For example, it is clear that the modern written characters for "turtle" and "fruit" evolved gradually from pictographic representations, as illustrated below.

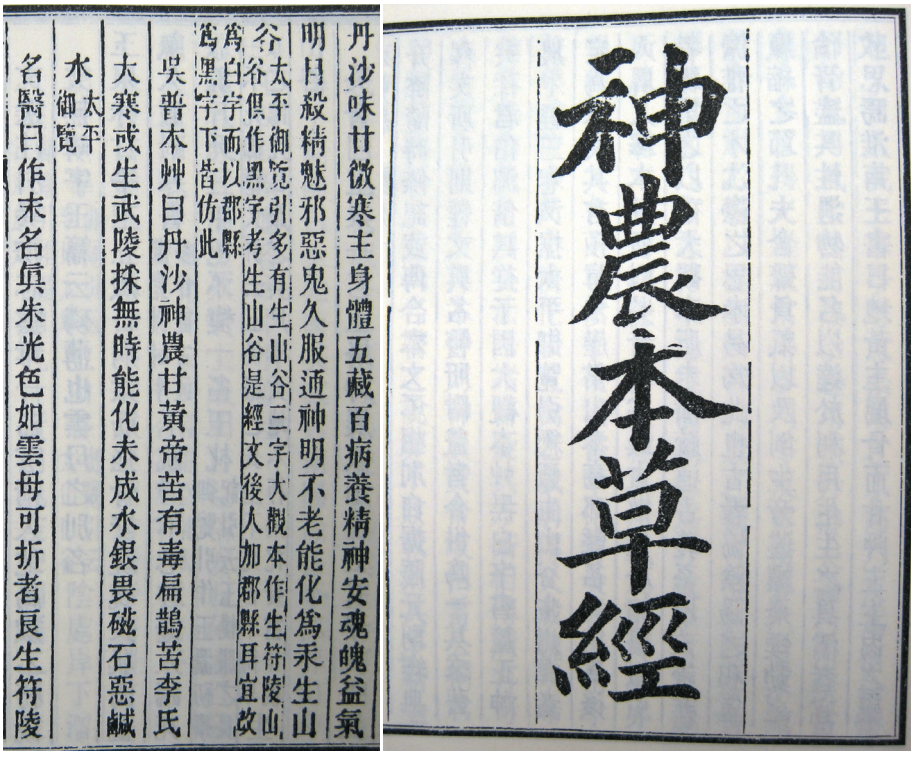


The evolution of written characters from pictographic representations of "turtle" and "fruit'

The manuscript *Formulas for 52 Diseases* (*Wu Shi Er Bing Fang*), found in a burial chamber at Ma Wang Dui, is the earliest record of Chinese medical formulas, as well as the first text to clearly illustrate specific macroscopic features of medicinal plants. This manuscript, which dates to 168 B.C.E. and records 247 medicinal substances, includes several examples of distinguishing features related to the appearance and taste of specific medicinal materials.

Ancient Chinese materia medica literature documents the fundamental knowledge and refinement of ideas inherited from prior generations, and represents a rich resource for modern research and development. Historical materia medica texts contain abundant records derived from practical experience that illustrate how to differentiate the authenticity and quality of medicinals based on characteristics such as appearance, color, odor and taste.

Valuable records of herbal knowledge dating to the Han Dynasty and its preceding periods are summarized in the text the *Divine Husbandman's Classic of Materia Medica* (*Shen Nong Ben Cao Jing*), which records 365 medicinals along with their definitions, combinations, properties, harvesting details, processing methods, and medical applications. Production areas and macroscopic descriptions (such as appearance, color, odor and taste) of some medicinals are also recorded briefly. The first historical reference to "testing with fire" is found in this text, in the statement that "*dan sha* (cinnabar) can transform into mercury." *The Divine Husbandman's Classic of Materia Medica* (*Shen Nong Ben Cao Jing*) is known only from compiled versions dating from the Ming Dynasty (c. 1400 C.E.), as the original book has been lost.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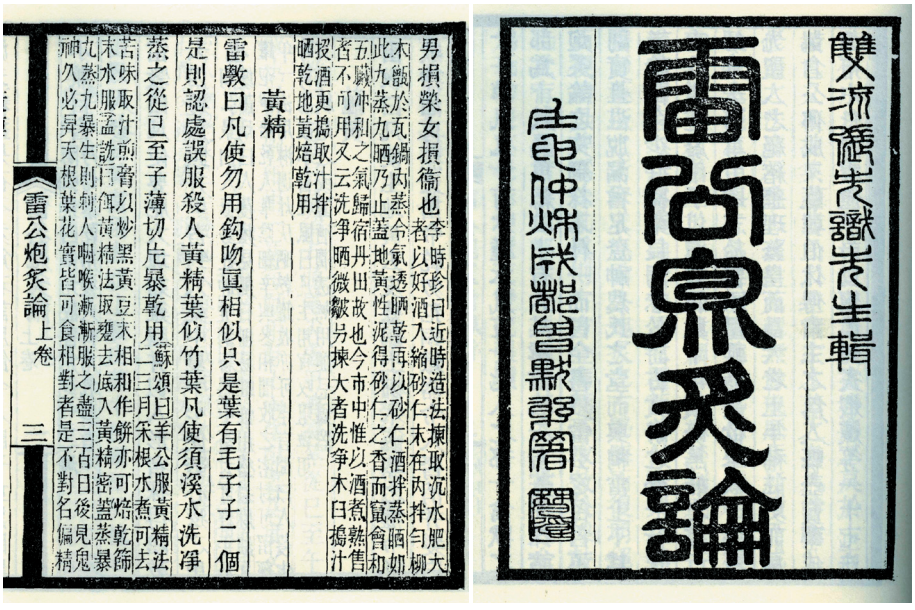
Records describing *dan sha* (Cinnabar) in the *Divine Husbandman's Classic of Materia Medica*

During the Northern and Southern Dynasties period (ca. 500 C.E.), the first specialized text on medicinal processing was written. This text, *Grandfather Lei's Treatise on Medicinal Processing* (*Lei Gong Pao Zhi Lun*), is rich with detailed information on medicinal identification, including the first documented comparisons between different medicinals. For example, distinctions were illustrated between *huang jing* and *gou wen*, *jie geng* and *mu geng*, *qian hu* and *ye hao gen*, *zi su* and *bo he*.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Records describing *huang jing* (Polygonati Rhizoma) in *Grandfather Lei's Treatise on Medicinal Processing*

Tao Hong-Jing, a physician of the Liang Dynasty, revised the *Divine Husbandman's Classic of Materia Medica* (*Shen Nong Ben Cao Jing*) and added another 365 medicinals to increase the total to 730 medicinals. This edited collection forms the *Collection of Commentaries on the Classic of the Materia Medica* (*Ben Cao Jing Ji Zhu*). Tao distinguished the text quoted directly from the *Divine Husbandman's Classic of Materia Medica* (*Shen Nong Ben Cao Jing*) from his own annotations through the use of red and black ink. Tao added morphological descriptions of medicinal materials and noted their production regions. He also listed examples of incorrect, low-quality, and confused medicinal materials and described his contemporary situation in the following quote: "Many doctors do not recognize medicinals, and only listen to the vendors. However, the vendors are not experts, and they trust those that collect and distribute medicinals. Those who collect and distribute rely on inherited knowledge of handling medicinal materials; it is thus impossible to predict the authenticity and quality of medicinals from the distributors."

Records describing *zhu* (atractylodes) in the *Collection of Commentaries on the Classic of Materia Medica*, with the original quotations from the *Divine Husbandman's Classic of Materia Medica* illustrated in red ink

Text-based records have always made up the primary body of historical Chinese materia medica literature. However, as the range of recorded medicinals expanded, text alone was insufficient to convey information regarding the appearance of medicinals, compelling authors to add explanations and illustrations. The situation surrounding medicinal illustrations in ancient times was extremely complex; examples can be seen of one medicinal with multiple different illustrations, as well as disparities between the text and illustrations. Nonetheless, this literature provides a reference for us to understand more about the authentication and processing methods used in ancient times.

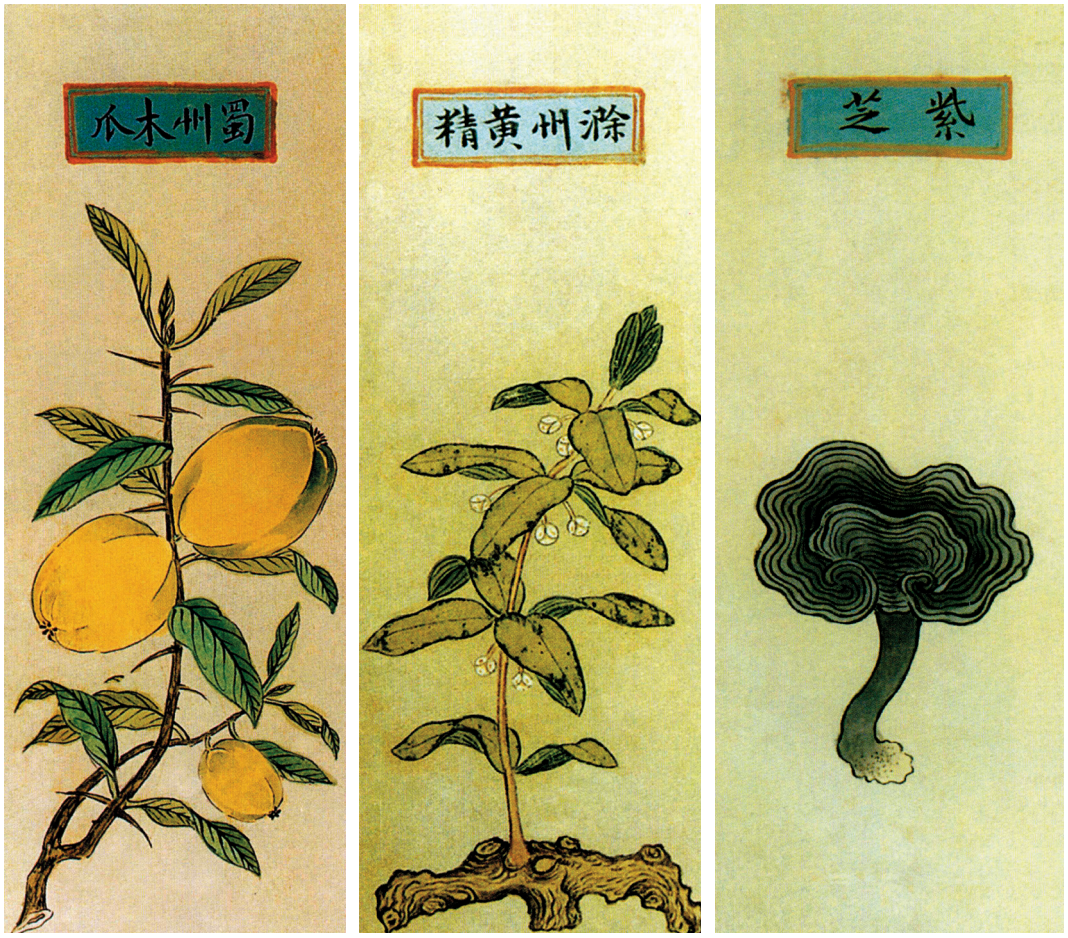
Illustrated Texts

In 659 C.E., the government of the Tang Dynasty commissioned the *Newly Revised Materia Medica* (*Xin Xiu Ben Cao*), documenting 850 medicinals. In addition to being China's first illustrated materia medica, it is considered to be the world's first national pharmacopoeia. This 54-volume materia medica was composed of three sections: written text, drawings of medicinals, and captions for the illustrations. All of the drawings were in full-color in the original text. Unfortunately, the original has been lost, and the only extant versions were reconstructed by later generations of editors.

