Identification of *Cannabis* Fiber from the Astana Cemeteries, Xinjiang, China, with Reference to Its Unique Decorative Utilization[1]

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Identification of *Cannabis* Fiber from the Astana Cemeteries, Xinjiang, China, with Reference to Its Unique Decorative Utilization: In the Turpan District of Xinjiang, China, large numbers of ancient clay figurines, with representations including equestrians, animals, and actors, have been excavated from the Astana Cemeteries and date from about the 3rd to the 9th centuries C.E. Based on visual inspection, the tails of some of the figurines representing horses are made of plant fibers. Fourier Transform Infrared (FTIR) spectroscopy, light microscope examination, and drying–twist tests demonstrated that these fibers were extracted from one or more stalks of hemp (*Cannabis*) plants. This is a unique report of the utilization of *Cannabis* bast fibers for figurine decoration in ancient Turpan.

阿斯塔那古墓群出土大麻纤维的鉴定分析及其装饰功能的探讨. 中国新疆吐鲁番地区阿斯塔那古墓群出土了大量年代为公元3–9世纪的泥俑, 其中包括骑马俑, 动物俑和演员俑等。肉眼观察发现骑马俑的马尾可能由植物纤维制成。通过傅里叶变换红外光谱、光学显微镜观察和纤维旋转方向实验鉴定出这些植物纤维来自于大麻纤维。这一发现为我们提供了吐鲁番先民利用大麻纤维装饰泥俑的新证据。

Key Words: *Cannabis*, fiber plant, Astana Cemeteries, clay figurines, ethnobotany.

Introduction

The ancient tombs of the Turpan District in Xinjiang of northwestern China have very stable, extremely dry environments. These consistently arid conditions have helped preserve numerous artifacts over many centuries, even millennia. Among these ancient Turpan tombs, those in the Astana Cemetery complex are particularly well–known for their abundant unearthed mummies, written documents, textiles, plant remains, and food residues (Chen et al. 2012; XIA 1983). This ancient cemetery, which covers an area approximately 10 km^2, served as a public graveyard for the ancient Gaochang people (residents of Turpan, dating from about the 3rd to the 9th centuries C.E.). The cemeteries are located at the base of the Flaming Mountains (Huoyan Shan), and lie in the delta plain of the Mutougou River (Fig. 1).

Like many ancient tombs in China, a large number of figurines deposited with the deceased as grave offerings have been excavated from the Astana Cemetery complex. The figurines recovered from these tombs consist of two types according to the

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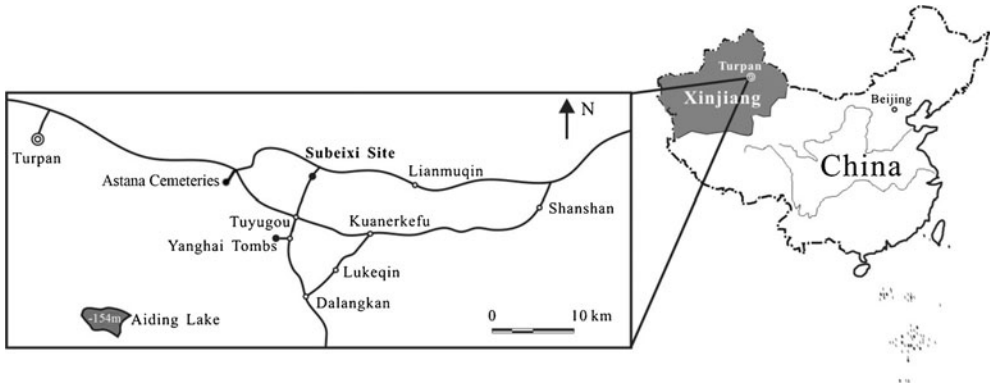

Fig. 1. Location of the ancient Astana Cemeteries in the Turpan District of Xinjiang in Western China. Adapted from Gong et al. 2011.

material from which they were fabricated: wooden and earthen, with the latter accounting for the vast majority of these kinds of artifacts (XIA 1983). The clay figurines represent a great variety of types of people and animals, including actors, horses, etc. Most of the equestrian figurines were coated with pigment and some contain wood skeletons inside the ceramic structures. The figurine under study here has plant fibers extending from the posterior area to represent a horsetail (Fig. 2).

