CLOSE WORK WITHOUT MAGNIFYING LENSES?

A Hypothetical Explanation for the Ability of Ancient Craftsmen to Effect Minute Detail

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1a, b
The remarkable minute engraving can be seen on this gem stone. It is shown at 1:1 (1a) and in a four to one (4:1) enlargement (1b). The gem stone is Roman, about third century A.D. It is made of carnelian and is from the Metropolitan Museum's Collection, published by Gisella Richter, *Catalogue of Engraved Gems*, Plate LX, 1956.

To many, a puzzling mystery of the ancient world is how minute artifacts or parts of them were made without magnification. Dramatic examples of this include small engraved Greek and Roman gems (Fig. 1a, b), coins with tiny engraved letters (Fig. 2a, b), the small intricate carving on certain ancient Near Eastern cylinder seals (Fig. 3a, b), the diminutive, compact cuneiform letters on certain clay tablets (Fig. 4) and the intricate jewelry of the Greek and Islamic Periods.

The craftsmen include not only the jeweler, scribe and lapidary, but the engraver of wood, ivory, metal and metal dies for coins. While there is no complete agreement, one prevailing scholarly view holds that magnification was not used in the ancient world, even though it may have been technically feasible. For example, Boardman in *Greek Gems and Finger Rings* states:

> Remarkably fine detail was achieved on some gems, detail which is not easily appreciated by the naked eye . . . and yet we must suppose that for ordinary purposes no magnifying aids were used for studying . . . the devices. Indeed, it seems very probable that the artists themselves had no such aids . . . Planoconvex inlays of rock crystal from Knossos have some value as lenses and some scholars have thought that they were in fact so used by Bronze Age engravers. But to be of any use to an engraver the lens must not seriously distort, and although the magnifying effect of crystal or glass in lens form may well have been observed at an early date, it is highly improbable that it was exploited by artists. No deliberately fashioned lenses have been found and it is unlikely that Pliny would have failed to mention their use.

The eyes made of rock crystal found on certain Egyptian sculptures such as that of Rahotep of the Old Kingdom and the convex rock crystal found by Layard at Nineveh fall into the same category as the pieces from Knossos described by Boardman.

There is general agreement that magnification, using eyeglasses, was not invented until the thirteenth century A.D. There is contention as to whether the inventors were English (Roger Bacon 1214-1294), Italian or Chinese at about the same time. The use of magnification during Greek times was recorded, but only for use as a burning glass; e.g. in Aristophanes' play *Clouds*, one of the characters says,

2a, b
a: The Islamic silver coin struck A.D. 968-79 was described by Carol M. Bier in *American Numismatic Society Museum Notes*, Vol. 24, June, 1979. It is of special interest because it bears the signature of the die engraver. Signatures are unique in the history of Islamic coinage. The inscription, according to Ms. Bier reads: "amal al-Hasan b. Muhammad (the work of Hasan, Son of Muhammad). It measures 5 mm. in length by 1.5 mm. in height . . . it is almost invisible without magnification (and) is finely and artistically executed." It is shown 1:1.
b: The inscription can be seen at four times magnification. There are almost twenty letters, some with serifs.

3a, b
a: The intricately engraved Early Dynastic III-A cylinder seal (about 2600-2500 B.C.) is from Syria (Gorelick Collection). The impression shows the minute, complex design. Seal height 3.6; diam. 1.29 cm.
b: This Scanning Electron Photomicrograph is of a cross section of a silicone impression. Since close work is made more difficult when it is complex and multilayered, as it is shown here, keen close vision is particularly critical.

When a summons is sent to me I will take this stone (i.e. burning glass) and place myself in the sun, I will at a distance melt all the writings of the summons.

In China the burning glass was used for cautery.

The purpose of this article is to explain, in hypothetical terms, how very close work, which today would be done under magnification, could have been accomplished in ancient times without it.

HYPOTHESIS

The hypothesis has several parts, as follows:

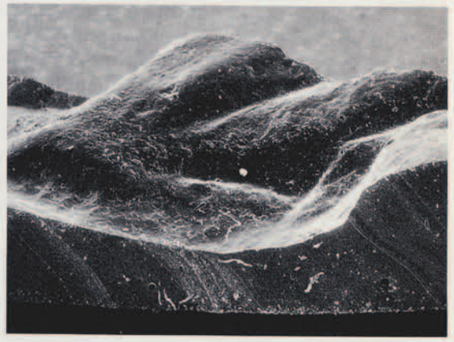
1. Close work was done by craftsmen who, due to their myopia, had excellent close vision and the capacity to see objects magnified.
2. An increase in the number of myopic craftsmen took place in fields requiring close work due to (a) the genetic nature of myopia, (b) the cultural patterns of the society, its ideological strictures and socio-economic organization which led to the relaxation of selection, i.e. as opposed to natural selection.