Completed in 1220 C.E. in the Southern Song Dynasty, the *Materia Medica from Steep Mountainsides* (*Lu Chan Yan Ben Cao*) was the first illustrated materia medica dedicated to local medicinal plants, focusing on the area around modern day Hangzhou. Copies dating back to the Ming Dynasty have been preserved, and 206 folk medicinals are referenced with beautiful color illustrations.

Hu er cao (Saxifragae Herba) and *che qian cao* (Plantaginis Herba) from the *Materia Medica of Steep Mountainsides*

Completed in 1505 C.E., *Materia Medica Distinctions* (*Ben Cao Pin Hui Jing Yao*) was a Ming Dynasty government-commissioned materia medica that contained 1815 medicinals. It featured 1367 illustrations that were produced by artists selected from the imperial palace. About half of these illustrations were new, and the other half were colored and modified images based on black and white illustrations from the Song Dynasty *Illustrated Classic of the Materia Medica* (*Ben Cao Tu Jing*). Many of the new images were very realistic representations of the medicinals in their natural environment. However, shortly after the book was completed, its sponsoring Emperor Xiao Zong died. In the aftermath of his death, the chief editor Liu Wen-Tai and others were charged as criminals, and the book was stored in the palace and kept out of circulation. Thus, later generations were only transmitted via hand-written copies.



Illustrations of *mu gua* (Chaenomelis Fructus), *huang jing* (Polygonati Rhizoma), and *zi zhi* (Ganoderma) from *Essentials of Materia Medica Distinctions*

In 1591, the *Concise Addendum to Grandfather Lei's Treatise on Herbal Processing* (*Bu Yi Lei Gong Pao Zhi Bian Lan*) was completed. This text contains the greatest known collection of color illustrations and is the most complete, with rare and unique content. It is composed of 14 scrolls that are divided into 10 sections, covering metals/stones, herbs, woods, human, beasts, birds, worms/fish, fruits, grains, and vegetables. 1193 color illustrations depict 957 medicinals; 829 illustrations came from the *Essentials of Materia Medica Distinctions* (*Ben Cao Pin Hui Jing Yao*), and 293 had never been previously seen. The color illustrations primarily show the appearance and processing of medicinals. In addition to being an important reference point as a Ming Dynasty color materia

medica, this text also preserved the greatest number of illustrations from the *Essentials of Materia Medica Distinctions* (*Ben Cao Pin Hui Jing Yao*).

The original text disappeared for 400 years and only recently resurfaced. It contains 219 illustrations of medicinal processing scenes that provide insight into ancient processing practices. As shown in the illustrations below (featuring medicinal processing scenes and equipment and steps of processing the medicinal *fu zi*, such as cutting, mixing with adjuvants, boiling, sun-drying, and rinsing in running water), this book is akin to an ancient illustrated version of standard operating procedures in Chinese medicinal processing.

Medicinal processing scenes and steps of processing the medicinal *fu zi* (Aconiti Radix Lateralis Praeparata) in the *Concise Addendum to Grandfather Lei's Treatise on Herbal Processing*

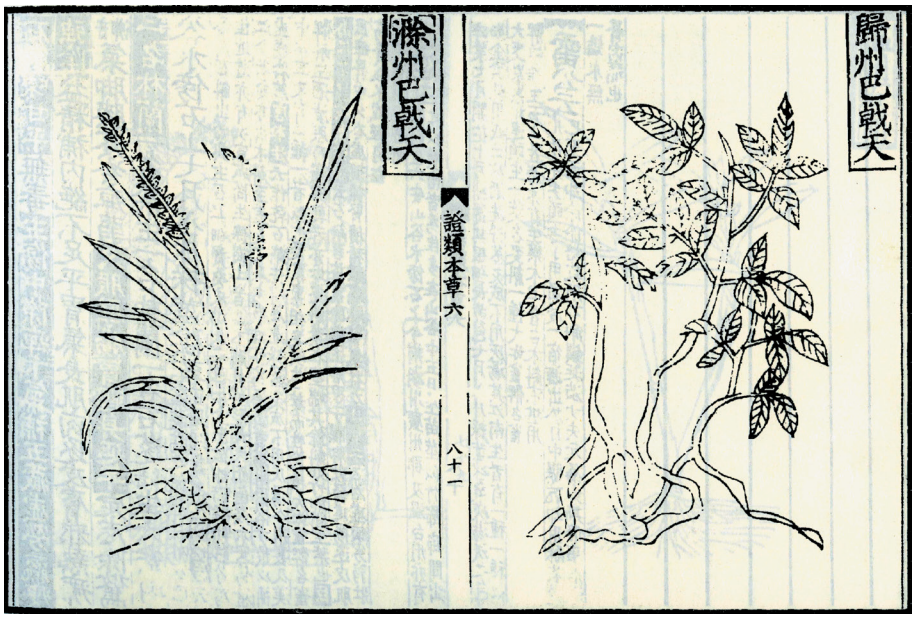
Printed Texts

After the development of the printing press in the Song Dynasty, the use of different character sizes was substituted to preserve the distinction of red vs. black ink, and practical black and white illustrations emerged. Although black and white images cannot match the clarity of full color, the comparatively low cost achieved through the use of the printing press allowed text and illustrations to become widely distributed, and the invention of the printing press greatly promoted the development of materia medica literature.

During the reign of the Emperor Jia You in the Northern Song Dynasty, Zhang Yu-Xi and Su Song completed the *Materia Medica of the Jiayou Era* (*Jia You Ben Cao*) in 1057 C.E., and its sister text the *Illustrated Classic of Materia Medica* (*Ben Cao Tu Jing*) in 1062. The former text emphasized information from the literature, while the latter referenced practical medicinal use and medicinal differentiation experience in the Song Dynasty. The *Illustrated Classic of Materia Medica* (*Ben Cao Tu Jing*) was based on a national assessment of medicinal resources, with images of medicinals from each region and the addition of images from materia medica texts from the Imperial collection. These images were made into black and white printing plates, and this publication is known as the world's first printed atlas of medicinal substances. Later generations of materia medica texts

reproduced these images or their modifications extensively, and this text offers significant academic value for research into the origins of medicinal substances up through the Song Dynasty period.

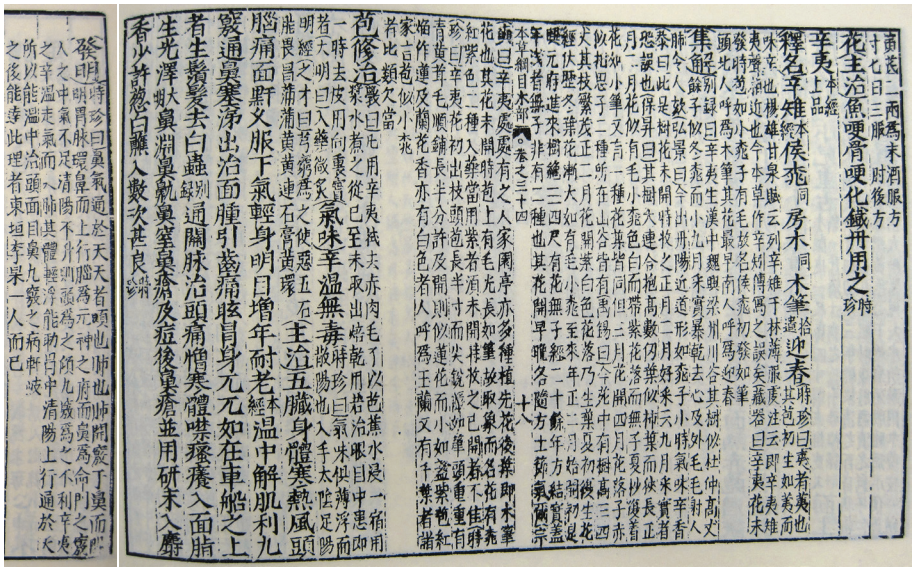
In 1108 C.E., Tang Shen-Wei completed the *Materia Medica Arranged According to Pattern* (*Jing Shi Zheng Lei Bei Ji Ben Cao*, which is typically abbreviated as *Zheng Lei Ben Cao*). This text has been transmitted to the modern day in three textual versions known as the "*Da Guan*," "*Zheng He*," and "*Shao Xing*" editions. Written by one of the most respected authors of the Song Dynasty, this text collected China's Song and pre-Song Dynasty materia medica literature into a great compendium. In addition to being the most complete specialized text dedicated to medicinals from this era, it preserved the images and text from the *Materia Medica of the Jiayou Era* (*Jia You Ben Cao*) and the *Illustrated Classic of Materia Medica* (*Ben Cao Tu Jing*) for later generations.



Line drawings illustrating two varieties of *ba ji tian* (Morindae Radix) from the *Materia Medica Arranged According to Pattern*

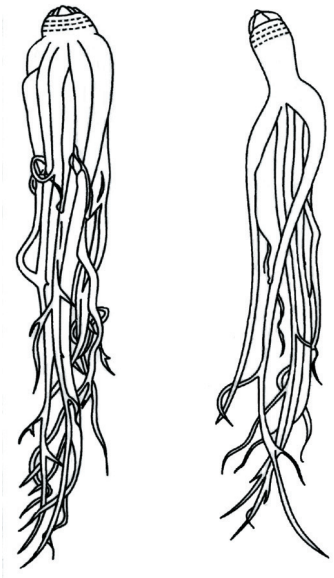
In 1116 C.E., the text *Extension of the Materia Medica* (*Ben Cao Yan Yi*) was completed by Kou Zong-Shi. Kou had extensive personal experience and added comments about the differentiation of authentic and incorrect medicinals. Later on, Kou was regarded as an authority in medicinal identification, holding a position similar to that of a modern-day expert in charge of an authentication lab. Later generations often printed and transmitted the text of his book together with the *Materia Medica Arranged According to Pattern* (*Zheng Lei Ben Cao*).

Similar to the pioneering personal effort of Tang Shen-Wei, the Ming Dynasty author Li Shi-Zhen worked from 1552 to 1578 C.E. to complete his monumental *Compendium of Materia Medica* (*Ben Cao Gang Mu*). This text was first published in 1593 C.E. and recorded 1,892 medicinals, offering details on each medicinal's nomenclature, production regions, nature and flavor, appearance, and processing methods. With a novel structure and rich references to the existing literature, this text embodies the peak of the historical Chinese materia medica literature. Li Shi-Zhen's son added two scrolls of medicinal illustrations preserving 1109 images, and the lone imperfection in this beautiful text is the fact that these illustrations are relatively simple and rough. Most of the medicinal images were new, but a small portion of the images were reproduced from the *Illustrated Classic of Materia Medica* (*Ben Cao Tu Jing*).