Previous studies of these figurines have been undertaken from the perspectives of art form, manufacture technique, and pigment source (Sun 2007; Zheng et al. 2013), but no detailed analysis had focused on the plant fiber source of the horsetails. Basic preliminary observations suggested that these fibers derive from plant phloem fiber. However, prior to this study, the anatomy and species source of fiber had not been identified scientifically. In order to verify the botanical source of the horsetail fibers, to determine any possible symbolic or historical importance associated with the fibers, and to establish their relationship with the equestrian figurine, the plant fibers used to represent the horse's tails were studied using methods described below. This was followed by a review of the archaeological and traditional ethnobotanical significance of fiber in the region where it was discovered.

Materials and Methods

Determination of the plant source of the fibers used to represent horsetails on the ancient earthenware models was carried out using samples

Fig. 2. The equestrian figurine from tomb No. 73TAM214 (36 cm in height, 29 cm in length, and 10 cm in width). Scale measure = 5 cm. The line drawings provide different perspectives of the artifact.

from an equestrian figurine excavated from ancient Astana tomb 73TAM214. Based on previous archaeological research (Lu 2000; XIA 2000), tomb 73TAM214 is a sloping cave–cum–shaft grave, which belongs to a family cemetery that is approximately 1,300 years old. Two bodies, one man and one woman, were discovered placed on reed mats in this tomb. A large number of funerary objects have been recovered from this tomb, including household pottery, wooden wares, figurines, textiles, etc. An epitaph with text dating it to 665 C.E. was unearthed in the same tomb, which indicates that the deceased in this burial place stemmed from an eminent family with high status in the local society.

The model of a male rider on the horse depicted in the equestrian figurine wears a Chinese traditional hat (called a "Fu head"), a round neck gown, and pair of black boots (Fig. 2). A black belt is shown tied around his waist. The rider's right hand is shown placed on his leg in a seemingly natural way with his left hand placed on his chest. The horse is coated with red and white colored pigment and the saddle is decorated with black patterns. This figurine artifact is currently deposited in the Xinjiang Uygur Autonomous Region Museum (specimen number 73TAM214:32). Published keys designed to aid fiber source identification were selected for comparison (e.g., Ilvessalo-Pfäffli 1995; Yu and Li 1955). Three analytical methods described below were used to determine the botanical identification of the decorative horsetails.

Fourier Transform Infrared (FTIR) Spectroscopy Analysis

The ancient fiber and three modern species of fiber—hemp (*Cannabis indica* Lam.), ramie (*Boehmeria nivea* L.), and velvetleaf (*Abutilon theophrasti* Medic.)—were examined and compared. The surfaces of the fibers were cleaned with absolute ethyl alcohol, and then pressed against the attenuated total reflectance (ATR) crystal "window" for quantitative assessment. Fourier Transform Infrared (FTIR) spectroscopy analyses were performed on a Nicolet 6700 FTIR spectrometer equipped with an ATR accessory in the Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences. The spectra were recorded over the range of 4,000–600 cm^{-1}, with a resolution of 4 cm, and averaged over 32 scans. Subsequent manipulation was carried out with OMNIC software.

Light Microscope (LM) Examination

A short piece of the horsetail bundled with fibers was cut with a scissors and embedded in collodium to form a block. Subsequently, cross–sections were sheared from the block using a slide microtome, then dyed and observed using an optical microscope.

A small amount of the horsetail fibers were removed from the ancient figurine and placed in a 1:1 acetic acid and hydrogen peroxide mixture solution, and then isolated at a temperature of 60 degrees centigrade for six hours in a drying oven. Subsequently, deionized water was added to rinse the mixture solution. This procedure was followed by selecting individual fibers that were chosen for examination. Each fiber was dipped in glycerin and then placed on a slide with a cover slip affixed to the specimen. Slides were then viewed under a Nikon eclipse LV100POL light microscope at a magnification of 500× for species identification and photographic documentation.