Records describing the medicinal *xin yi* (Magnoliae Flos) in the *Compendium of Materia Medica* ("*Jin ling*" edition)

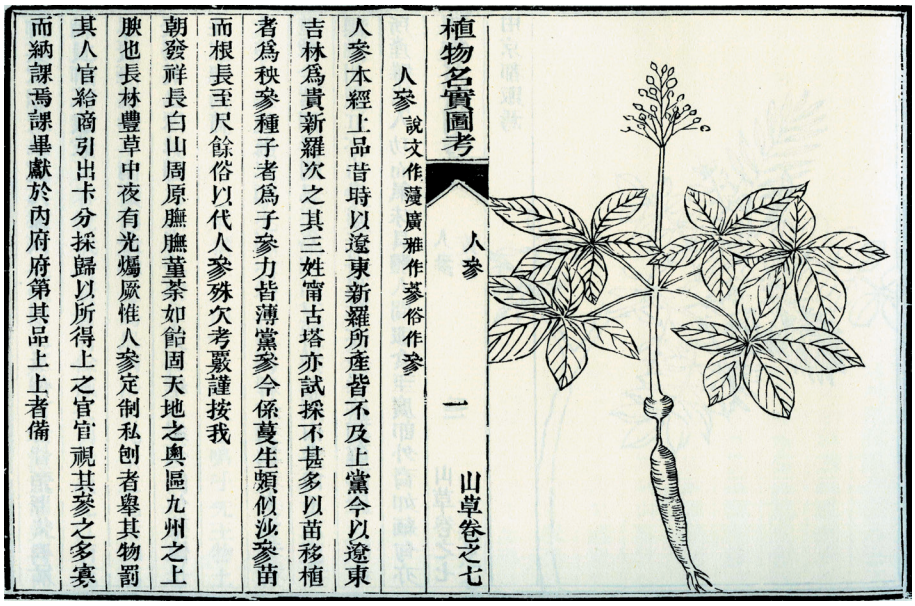
In 1612, the Ming Dynasty author Li Zhong-Li completed the *Origins of the Materia Medica* (*Ben Cao Yuan Shi*). Composed of 12 scrolls covering 508 medicinals, it is considered to be the most distinctive specialized text on medicinal differentiation in the historical materia medica literature. It notably featured comparative illustrations of the medicinal material instead of the whole plant or substance, with 426 very realistic illustrations combined with text. Some medicinals had notes and annotations to clearly point out distinguishing features, and later generations of clinical texts often reproduced its illustrations of medicinal materials. For example, the following description is recorded for *dang gui* (Chinese angelica root): "*Ma wei dang gui* [horsetail *dang gui*] has a round head and many purple tails, and is aromatic, fat and oily; it is the best *dang gui*. *Can tou dang gui* [silkworm head *dang gui*] has a large head and thick tails, the color is white and it is firm and desiccated; it is not suitable for use as a dispersing medicinal."



Illustrations of "horsetail" (left) and "silkworm head" (right) forms of *dang gui* (Angelicae Sinensis Radix) from the *Origins of the Materia Medica*

In 1848, the Qing Dynasty botanist Wu Qi-Jun completed the *Illustrated Reference of Botanical Nomenclature* (*Zhi Wu Ming Shi Tu Kao*). In addition to being an expert in botany, Wu was an elite scholar, earning the honor of the highest score in the traditional Chinese national civil service examination. He served as the governor of Hunan, Hubei, and Yunnan, and he was fond of observing the plants in each region that he was posted to. He drew pictures of all the plants that he observed, and later completed the text from Henan province's *Ji Gong* Mountain, where he spent three years immersed in research and concentration while mourning his parents.

His 38-volume book recorded 1,714 plant species, and included 1,790 illustrations and nearly 1,500 sketches. The images in this text are the most accurate representations found in ancient Chinese *materia medica* literature, and this book serves a bridge linking ancient Chinese herbology to modern botany and agricultural science.


植物名實圖考
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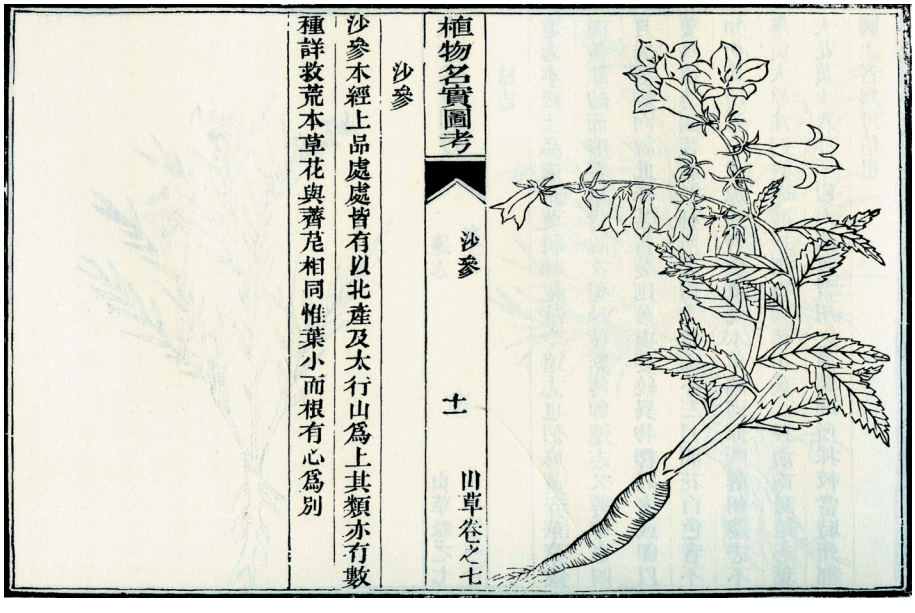
Ren shen (Ginseng Radix et Rhizoma) in the *Illustrated Reference of Botanical Nomenclature*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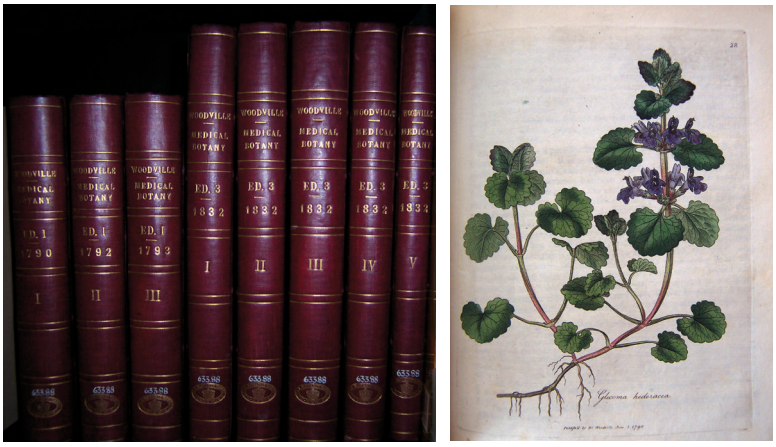
Sha shen (Adenophorae Radix) in the *Illustrated Reference of Botanical Nomenclature*

Overseas Materia Medica Texts

Western nations also have a rich collection of traditional knowledge related to medicinal plants, particularly in the relatively recent pre-modern era when many texts dedicated to botany and pharmacognosy emerged.

In the UK, many texts dedicated to medicinal plants were published in the 18th and 19th centuries. For example, William Woodville's text *Medical Botany* from the year 1790 contained many full-color botanical illustrations.



Medical Botany, featuring an illustration of *Glechoma hederacea* L.

Inspired by the Ming Dynasty Chinese term for a crude drug storehouse (生藥庫), the term 生藥學 *sheng yao xue* (pharmacognosy, literally "the study of crude drugs") emerged in the late 19th century in Japan. In the era around the 19th century, numerous texts devoted to crude medicinals were published in Japan. For example, the 1828 C.E. *Materia Medica Atlas* (*Ben Cao Tu Pu*) by Tsunemasa Iwasaki recorded over 2000 medicinal herbs, and remains an important reference text in pharmacognosy. Other examples include the 1888 text *Makino's Atlas of Japanese Plants* by Tomitaro Makino and the first edition of the Japanese text *Pharmacognosy* in 1890 C.E. by Junichiro Shimoyama.

Medicinal Authentication in Modern Literature

Japan emerged as a global leader in the early field of pharmacognosy prior to the modern era, and had a major influence on the development of pharmacognosy in China. In 1905, a professor named Zhao Shaohuang studied in Japan, and later became an instructor at the Chinese Academy of Chinese Medical Science as well as Beijing University. As a pioneer in the field of Chinese pharmacognosy, his Qizhou Medicinal Journal was the first to organize materia medica research based upon modern taxonomy.

Over the past 60 years, Chinese medical publishing has developed tremendously. From the 1950s to the 1980s, black line drawings and black and white pictures dominated, and publications about new botanical varieties used black line illustrations and copperplate printing. Later on, black and white photographs gave way to color photographs. The gradual development of the publishing industry and the widespread availability of improved photographic technology have led to a great increase in content related to medicinal materials, microscopic differentiation, and illustrated texts on Chinese medicinal authentication. A number of representative examples are described below:

Handbook of Chinese Medicinal Materials (*Zhong Yao Cai Shou Ce*): Compiled by the Chinese Ministry of Health in 1959 (first ed.), this text covers 516 medicinal materials with over 200

The *Materia Medica Atlas* by Iwasaki Tsunemasa, featuring an illustration of *Bletilla striata* (Thunb.) Reichb. f.

illustrations. Covering nomenclature, production regions, processing, properties, identification, quality assessment, and storage, it is a representative text summarizing the knowledge and medicinal identification experience of traditional pharmacists.

The *Chinese Materia Medica* (*Zhong Yao Zhi*), published from 1959 to 1961, records more than 500 species. The revised 6-volume edition (1982–94) records 637 herbal substances (including spores, volatile oils, and processed products), involving more than 2,100 medicinal plant species.

Medicinal Materials (*Yao Cai Xue*): First published in 1960, this text utilized scientific methods to assess traditional differentiation experience, and recorded over 700 medicinals. The content drew upon knowledge related to the production and authentication of medicinals, and the appendix contained illustrations of medicinal flora and fauna, as well as illustrations of the external appearance of medicinal materials, decoction pieces, and powders. It was systematically updated in 1996 and republished under the title *Chinese Medicinal Materials* (*Zhong Guo Yao Cai Xue*).

Pharmacopoeia of the People's Republic of China (*Zhong Hua Ren Min Gong He Guo Yao Dian*): The first edition of the Chinese Pharmacopoeia was published in 1953, and contained 531 drugs. The 1963 edition began to formally record Chinese medicinals, defining legal standards for medicinal identity. It has been continually revised for each subsequent edition. At the very beginning, authentication standards were lacking, yet modern editions now cover macroscopic descriptions, microscopic and chromatographic differentiation, as well as constituent specifications. The 2010 edition of the *Chinese Pharmacopoeia* lists 616 official Chinese medicinal materials.