Drying–Twist Test

Previous studies have shown that once a wet bast fiber is exposed in the air and gradually dries, it will rotate in a clockwise or counterclockwise direction according to the tendency of the plant species to which it belongs (Martha 1987; Wang et al. 2007). In this study, a wet fiber was taken and one of its ends was clasped with a tweezers. The other end was hung in the air and turned to face the observer. As the fiber dries, its hanging end will rotate. Available published references as well as our own studies have demonstrated that flax (*Linum usitatissimum* L.) and ramie fibers will rotate clockwise, while fibers of hemp and velvetleaf, two other known species that could have been available as a source of bast fiber for use in the ancient figurine production, will rotate counterclockwise (ARGSTRI and SSIC 1980; Haugan and Holst 2013a, 2013b; Wang et al. 2007).

Results

The artificial horsetail on the ancient figurine under study is 25 cm in length. While the individual fiber strands (a combination of multiple individual fibers) vary in thickness, they are on average 1.0 mm in width. The fibers comprising the artificial horsetail still retain a brown cortex, even without the use of a degumming treatment. There are no epidermal hairs present and only some hair bases can be

observed (Fig. 3A). The inner phloem exhibits a natural yellow–white color (Fig. 3B), and under transmitted light, a single fiber appears as long and thick–walled, tapering gradually to a blunt end. Pronounced dislocations, cross–markings, and longitudinal striations occur on the surface (Fig. 3H, I). Part of each fiber is a cylindrical tube, and the other section forms a flat ribbon–like structure. The average width of an individual fiber is 20 µm. The cross–section is polygonal or subovate in outline, with irregular shape (Fig. 3C). The lumen, or hollow sections of the fiber cells are predominately rectangular, oval, or linear; as noted above, the drying–twist tests

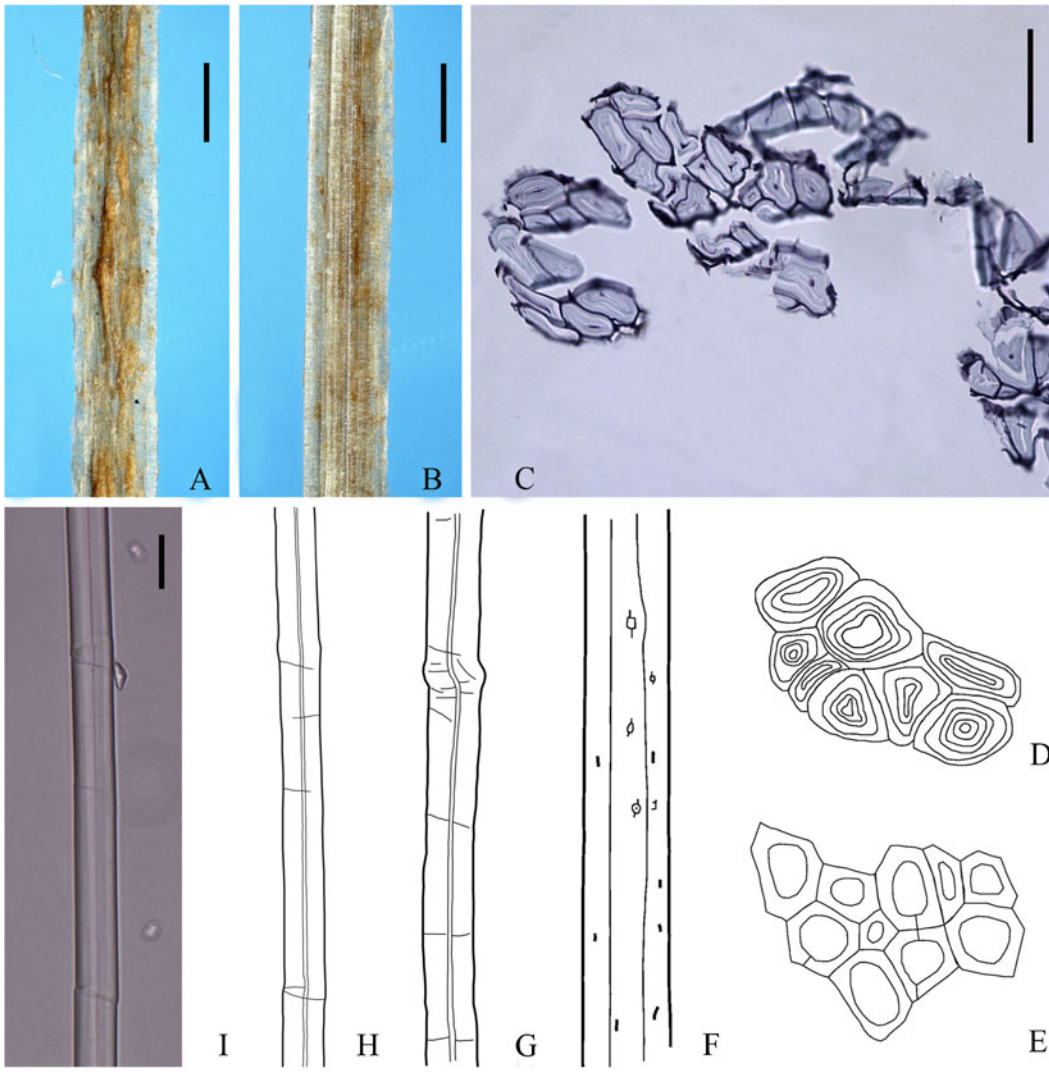

Fig. 3. Fibers from archaeological and modern samples. (A) The typical outer side of the archaeological fibers from the tomb of 73TAM214, scale measure = 1 mm; (B) The typical inner side of the archaeological fibers from the tomb of 73TAM214, scale measure = 1 mm; (C) The cross–section of the archaeological fibers from the tomb of 73TAM214, scale measure = 50 µm; (D) Line drawing of the cross–section of *Cannabis* sp., which is polygonal or subovate in outline; (E) Line drawing of the cross–section of *Abutilon theophrasti*, which has an oval shape and relatively large lumen; (F) Fiber of *A. theophrasti*, which has no cross–markings on the surface, but many visible pits; (G) Fiber of *Cannabis* sp. with pronounced dislocations, cross–markings, and longitudinal striations present on the surface; (H) Line drawing of an individual isolated fiber from the archaeological fibers from the tomb of 73TAM214; (I) An individual isolated fiber from the archaeological fibers from the tomb of 73TAM214, scale measure = 20 µm (Figs. 3D–3H are adapted and modified from Yu and Li 1955).

showed that the ancient fibers rotate in a counterclockwise direction.

Figure 4 shows the results of the ATR–FTIR spectra analyses of fiber samples from (A) the ancient artificial horsetail, (B) modern hemp, (C) modern ramie, and (D) modern velvetleaf. The spectra of the ancient fibers showed recognizable infrared absorption peaks at 3,334, 2,920, 2,851, 1,622, 1,557, 1,418, 1,370, 1,317, 1,240, 1,100, 1,054, 896, and 779 cm^{-1}. The spectra of the modern hemp and ramie samples were very similar to those for the ancient fiber. Although the spectra of velvetleaf fiber samples had more peaks within the 1,650–750 cm^{-1} range, they had no peak at 779 cm^{-1}. In addition, the strength of the peaks for the velvetleaf fiber, which are related to the content, also was different from those of the ancient fiber (Liu et al. 2010; Paul and Paul 2003; Wang et al. 2007).

Affinity

The data from the FTIR analyses showed that the previously unidentified ancient fiber is more akin to hemp and ramie. However, the result of the drying–twist test demonstrated that the unknown fiber rotated counterclockwise when it became dry, which is similar to the rotation direction of hemp and velvetleaf fibers, but opposite to that of ramie and flax. Compared with published cross–references (e.g., Ilvessalo-Pfäffli 1995; Yu and Li 1955), the ancient fibers most closely resemble those of *Cannabis* based on the cell shape of the cross–section as well the structure of the radial cell wall (Fig. 3D, E, F, G). By virtue of the above studies, the present specimen shows the most affinity with bast fiber of *Cannabis*.