Handbook of Chinese Medicinal Materials: Compiled by the Chinese Ministry of Health in 1959 (first ed.), this text covers 516 medicinal materials with over 200 illustrations. Covering nomenclature, production regions, processing, properties, identification, quality assessment, and storage, it is a representative text summarizing the knowledge and medicinal identification experience of traditional pharmacists.

Records of Chinese Medicinals (*Zhong Yao Zhi*, first edition in 1959): First published in 1959, this text systematically organized information on over 500 commonly used medicinals, integrating content on botanical sources with their respective medicinal materials. The appendix featured botanical line drawings and a small number of color illustrations, and the text contains a summary of knowledge from the 10-year formative period of modern China. Later on, two large-scale editing projects were undertaken.

The first revision, from 1982-1998, produced a second edition with 6 volumes. This revised 6-volume edition recorded 637 herbal substances (including spores, volatile oils, and processed products), involving more than 2,100 medicinal plant species (Institute of Materia Medica, Chinese Academy of Medical Sciences, 1959, 1982-1998). In 2002, the third edition (*Newly Revised Records of Chinese Medicinals*, *Xin Bian Zhong Yao Zhi*) was published in a 5-volume format.

Medicinal Materials (*Yao Cai Xue*): First published in 1960, this text utilized scientific methods to assess traditional differentiation experience, and recorded over 700 medicinals. The content drew upon knowledge related to the production and authentication of medicinals, and the appendix contained illustrations of medicinal flora and fauna, as well as illustrations of the external appearance of medicinal materials, decoction pieces, and powders. It was systematically updated in 1996 and republished under the title *Chinese Medicinal Materials* (*Zhong Guo Yao Cai Xue*).

Pharmacopoeia of the People's Republic of China (*Zhong Hua Ren Min Gong He Guo Yao Dian*): The first edition of the Chinese Pharmacopoeia was published in 1953, and contained 531 drugs. The 1963 edition began to formally record Chinese medicinals, defining legal standards for medicinal identity. It has been continually revised for each subsequent edition. At the very beginning, authentication standards were lacking, yet modern editions now cover macroscopic descriptions, microscopic and chromatographic differentiation, as well as constituent specifications.

Discussion of Varieties of Medicinal Materials (*Zhong Yao Cai Pin Zhong Lun Shu*): First published in 1964, this text brought integrated traditional materia medica literature and real-world investigation to analyze the varieties and historical causes of medicinal confusion. It is a representative reference work for the subject of confused medicinals, and it has been edited and republished in subsequent years.

National Collection of Chinese Herbal Medicinals (*Quan Guo Zhong Cao Yao Hui Bian*): This two-volume text, which was first published in 1975, recorded more than 4,000 medicinals and included nearly 3000 black line illustrations. A third volume containing 1156 color illustrations was integrated with the original text to form a complete set known as the *Color Atlas of the National Collection of Chinese Herbal Medicinals* (*Quan Guo Zhong Cao Yao Hui Bian*). Initially published from 1975 to 1978, it contains a vast collection of medicinal plants used in folk medicine, and over 100,000 copies were printed in six print runs from the 1970s-1990s. A revised edition was published in 1996.

Microscopic Authentication of Chinese Medicinal Powders (*Zhong Yao Cai Fen Mo Xian Wei Jian Ding*): Featuring 377 medicinals, this text was the first to focus on the microscopic differentiation of Chinese medicinal materials. Each monograph features black line illustrations that highlight the special characteristics of the respective powder, and the special distinguishing characteristics of powders when examined with a microscope were systematically described for the first time.

Handbook of Chinese Medicinal Authentication (*Zhong Yao Jian Bie Shou Ce*): Using state-sponsored market investigation as a basis, this text summarizes experience in medicinal material differentiation, elucidating the phenomenon of instances of the "same name, different substance; same substance, different name." Containing illustrations of the original plants as well as the medicinal materials, this text was published in three separate volumes that were completed in 1972, 1979, and 1994, and was later reprinted numerous times.

After this period, modern texts such as handbooks on the identification of Chinese medicinal materials and textbooks on Chinese medicinal authentication have been published continually. Following the year 2000, many texts related to Chinese medicinal authentication have been published based on experimental research and digital images. For example, the *Pharmacopoeia of the People's Republic of China*: *Color Atlas of Microscopic Identification of Chinese Medicinal Powders* was the first full-color atlas focused on the special features seen in the microscopic assessment of powdered Chinese medicinal materials.

The text *Illustrated Microscopic Identification of Chinese Materia Medica* uses line drawings, depictions, and digital color photographs to comprehensively elucidate special distinguishing characteristics, and also describes the techniques to perform Chinese medicinal microscopy. Published by the Macao International Society of Chinese Medicine in both English and Chinese versions, it has been widely distributed worldwide.

Based on a systematic market investigation completed in Hong Kong, the text *Easily Confused Chinese Medicines in Hong Kong* features rich comparative photographs and concise text, illustrating the key distinguishing features of commonly confused medicinals.

Published in Taiwan, the *Illustrated Atlas of Daodi Medicinal Materials* is a collection of traditional medicinal differentiation experience that has preserved a great deal of valuable knowledge that has been lost on the Chinese mainland, as well as a deep investigation into Chinese medicine within the local *Heluo* culture.

Recently, the beautifully illustrated *Encyclopedia of Medicinal Plants* was published in both a Chinese and English version, combining text with beautiful images of both the original plants and medicinal materials. This text, which won one of China's highest awards for scientific publications, features 800 commonly used herbal medicines from both ancient and modern times, drawn from both the East and the West.

Over the course of history, the development of medicinal descriptions has progressed from ancient images similar to characters, to formal written characters, followed by hand-created illustrations, black and white printing plates, black line illustrations, black and white photographs, and finally color photographs. Digital photographs are convenient in terms of materials and editing, yet they cannot fully substitute for black and white photographs and black line illustrations; each complements the other. These methods have been used differently in different eras, resulting in the ideal combination of both text and illustrations together.

Representative texts on Chinese medicinal identification from different eras

Modern research shows that the left-brain is dominant in reading, while the right brain is dominant when processing images. Using a simple combination of illustrations and text, memory retention improves regardless of the efficiency or duration of study. Because of this, the combination of illustrations and text is even more important in the study of Chinese medicinal authentication.

Macroscopic Identification

In macroscopic identification, the naked senses are used to assess the appearance, odor, texture, and flavor of medicinal materials. As macroscopic identification focuses on gross morphological features and organoleptic properties that can be perceived without modern instruments, it is a simple, fast, and easy way to authenticate medicinal materials.

Traditionally, macroscopic identification is conducted by observing, touching, smelling, tasting, and/or testing with water or fire. Characteristics such as shape, size, color, odor and taste are assessed, and attention is given to the texture and cross-section of the medicinal material.

In ancient times, macroscopic identification was the main method used to determine the identity and quality of Chinese medicinal materials. Many traditional terms arose to denote features of authenticity or quality in specific medicinal materials, such as "chicken head" to describe the shape of *huang jing* (Polygonati Rhizoma), "lion head" to describe the root head of *dang shen* (Codonopsis Radix) and "chicken claw" to describe the shape of *huang lian* (Coptidis Rhizoma).

In some cases, there is a correlation between traditional macroscopic features and quality. For example, *huang bai* (Phellodendri Cortex) with thick cork and a yellow color is traditionally thought to be superior in terms of quality; indeed, specimens with a more prominent yellow color exhibit higher levels of the active constituent berberine.

Despite its many advantages, macroscopic identification relies heavily on personal experience and is not effective for distinguishing closely related medicinals that have very similar morphological features. This is especially true for plants from the same genus, such as *chai hu* (Bupleuri Radix) and its substitutes from related plants in the *Bupleurum* genus. Furthermore, chemical analysis has shown that not all ancient statements on authenticity and quality based on macroscopic characteristics are inherently correct. For example, large *ren shen* (Ginseng Radix) specimens are traditionally thought to be superior in quality. However, modern studies have indicated that the ginsenoside content is higher in the thin fibrous roots and lower in the larger main root.

Additionally, different growing environments and different processing methods can greatly influence the macroscopic characteristics and chemical constituents of Chinese medicinals. Historical changes must be considered, such as the increasing use of cultivated instead of wild resources, as well as the effects of modern agricultural techniques on macroscopic characteristics and medicinal quality. Recent developments such as the impact of new botanical varieties and new methods of preparing decoction pieces need to be systematically investigated, and many ancient specifications related to quality still need to be validated using modern analytical methods.

Key aspects of macroscopic identification

Appearance

Observing appearance is an important aspect of macroscopic identification. Many commonly confused medicinals can be distinguished based on their visual features. Our book *Differentiation of 100 Medicinals* (百藥鑑別) illustrates the key distinguishing characteristics for 100 pairs of easily confused medicinals, which can be primarily differentiated based on appearance.

For example, the medicinals *bai qian* (Cynanchi Stauntonii Rhizoma et Radix) and *bai wei* (Cynanchi Atrati Radix et Rhizoma) are often confused with one another due to similarity in their morphological characteristics. However, the rhizome of the former grows horizontally and the middle of its cut surface is hollow, while the rhizome of the latter grows vertically and the middle of its cut surface is solid. These two species can thus be distinguished visually.

Chinese medicinals from the same botanical family often have similarly shaped plant parts. For example, Chinese medicinals from the Apiaceae have cremocarps, conical roots, rhizomes with ring-like nodes, and oil dots scattered in their cut surfaces.

In the process of macroscopic identification, attention should be paid to different medicinal parts. Different features are used in describing and distinguishing medicinals from anatomically different plant parts. For example, the key identifying features of root medicinals include their shape, texture, and fractured surface. Medicinals derived from stems generally should be investigated based on their shape, size, surface, texture and fracture. Medicinals derived from fruits should be assessed based on their shape, size, surface, texture and fracture, as well as the appearance of the top and base of the fruit. Seeds should be investigated based on their shape, size, surface, texture, and the positions of their hilum, chalaza and raphe, as well as other morphological characteristics.

Many traditional technical terms are brief and succinct. For example, the description of wild ginseng often refers to: "a long rhizome with multiple dense nodes, a jujube seed-like adventitious root, a tight bark with fine striations, and 'pearl beards' (meaning fine long rootlets with distinct small protuberances)"; these terms illustrate key features in ginseng identification. For superior quality *tian ma* (Gastrodiae Rhizoma), the key identification points are "a top similar to the beak of a parrot, a disc-like bottom, an oblate body with dotted-annulations, and a horn-like texture at the fractured surface." The "mouth of a parrot" refers to the remnants of the caudex on the top, while the dotted-annulations refer to punctiform dormant buds on the surface.

Wild *ren shen* (Ginseng Radix et Rhizoma)

Tian ma (Gastrodiae Rhizoma), "winter" form (*dong ma*)

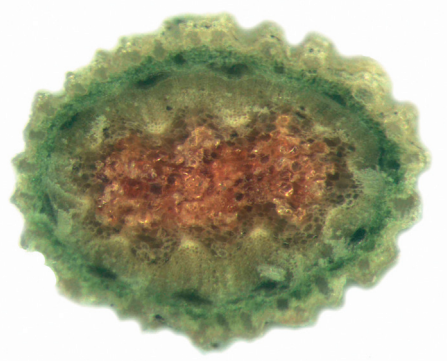
In addition to the above examples, other evocative technical terms are also used in traditional macroscopic identification. Examples include "pearl-like scales," which describe the body surface of *ge jie* (Gecko). This term refers to grey, round and slightly protruding scales that look similar to pearls. In another example, the term "compass striations" describes the concentric annulations in the cut surface of *shang lu* (Phytolaccae Radix).

"Pearl-like scales" on the surface of *ge jie* (Gecko)

"Compass striations on the cut surface of *shang lu* (Phytolaccae Radix)

Color

Assessing color is essential in the macroscopic identification of Chinese medicinal materials. According to traditional experience, color is important for the evaluation of quality. For example, the "rose heart" phenomenon of *ma huang* (Ephedrae Herba) refers to the reddish-brown color of its pith, and modern experimental studies have demonstrated that this "rose heart" phenomenon is indeed correlated with higher alkaloid content.



"Rose heart" of *ma huang* (Ephedrae Herba)

Different medicinal materials each have their own requirements in terms of color. For example, in the case of *long dan* (Gentianae Radix), the text *Origins of the Materia Medica* (*Ben Cao Yuan Shi*) states: "thick, long, and yellowish-white roots are superior." In the case of *mu xiang* (Aucklandiae Radix), it specifies that items "with a shape like desiccated bones are superior; if the flesh is blue-green the quality is high, yellowish-white is mid-grade, and if it is black and oily, it is inferior." In the case of *huang lian* (Coptitis Rhizoma), it states that superior rhizomes are "thick and large, fresh yellow and bright in color, with multiple nodes, a firm and heavy texture, and they make a sound when they strike each other."

In many individual instances, modern experimental research has validated the close relationship between color and the quality of specific medicinals. As noted above, research has demonstrated that the yellow color of *huang bai* medicinal material can be correlated with its berberine content. Similarly, *huang lian* (Coptidis Rhizoma) with a yellowish-red fractured surface is traditionally regarded as superior, and this phenomenon is also correlated with relatively high berberine content.

In the case of *yan hu suo* (Corydalis Rhizoma), superior medicinal material has a golden yellow and shiny fractured surface; experiments on plants in the same genus that have a yellowish-white or white fractured surface reveal that their alkaloid content fails to meet the medicinal standard. There is also a clear relationship between color and quality for several other medicinals, including *hong hua* (Carthami Flos), *dan shen* (Salviae Miltiorrhizae Radix), and *qian cao* (Rubiae Radix), all of which should be red in color, and *zi cao* (Arnebiae/Lithospermi Radix), which should be purple.

Beyond quality evaluation, color is also important for the identification of decoction pieces, i.e., the processed (usually sliced) medicinal materials dispensed at Chinese herbal pharmacies. Processing often—if not usually—changes the color of the decoction pieces; for example, many items become yellow after being stir-fried with honey or become darker after being steamed. Thus color can sometimes indicate whether and/or how a medicinal has been processed.

Odor

Many Chinese medicinal materials have an aromatic, distinctive, or unpleasant smell. Each medicinal has its own special odor to some extent, especially those containing volatile oils, such as *chuan xiong* (Chuanxiong Rhizoma), *dang gui* (Angelicae Sinensis Radix), *bo he* (Menthae Herba), and *xin yi* (Magnoliae Flos). Traditionally, samples of the same medicinal material that have a strong odor are considered to be superior in quality to samples with a weaker odor. In the modern day, it is understood that the strength of the odor often reflects the volatile oil content.

Taste

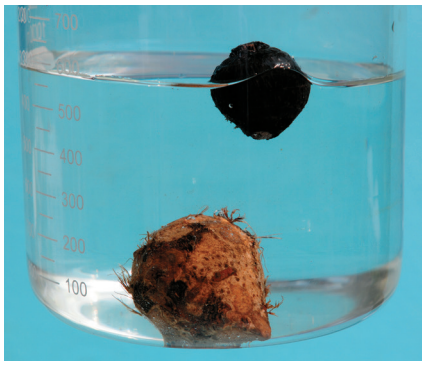
Taste refers to the experience when the medicinal material is put in the mouth or on the tongue; taste is usually classified as sour, bitter, sweet, acrid, salty, or astringent.

In the context of medicinal properties, the concept of taste is often related to clinical effects: acrid medicinals can disperse and move, sour medicinals can contain and astringe, sweet medicinals can moderate and supplement, bitter medicinals can dry and drain, and salty medicinals can soften and promote downward movement. However, in the context of macroscopic identification, the concept of taste refers to the sensation directly experienced by the mouth when the medicinal material is chewed. In many situations, the actual taste of the medicinal in the mouth is similar to the taste ascribed to it in Chinese medical theory, but there are many examples where these two descriptions differ. For example, when the medicinal *zi cao* (Arnebiae/Lithospermi Radix) is chewed in the mouth, it has a slightly bitter, astringent taste, but according to Chinese medical theory, its taste is classified as sweet and salty.

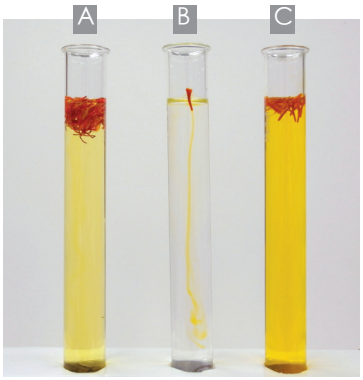
The taste of a medicinal is closely correlated with its chemical constituents. For example, the bitter taste of *huang lian* (Coptidis Rhizoma) is related to its alkaloids; generally speaking, the more bitter the taste, the higher the alkaloid content. In the case of *gan cao* (Glycyrrhizae Radix), its sweet taste comes from glycyrrhizin, which is also its key active constituent. Some medicinals have several different tastes caused by different chemical constituents; for example, ginseng has a slightly sweet and slightly bitter taste because it contains both polysaccharides and saponins.

Testing with water

Some Chinese medicinal materials exhibit various special changes after being put in water. Certain medicinals will sink or float depending on their relative density; some will change the color of the water, or may produce phenomena such as foam, viscidity, or a creamy appearance that can be linked to chemical constituents.



When submerged in water, *jing san leng* (Sparganii Rhizoma) sinks and *pao san leng* (Scirpi Yagarae Rhizoma) floats

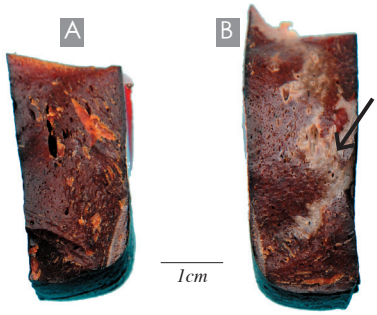


Hong hua (Carthami Flos) [A] and *fan hong hua* (Croci Stigma) [B, C] after being submerged in water

On the basis of these changes, medicinal materials from different sources can be identified. For example, the medicinals *san leng* (Sparganii Rhizoma) and *pao san leng* (Scirpi Yagarae Rhizoma) can be differentiated by submersion in water. When submerged in water, the former will sink because of its higher relative density while the latter will float because of its lower relative density.

Water testing is also used to differentiate true saffron (*fan hong hua*, Croci Stigma) from safflower (*hong hua*, Carthami Flos). After *hong hua* is steeped in water, the water becomes golden yellow and the color of the flower does not fade. When *fan hong hua* is steeped in water, a single strand of yellow color first sinks straight down, the tip of the stigma swells to form a long, trumpet shape, and the water then gradually fills in to become yellow, without any obvious red color.

Pang da hai (Sterculiae Lychnophorae Semen) after swelling in water



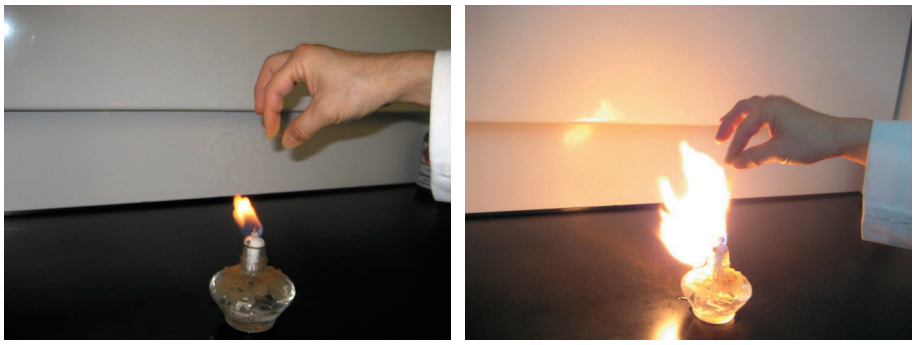
Chan su (Bufonis Venenum) [A] becomes milky white after the fractured surface is exposed to water [B]

In another example, when *pang da hai* (Sterculiae Lychnophorae Semen) is submerged in hot water, it swells like a sponge and becomes several times larger than its original size. Some seed medicinals, such as *ting li zi* (Semen Lepidii) and *che qian zi* (Plantaginis Semen), become sticky and swell after being soaked in water.

Certain medicinal materials derived from animals will also produce special changes after being tested by water. For example, *chan su* (Bufonis Venenum) exhibits ivory white swelling when the fractured surface is exposed to water.

Testing with fire

When medicinal materials are burned or processed with heat, the resulting odor, color, smoke and sound can be investigated for the purposes of identification. Characteristics such as swelling, melting and burning can be investigated as well. For example, *ru xiang* (Olibanum) produces a slight fragrance after burning and melts slowly while the mixture of frankincense (*ru xiang*) and *feng xiang zhi* (Liquidambaris Resina) produces a strong fragrance and melts quickly. In another notable example, the medicinal *hai jin sha* (Lygodii Spora) produces a crackling sound and a bright flame without any residue when exposed to fire.



Hai jin sha (Lygodii Spora) exposed to flame

On the whole, macroscopic identification is convenient and practical, and it is less expensive and more environmentally friendly than modern chemical analysis due to the lack of solvents. Macroscopic examination remains the most practical and widely used basic method of evaluating the authenticity and quality of Chinese medicinal materials, and it is extensively employed in herbal stores, pharmacies, and herbal wholesale markets. Due to the unique nature of macroscopic identification, an experienced Chinese medical pharmacist can not only quickly evaluate the authenticity and quality of a given medicinal material, but can also give an appropriate appraisal of its production area, wild or cultivated origin, and even its age.