Discussion and Conclusions

Since prehistoric times, biotypes of *Cannabis* have been widely used for a number of significant purposes. For example, the seeds have been eaten and crushed to produce oil for lamps or cooking, the flowering heads and leaves produce resin that has long been used as medicine or mind–altering substance, and the stems produce long, durable

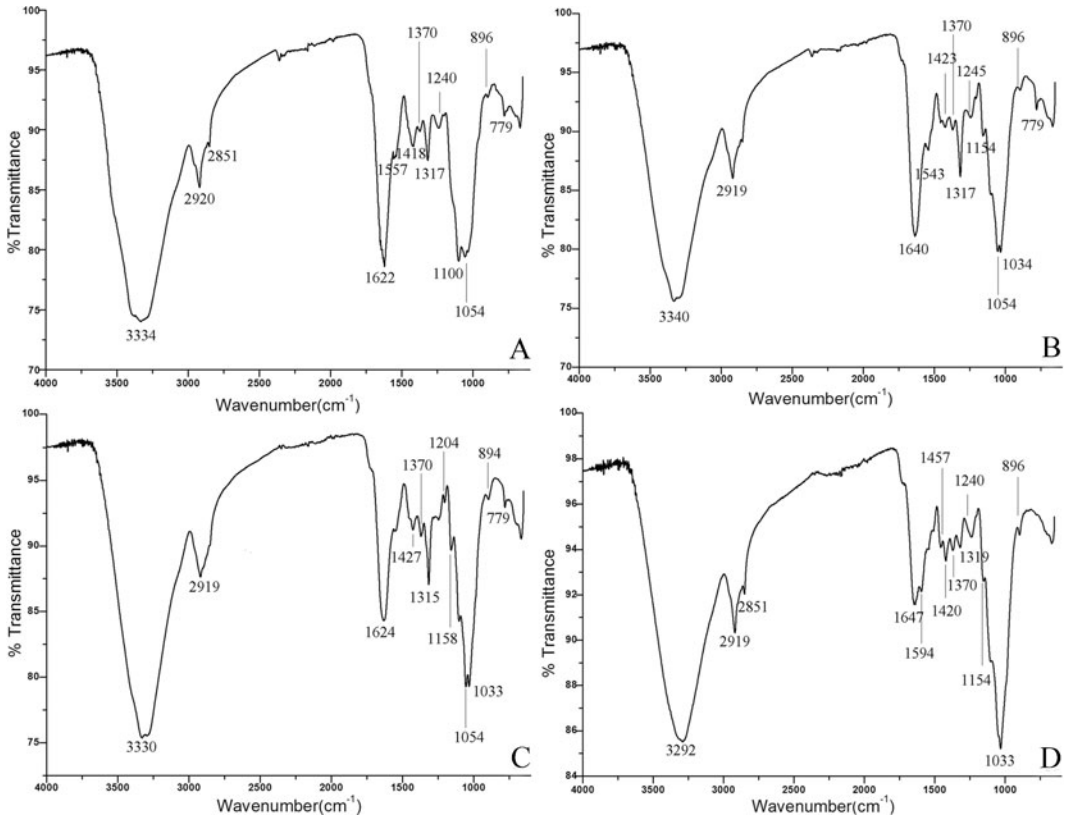

Fig. 4. ATR–FTIR spectra of (A) ancient fiber, (B) modern hemp, (C) modern ramie and (D) modern velvetleaf.

fibers for textile, rope, paper, etc. (Merlin 2003). Among the various usages, it can be argued that fiber derived from *Cannabis* has served as one of its most important applications for humans through the ages (Li 1974a, 1974b; Lu and Clarke 1995). The available data suggest that the utilization of plant fibers for cordage or even cloth processing may be dated to as early as about 30,000 years ago (e.g., Kvavadze et al. 2009). The ancient distribution, antiquity, and significance of *Cannabis* use for fiber and several other uses in terms of the archaeobotanical, archaeological, and historical record are discussed in detail by Clarke and Merlin (2013).

As one of the most significant traditional sources of bast fibers, we know that *Cannabis* has been used as a fiber source and other purposes for thousands of years in China. In Turpan, archaeological records have substantiated a close, ancient association between people and *Cannabis*. Presently, the earliest finding of macrofossils including seeds and other plants parts of *Cannabis* were recovered from the Yanghai Tomb, which also contained an entombed man associated with shamanistic tradition. The remarkable intact floral and other plant remains from this site have been unambiguously identified as belonging to *Cannabis* and dated to be around 500 B.C.E. Based on the shamanistic background of the deceased man, the preserved female floral parts of the *Cannabis* material are assumed to have been placed in the tomb for ritual/medicinal purposes (ATXUAR and XIA 2011; Jiang et al. 2006; Russo et al. 2008). Furthermore, a small cache of *Cannabis* fruits supplied as funeral objects, possibly as cereal offerings, was discovered in another contemporaneous tomb, 72TAM209, of the Astana Cemeteries; these archaeobotanical remains have been dated to 658–706 C.E., according to an unearthed epitaph and the written documents discovered in the tomb (Chen et al. 2012).