Combined with microscopy, the above techniques of macroscopic identification have even been used to identify remarkable specimens from archeological sites, including a specimen of *xin yi* (Magnoliae Flos) that was preserved for 2000 years in a burial chamber at Mawangdui, as well as *chen xiang* (Aquilariae Lignum Resinatum) and *jiang xiang* (Dalbergiae Odiferae Lignum) specimens recovered from a shipwreck dating back to the Song Dynasty, nearly 900 years ago.

In recent years, a number of new techniques and technologies have emerged, such as an "electronic nose" and "electronic tongue," which aim to reduce the traditional subjectivity of assessing odor and taste. These new methods and technologies are an extension of macroscopic identification and may be helpful in its scientific development.

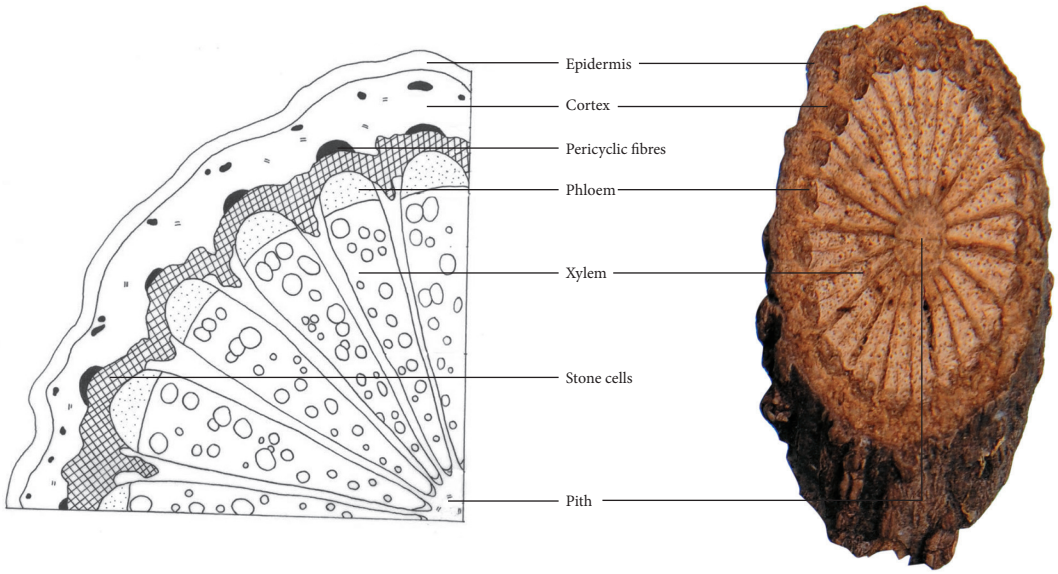
Scientific elucidation of macroscopic identification

The special characteristics seen in medicinal materials are not just superficial features of appearance, but also reflect internal structures and chemical constituents. Thus, there is a close relationship between macroscopic features, anatomical structures, and chemical components.

Morphological features and anatomical structures

Morphological features are the outside manifestations of anatomical structures. For example, the figure below shows the relationship between the morphological characteristics and anatomical structures of *qing feng teng* (Sinomenii Caulis).

Anatomical structures are also reflected in the features seen on the fractured surface of Chinese medicinal materials. If the fractured surface is relatively flat, it usually indicates that the tissues are rich in parenchymatous cells, as seen in *mu dan pi* (Moutan Cortex). The protuberances shown on the fractured surface of *rou gui* (Cinnamomi Cortex) are due to tissues that are rich in stone cells. The fibrous appearance of the fractured surface of *hou po* (Magnoliae Officinalis Cortex) comes from tissues that are rich in fibers or fiber bundles.



Many technical terms that were traditionally used in macroscopic identification are closely related to anatomical structures. In many cases, the enigmatic descriptions from ancient texts can be objectively explained by modern anatomical terms. For example, the term "chrysanthemum center" (referring to radial striations that appear similar to an open chrysanthemum flower) describes the interlaced structure of rays of xylem and phloem seen in medicinals such as *gan cao* (Glycyrrhizae Radix), *huang qi* (Astragali Radix), and *fang feng* (Saposhnikoviae Radix).

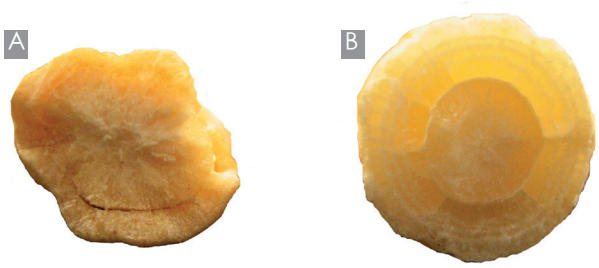
Technical terms in Chinese medicinal identification

In another example, the term "wheel radial striations" refers to xylem rays presenting with a homogeneous radial arrangement on the cut surface, as seen in *guang fang ji* (Aristolochiae Fangchi Radix). The term "spotted vascular bundles" refers to vascular bundles visible on the cut surface that are scattered or arranged in concentric rings, such as those seen in *chuan niu xi* (Cyathulae Radix). The term "cloudy-brocaded patterns" refers to the cut surface of *he shou wu* (Polygoni Multiflori Radix), which exhibits a cloud-shaped decorative pattern that is composed of 4–11 abnormal vascular bundles arranged in a ring. Finally, the term "golden well with jade fence" refers to a phenomenon seen in medicinals such as *jie geng* (Platycodonis Radix), where comparatively yellow xylem is contrasted with relatively white phloem on the cut surface, like the contrast of gold and white jade.

In recent years, the close relationship between macroscopic features and microscopic characteristics has been demonstrated in a variety of examples. Different medicinal materials that share the name *bai tou weng* have been assessed based upon their microscopic features, and microscopy has also been used to assess specimens of *hou po* that were stored for 1300 years in the Shōsōin storehouse, an ancient repository located in Japan.

In practice, macroscopic identification combined with observation of botanical structures can be used to rapidly authenticate medicinal materials. For example, the two medicinals *ming dang shen* (derived from *Changium smyrnioides* Wolff) and *chuan ming shen* (derived from *Chuanminshen viloaceum* Sheh et Shan) have a similar external appearance but they differ in the

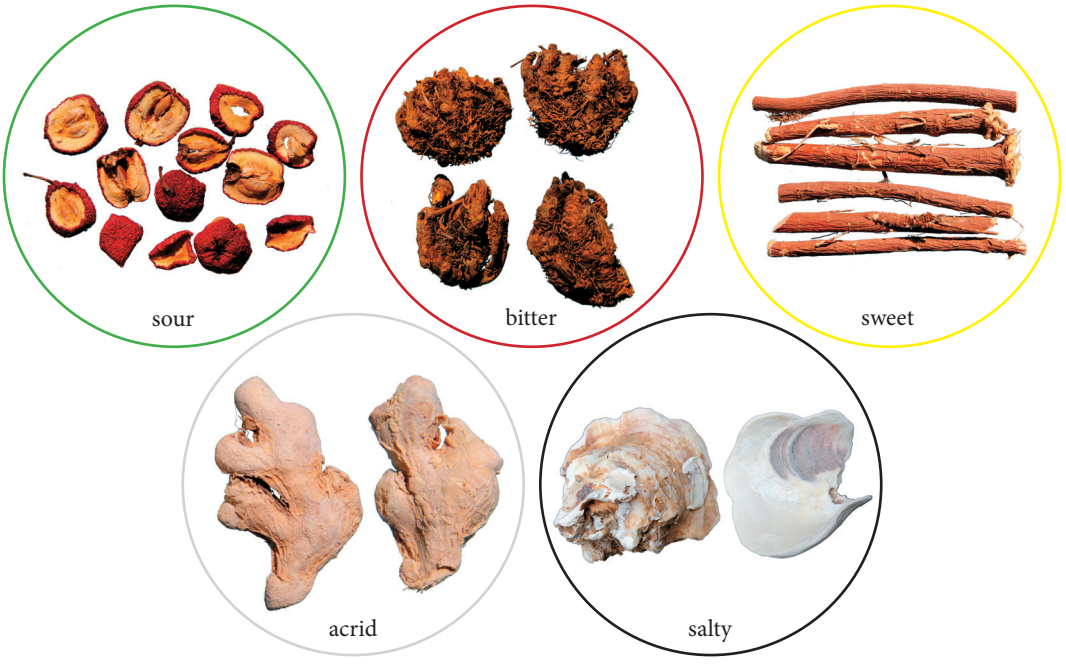
appearance of their fractured surface. The fractured surface of *ming dang shen* reveals a relatively thin cortex that easily separates from the woody portion, while translucent concentric rings can be seen on the fractured surface of *chuan ming shen*. These two items can thus be clearly distinguished by examining their horizontally cut surface.



Comparison of the transverse cut surface of *ming dang shen* (Changii Radix) and *chuan ming shen* (Chuanminshen Radix)

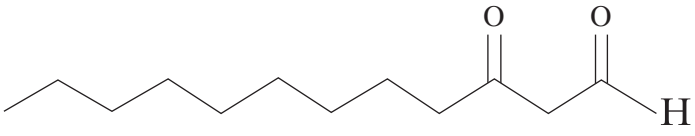
Macroscopic features and chemical components

Chemical components influence the taste of medicinal materials. In some situations, the bioactive constituents in a given medicinal are linked with the chemicals that produce taste. For example, sour medicinals generally contain organic acids, such as *shan zha* (Crataegi Fructus) and *shan zhu yu* (Corni Fructus). The bitterness of some medicinals is often related to the presence of alkaloids, iridoid glycosides and some saponins; examples include *huang lian* (Coptidis Rhizoma) and *zhi zi* (Gardeniae Fructus). Sweet medicinals often contain polysaccharides, such as *gou qi zi* (Lycii Fructus) and *dang shen* (Codonopsis Radix). Acrid medicinals typically contain volatile oils, such as *gan jiang* (Zingiberis Rhizoma) and *xi xin* (Asari Radix et Rhizoma). The saltiness of some medicinals is related to the presence of inorganic salts, as in the case of *mu li* (Ostreae Concha) and *hai piao xiao* (Sepiae Endoconcha). Astringency is generally associated with tannins; examples include *wu bei zi* (Galla Chinensis) and *he zi* (Chebulae Fructus). In the above examples, taste reflects medicinal quality to a certain degree.



The five flavors of Chinese medicinals- sour (*shan zha*), bitter (*huang lian*), sweet (*gan cao*), acrid (*gan jiang*), and salty (*mu li*)

The odor of medicinal materials can also reflect chemical constituents. For example, the fishy smell of *yu xing cao* (Houttuyniae Herba) correlates with its constituent houttuyninum. Similarly, the medicinal *ji shi teng* (Paederiae Herba) has an unpleasant odor similar to chicken excrement, which correlates with its characteristic volatile oil composition.

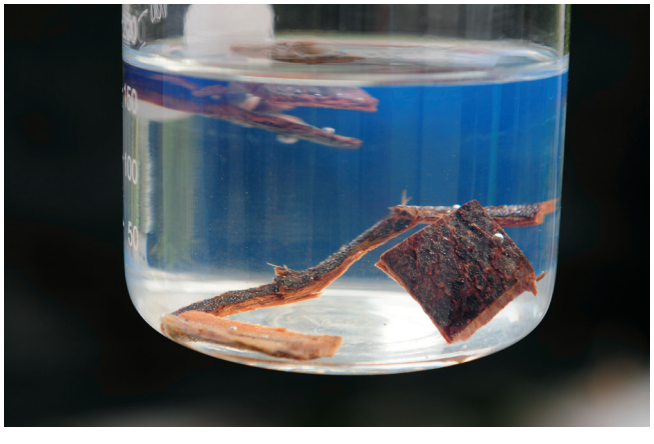


The chemical structure of houttuyninum

Historically, materia medica texts often recorded standards of quality assessment related to macroscopic features. For example, in the *Origins of the Materia Medica* (*Ben Cao Yuan Shi*), the text notes that "*rou cong rong* (Cistanches Herba) that is fat, large and soft is high quality, while that which is dry, withered, and thin is inferior"; regarding *da huang* (Rhei Radix et Rhizoma), it states "[material] from the Sichuan region with a brocade pattern is superior."

Generally speaking, medicinal materials that are dry, large, heavy, and firm are regarded as high quality. Dry medicinal materials have typically not absorbed moisture or become damaged by mold, while large, heavy, and firm materials often indicate that the original plant was vigorous and well-nourished, potentially indicating higher levels of active constituents.

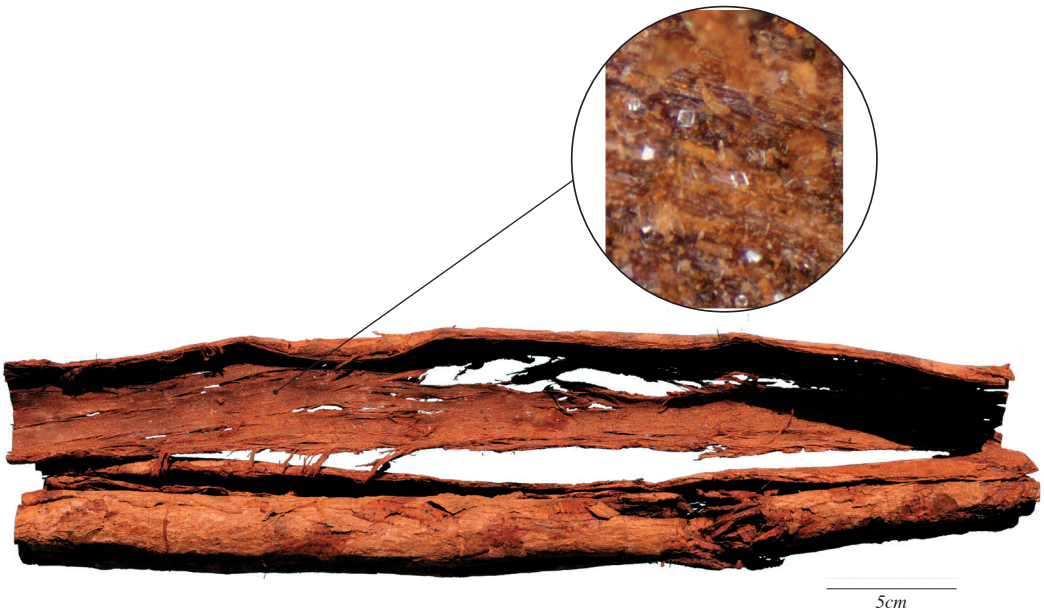
Modern research has shown that the macroscopic features seen in medicinal materials are often closely correlated with chemical constituents. For example, when genuine *qin pi* (Fraxini Cortex) is submerged in water, a fluorescent blue color can be seen in the water when observed under sunlight. This phenomenon is related to constituents found in *qin pi* known as esculin and esculetin. This observation was first recorded in the ancient Han Dynasty text *The Philosophers of Huainan* (*Huai Nan Zi*), which stated that "ash wood…when its bark is scraped off and submerged in water, [it becomes] true blue-green."



Qin pi (Fraxini Cortex) exhibits a fluorescent blue color when it is soaked in water and exposed to sunlight

In another example, *cang zhu* (Atractylodis Rhizoma) that has more "cinnabar dots" and shows frosting on the fractured surface after long storage periods is thought to be superior (Fig 14). The cinnabar dots are oil cells and the frosting results from the crystallization of atractylol, presenting as white needles on the outer fractured surface after prolonged exposure.

Frosting in the fractured surface of *cang zhu* (Atractylodis Rhizoma)



"Bright silver stars" in the inner surface of *hou po* (Magnoliae Officinalis Cortex)

The traditional technical term of "bright silver stars" refers to the educts of some chemicals. Examples include the educts of magnolol and honokiol in *hou po* (Magnoliae Officinalis Cortex) and the educts of paeonol in *mu dan pi* (Moutan Cortex).

Modern research on *Magnolia officinalis* and *Magnolia officinalis* var. *biloba* has demonstrated that trunk bark gradually increases in size and thickness over time, and the magnolol and honokiol content is highest after the tree has been growing for about 25 years. The quality of *hou po* (Magnoliae Officinalis Cortex) is thus related to macroscopic features such as thickness, color, and texture;

specifically, medicinal material that has thick bark, a deep color and a rough surface contains higher levels of magnolol and honokiol and is qualitatively superior. This largely reflects agreement with the traditional assessment criteria used to determine the quality of *hou po*.

In the case of *qing feng teng* (Sinomenii Caulis), research has revealed a relationship between the diameter of the vine and sinomenine, its main bioactive constituent. Large vines (over 3 cm) have the highest sinomenine content, followed by vines of a medium size (1–3 cm), while small vines with a stem diameter of less than 1 cm have the lowest content. In this example, there is a clear relationship between macroscopic features and quality.

Following the authentication and analysis of market specimens of *he shou wu* (Polygoni Multiflori Radix), it was discovered that the medicinal material on the market can be divided into two categories based on macroscopic features. One features a cut surface that is light yellowish-brown, strongly powdery, and has an obvious cloudy brocade pattern at the cortex. The other has a cut surface that is reddish-brown to reddish-purple, with a weakly powdery nature and a slightly horn-like texture; the markings in the cortex are small and generally do not form a cloudy brocade pattern. Chemical analysis reveals that the former group contains higher levels of anthraquinones while the latter group lacks or contains only trace amounts of anthraquinones. Further investigation shows that the former group contains higher levels of stilbene glucosides while the latter group contains low levels and thus may not be suitable specimens.

In addition to directly analyzing chemical constituents and gross macroscopic features, correlations between the appearance of medicinal materials and chemical constituents have been revealed by research investigating internal plant structures and chemical constituents. For example, it has been discovered that changes occur in the internal structures of American ginseng (*xi yang shen*) as the taproot develops with age; the relative proportions of xylem and phloem change, secretory ducts gradually stop developing, the starch content gradually declines, and the ginsenoside content gradually increases. By bringing together microscopic features, macroscopic features, and chemical analysis, such preliminary investigations are advancing Chinese medicinal quality control.

In another example, chemical analysis of the anatomical structures and plant tissues of *shan zhu yu* (Corni Fructus) has revealed that the pigment cells within the exocarp and mesocarp are rich in saponins and polysaccharides, and the thin-walled cells in the mesocarp have already formed saponins before the fruit is mature. As the fruit matures, the saponins gradually increase and accumulate. Thus, *shan zhu yu* medicinal material is best when the fruit is mature and the color is purplish-red.

In recent years, laser microdissection (LMD) has been applied to separate target plant cells and tissues. Using laser microdissection to determine the distribution of chemical components in specific plant cell populations makes it possible to map the active components in the tissues of Chinese medicinal materials. In the future, laser microdissection and modern analytical techniques should be combined to map active components in the tissues and cells of medicinal materials. By using these techniques, the relationship between macroscopic features and active components can be more fully explored.

For example, recent research using new technology has revealed close relationships between the internal structures, macroscopic features, and chemical constituents of certain medicinal materials. In the case of *qing feng teng* (Sinomenii Caulis), research utilizing matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry (MALDI-TOF-MS) has revealed that

different alkaloids are localized in different plant tissues of the stem, such as the cortex, phloem, xylem, and pith. Further research revealed that the active constituent sinomenine is primarily distributed in the stone cells and fibers.

From the above examples, it can be seen that modern anatomical, histochemical and phytochemical methods provide scientific data that has the potential to validate relationships between macroscopic features and medicinal quality. Exploring correlations between active components and macroscopic characteristics is an important aspect of Chinese medicinal identification.

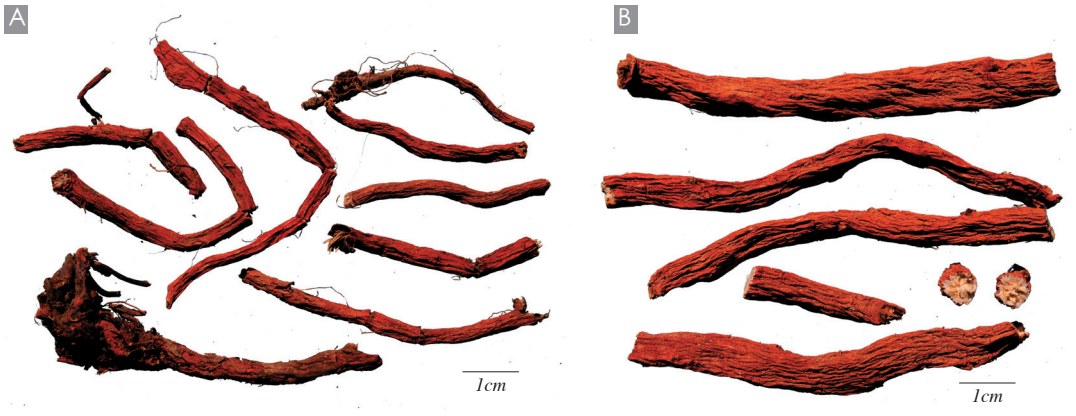
New Topics, New Debates

The gradual development of macroscopic authentication methods has resolved many problems over the past thousand years, but as society develops and the environment changes, new challenges arise that were not addressed in historical records. Newly emerging issues must be addressed and knowledge must be continually updated as new developments occur.

Cultivated and wild resources

In ancient times, most Chinese medicinal materials were derived from wild sources. In the modern day, wild resources have not been able to keep up with the increasing demand for medicinal products. The cultivation of medicinal plants has thus developed quickly, and standardized management approaches for the cultivation of medicinal plants are gradually being established in China.

However, factors such as soil, climate, temperature, and fertilizer application not only influence plant metabolites, but also affect macroscopic features. For example, wild vs. cultivated samples of *dan shen* (Salviae Miltiorrhizae Radix) appear very different. Wild samples have rough exterior cork bark that is easily peeled off; cultivated samples are bigger with a solid and dense epidermis and few fibrous roots. As there were few cultivated medicinal plants in ancient times, there is no advice in the ancient texts.