In addition to its psychoactive and food utilization mentioned above, the ancient fiber (or hemp) use of *Cannabis* in the Turpan region appeared to be at least as important and extensive if not more so. It is generally accepted, based on both literary sources and archaeological findings, that the primary textile fibers utilized in this region during the Subeixi Culture (1000 B.C.E. to 100 C.E.), and perhaps even earlier, was wool (TIACR 1984; XIA and BCRTP 2004; XIA and MT 2002). However, after the period of the Han dynasty (202 B.C.E. to 220 C.E.), with the further development of the "Silk Road" trade routes and the migration of people from the eastern part of China, the main textile fibers utilized in Turpan were hemp and silk. Since silk clothing was normally utilized by people with high status and great wealth, hemp fiber was generally used in the production of clothing for the masses (Qi 1997). Although additional fibers, such as cotton (*Gossypium* sp.), are infrequently mentioned in contemporary literary sources and unearthed from some ancient tombs, they did not play an important role in ancient Turpan (e.g., see Cao et al. 2009; Wang 1983). This fiber usage pattern has also been supported by archaeological findings. For example, large amounts of ancient cloth and paper, as well as shoes, made from hemp fiber have been unearthed from the Astana Cemeteries, and a large proportion of them were produced locally (Li 1974a; Wang 1981).

Previous studies have demonstrated that a variety of crops, including *Cannabis*, were cultivated by the indigenous people of ancient Turpan, and that agriculture rose to a fairly high level after the period of the Han dynasty (Chen et al. 2012). Furthermore, hemp is a fast growing plant and, when compared with other available crops, would have been less dependent generally to the regional vagaries of climate, soil quality, nutrients, and especially irrigation. With the availability of water, the relatively high levels of light and heat resources in Turpan would have provided adequate environmental conditions for the seasonal growth of hemp. A number of relevant archaeological studies suggest that *Cannabis* was an important economic plant and continued to be for the indigenous people in parts of Xinjiang from the period of the Subeixi culture (1000 B.C.E to 100 C.E.) to the Jin and Tang dynasties (about the 3rd to the 9th centuries C.E.) (Jiang et al. 2006, 2007; Wang 1981). Among the various ancient fiber uses of *Cannabis* fiber in this region is the unique ornamental utility described in this paper.

The practice of using organic matter, especially plant material, for a variety of purposes included usage as terracotta figurine accessories, which we now know had a long history in China. A large number of naked terracotta figurines without arms were discovered in the Yangling Mausoleum of Emperor Jingdi (188–141 B.C.E.), Western Han Dynasty. The arms and clothing of the figurines are generally considered to have

consisted of organic materials, most likely derived from plants (ATHDMIASP 1994). In a majority of cases, because of their perishable property, plant remains have not been commonly preserved. However, the plant remains of hemp fiber were well preserved in the Astana Cemeteries due to the extremely dry climate. The appearance and other properties of *Cannabis* fiber made it a suitable material for the horsetail of the terracotta ancient figurine featured here. The fibers of *Cannabis* hemp are relatively long and persistent when environmental conditions are adequate. The artificial horse tail attached to the ancient figurine is droopy and pliant. When a bundle of hemp fiber is put together, it closely resembles real horsetail as can be seen in Fig. 2. To date, no other bast fibers, such as *L. usitatissimum* or *A. theophrasti*, have been discovered in the Astana Cemeteries. Although fiber of cotton was present and utilized at that time, it is too soft to be made into a durable form that resembles a horsetail. Since the indigenous people in Turpan have long used hemp fiber in many aspects of their daily life, and were therefore very familiar with its features, it was quite natural for them to have associated the appearance of suspended hemp fibers as an adequate way to represent a horsetail like the one on the figurine in this study. The multiple utilization of hemp fiber provides us with significant information about aesthetic ideas and funeral concepts of inhabitants in Turpan and thus also helps provide a deeper understanding of the ancient utilization of *Cannabis* during the remote past.

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