Wild [A] and cultivated [B] *dan shen* (Salviae Miltiorrhizae Radix)

Similarly, the quality and appearance between wild and cultivated *fang feng* (Saposhnikoviae Radix) varies due to differences in soil, fertilizers, and water management. When compared with wild *fang feng*, cultivated medicinal material is generally thick and strong, and its "earthworm head" phenomenon is not obvious. Culivated material is also slightly heavy, relatively powdery, and the color of the "chrysanthemum center" is light; the fractured surface reveals a fissured and under-developed cortex, the aroma is slightly weak, and the taste is sweet and not acrid.

In recent years, the use of fertilizers has hastened plant growth, causing changes in morphological features. For example, cultivated *ban xia* (Pinelliae Rhizoma) not only grows very large, it also sometimes sprouts out small rhizomes. In the case of *jiao gu lan* (Gynostemmae Pentaphylli Herba), two varieties have emerged after cultivation, one bitter and one sweet. In many other examples, research has shown that cultivated products are not necessarily inferior to wild products.

Changes in macroscopic features that may be caused by cultivation should be recorded and updated. Furthermore, laboratory analysis should be used to determine which macroscopic characteristics are associated with higher quality, thereby providing useful information for growers, sellers, and consumers.

Closely related species and hybrids

As the natural resources of medicinal plants decline, many closely related species have become employed for medicinal use. Additionally, advances in cultivation techniques and biotechnology have introduced new hybrid varieties of medicinal plants onto the market. Looking at widely cultivated plants such as apples, it can be seen that a single species has produced hundreds of varieties through horticultural innovation. Thus, as wild resources decline and cultivation technology advances, Chinese medicinal classification and differentiation will also gradually transform.

For example, in the Nanyang region of Henan province, several hybrid varieties of *xin yi hua* (Magnoliae Flos) have already emerged. Among them, the varieties known as *ye hua wang chun yu lan*, *tao shi wang chun yu lan*, and *hou zhang wang chun yu lan* are superior.

Species closely related to the original species are often quite similar in terms of morphology, such as hybrids and intra-specific taxa. Such items must be carefully investigated and differentiated based on plant taxonomy or modern laboratory methods, such as molecular biological identification.

In the case of the various species used as *xin yi hua*, for example, the flower buds look very similar, but the varieties are easy to differentiate based on taxonomy. The species *luo tian yu lan* (*Magnolia pilocarpa* Z.Z. Zhao et Z.W. Xie) is similar to *wang chun hua* (*Magnolia biondii* Pamp.), but the leaves are inverse ovoid, the flat end often has a short, sudden sharp tip, the flower is relatively large, the outer whorls are triangular, the pistil base is covered in hairs and the aggregate fruit is often covered in hairs.

Magnolia pilocarpa Z.Z. Zhao et Z.W. Xie

Additionally, some closely related varieties or hybrids have obviously different macroscopic features. For example, in the case of *zhi zi* (Gardeniae Fructus), the *Chinese Pharmacopoeia* records the dried mature fruit of *Gardenia jasminoides* Ellis (*zhi zi*). However, in actuality the products on the market include the mature fruit of several varieties, including *G. jasminoides* Ellis f. *longicarpa* Z.W. Xie et Okada (*shui zhi zi*) and *G. jasminoides* Ellis var. *grandiflora* Wakai (*da hua zhi zi*). Notably, *Gardenia jasminoides* Ellis is the variety that should be used in Chinese medicine, while *G. jasminoides* Ellis f. *longicarpa* Z.W. Xie et Okada is generally used as a source of dye. Based on their appearance, *Gardenia jasminoides* Ellis is round and small, while *G. jasminoides* Ellis f. *longicarpa* Z.W. Xie et Okada has a long, elliptical, round shape and is roughly twice the size of *Gardenia jasminoides* Ellis. Some medicinal varieties that are sold on the market are viewed differently in the worlds of taxonomy and medicinal materials, and no records can be found to discuss the macroscopic features of these materials. Such items thus need to be systematically investigated.

In some situations, new cultivar varieties arise through cultivation and selection. In the case of *zhi qiao* (Aurantii Fructus), several cultivars of the source plant *Citrus aurantium* L. have been developed in its main production area of Guangdong province of China, such as *C. aurantium* 'Huangpi', *C. aurantium* 'Daidai', *C. aurantium* 'Chululan' and *C. aurantium* 'Tangcheng.'

When subjected to long-term cultivation, intra-species variation happens due to human interference. For example, in Shandong province, more than ten varieties of *Lonicera japonica* Thunb. can be observed based on differences in the plant shape, shoot shape, internode length, inflorescence, and shape of the flower bud.

Decoction pieces

Raw medicinal materials used in Chinese medicine are first processed into "decoction pieces" before they are employed clinically. "Decoction pieces" are dried, cut forms of medicinal materials that can be directly decocted or extracted, and they represent the most common form of Chinese medicinal materials in commerce and clinical practice.

Over time, the techniques and equipment used to process medicinals and decoction pieces have evolved, ushering in new topics in the field of macroscopic identification. The effects of these changes on macroscopic features, as well as variations in processing methods between northern and southern regions of China, are worthy of deep investigation.

Additionally, the development of a modern commodity-based society and the market economy has a certain influence on the macroscopic characteristics of some medicinals. In order to maximize profit, some items are processed to cosmetically alter the appearance of the material prior to sale. In particular, fumigation with sulfur is commonly used to enhance the appearance and prevent mold in certain medicinals, including: *bai he* (Lilii Bulbus), *chuan bei mu* (Fritillariae Cirrhosae Bulbus), *shan yao* (Dioscoreae Rhizoma), *ju hua* (Chrysanthemi Flos), and *dang gui* (Angelicae Sinensis Radix).

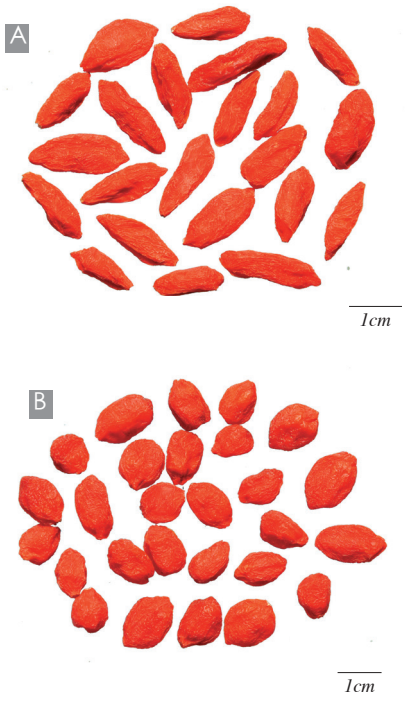
Of even greater concern, some unscrupulous vendors produce counterfeit or inferior medicinal materials. For example, the medicinal *he shou wu* (Polygoni Multiflori Radix) is supposed to be processed into *zhi he shou wu* (Polygoni Multiflori Radix Praeparata) by either steaming it directly or steaming it after soaking it in black bean juice. However, *he shou wu* that was simply dyed black to mimic the processed form *zhi he shou wu* has been found in herbal markets. These two items can be distinguished by observing their cut surfaces: The properly processed item has a brownish-black cut surface while the counterfeit has a brownish-yellow cut surface.

Zhi he shou wu (Polygonum Multiflori Radix Praeparata) [A] and artificially colored *he shou wu* (Polygonum Multiflori Radix) [B]

Harvest time, production area and storage period

Chinese medicinal materials harvested during different growing periods are often different in terms of morphology. For example, when *lian qiao* (Forsythiae Fructus) is harvested at an earlier stage, it has a greenish-brown, indehiscent tip and can be split to reveal seeds inside; when harvested at an advanced stage, it is yellowish-brown or reddish-brown, splits in two parts, and most of its seeds fall off. In another example, *tian ma* (Gastrodiae Rhizoma) is divided into *chun ma* ("spring gastrodia") and *dong ma* ("winter gastrodia") depending on its time of harvest. *Dong ma*, which is harvested after the winter solstice, is relatively firm and heavy, with a reddish-brown "parrot beak-shaped" sprout at the tip. *Chun ma*, harvested before the traditional Chinese tomb-sweeping festival in the spring, is relatively loose and light, with remnants of stem at the tip.

Medicinal materials from different production areas also exhibit different macroscopic features. For example, the shape of *gou qi zi* (Lycii Fructus) varies depending on its production region. The item produced in Ningxia province is a long oval shape, with a slightly sweet taste, and it is red and moist; when soaked in water, the water stays clear and the pieces are light and easily float. The item produced in Xinjiang province is round and sweet, and is initially red when fresh but later becomes dark and easily becomes soft; the pieces are heavy, and after soaking in water they turn the water red and easily sink.



Gou qi zi (Lycii Fructus) produced in Ningxia province [A] and Xinjiang province [B]

The case of *bai zhi* (Angelicae Dahuricae Radix) is another representative example of differences in production regions. Samples produced near the city of Yuzhou in China's Henan province are named "*Yu bai zhi*" and the resulting decoction pieces are named "starchy pieces (*fen pian*)"; they are relatively short and small, strongly powdery at the fractured surface, and have small, light brown oil cavities in the cortex. By contrast, samples produced near the city of Anguo in China's Hebei province are named "*Qi bai zhi*" and the resulting decoction pieces are named "oily pieces (*you pian*)"; they are only slightly powdery when fractured, with large and dense light-brown oil cavities in the cortex.

Prolonged storage often changes the color, odor or taste of medicinal materials. For example, *wu wei zi* (Schisandrae Chinensis Fructus) and *gou qi zi* (Lycii Fructus) become black after improper or prolonged storage. In the case of *shan zhu yu* (Corni Fructus), newly harvested samples appear purplish-red and have a sour odor; after storage they become brown, with a faint odor and a sour, bitter, and astringent taste. In the case of *chen pi* (Citri Reticulatae Pericarpium), newly harvested samples have an orange-red or reddish-brown surface and have an aromatic odor. After long-term storage, the color becomes dark, the odor becomes strongly aromatic, and the quality is regarded as superior.

Although my mentor Prof. Xie Zongwan passed away over five years ago, his 60 years of accumulated experience in medicinal authentication lives on in the concept of *bian zhuang lun zhi* (differentiating appearance to identify quality), the essence of macroscopic identification. The importance of macroscopic identification is evident in modern pharmacopoeia standards; indeed, macroscopic descriptions are listed prominently in the official pharmacopoeias of China, Japan, Vietnam, Korea, India, Britain, and the Philippines, as well as the United States Pharmacopoeia and the Pharmacopoeia of the European Union.

Many challenging topics related to the classification, differentiation, and quality assessment of medicinal materials have remained unresolved for over a thousand years, setting the stage for new scientific frontiers in authentication and medicinal safety. Regardless of whether in China or abroad, in the past or the present, traditional experience-based differentiation remains fundamental for resolving the questions that lie at the heart of Chinese medicinal authentication. Just as *bian zheng lun zhi* (differentiating patterns to identify treatment) is fundamental for the clinical practice of Chinese medicine, *bian zhuang lun zhi* (differentiating appearance to identify quality) captures the essence of medicinal authentication, and should be preserved, disseminated, and diligently explored.