REFRACTIVE NATURE OF MYOPIA

According to Vaughan and Asbury,

The emmetropic (normal) eye is one in which parallel rays of light are brought to focus on the fovea (area of the retina adapted for most acute vision) without the use of accommodation. A hyperopic (farsighted) eye is smaller than normal and fails to converge the rays of light enough to focus upon the fovea without the use of accommodation . . . A myopic (nearsighted) eye is larger than normal and tends to focus light in front of the fovea. A concave ("minus") lens in front of the eye helps to diverge the light rays to focus on the fovea . . . (The) size of the eyeball governs the focus to a large extent.

The particular advantage of the myope is that he can see small objects magnified and with clarity by being able to bring them closer to his eye. The closeness and magnification depend upon the degree of myopia. For example: a −6 diopter myope can see



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The cuneiform characters on this Sumerian tablet of about 2000 B.C. are so minute that the noted Sumerologist Samuel Noah Kramer wrote in *Expedition* 1, 3, "We wonder how the ancient scribe succeeded in writing them and how, once written, he could read them without magnifying glass or microscope." Professor Kramer titled his article, "A Sumerian Document with Microscopic Cuneiform."

an object clearly at 6.2 inches from his eye, *magnified one and a half times*. A −10 diopter myope can see an object clearly 4 inches from his eye, *magnified two and a half times*. The reason for this can be seen in Fig. 5. This shows how the magnified image of an object is formed by drawing lines through the nodal point. The closer the object can be brought to the eye, the larger the image. An emmetrope and a hyperope would require a lens to see the same size object clearly. The strength of the lens needed would depend on age, accommodative ability and refraction of the eye. Accommodation according to Vaughan and Asbury,

> is the mechanism by which the focusing apparatus of the eye adjusts to objects at different distances.

The degree of magnification can be expressed as the following ratio:

$$\frac{\text{size of object}}{\text{size of image}} = \frac{\text{distance of object from the eye}}{\text{distance between the retina and nodal point.}}$$

The lens of the eye gradually loses elasticity with age, and a loss of accommodation takes place which affects the ability to do close work.

There is a blurring of near objects or discomfort or fatigue with attempted near work . . . Reading material must be held farther from the eyes to see the print.

This is presbyopia or "old sight". (Vaughan and Asbury).

According to Sheard,

It is a common error to think that presbyopia is a condition which commences at about forty-five years of age in emmetropes and earlier in hypermetropes. It is important to remember that the condition has been increasing throughout life . . .

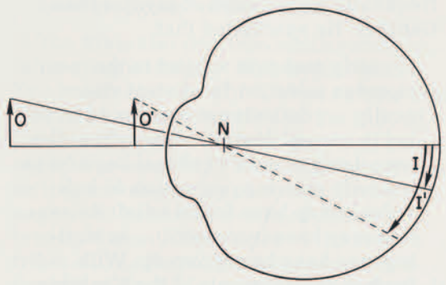
GENETIC NATURE OF MYOPIA

According to Keith,

The refraction of an eye is determined by the corneal curvature, depth of the anterior chamber, refractive index of the lens, curvatures of the anterior and posterior lens surfaces and the axial length of the eye. It can be shown that all these parameters are inherited as separate traits and there is a range of normal values for each one with a binomial distribution. However, the factors combined together tend towards emmetropia (normal) so that there is an excess of emmetropes over the theoretically expected number . . . it is now considered that the refraction is inherited in a multifactorial manner . . .

According to Vaughan and Asbury,

5
The diagram illustrates how and why magnification occurs as the object is brought closer to the lens. Magnification = $\frac{\text{diopters}}{4}$. According to the laws of optics, there is no difference in the essential nature of magnification, whether it is due to a lens, a myopic eye, or the accommodating power of a young normal eye. All three are capable of producing the angular magnification shown here.



Myopia may be caused by largeness of the eyeball (axial myopia) or by an increase in the strength of the refractive power of the media (refractive myopia). Myopia usually increases during the teen ages and levels off at about age 25 regardless of external factors, such as the amount of close work, lighting, rest, vitamins, endocrine balance, exercise, etc.

According to François,

The role of heredity in low myopia is . . . beyond doubt, as is shown by the study of twins . . . Low myopia is always transmitted as *an autosomal (i.e., non sex-linked) dominant* . . . In considering myopia in 257 cases Wold (1949) found that (1) when neither of the parents was a myope, there were 230 myopic children out of 645 (35%), a proportion corresponding, more or less, to that expected in recessive inheritance, and (2) when one or both parents were myopic, 309 out of 682 children (49%) were myopic, which corresponds to the proportion from dominant inheritance.

EVOLUTION AND MYOPIA

Population genetics provides a considerable amount of data consonant with our stated hypothesis. For example, in an article by Post (1971), *Relaxed Selection in Civilized Populations,* these data were considered. He showed how the incidence of myopia in primitive populations (African Bushmen, African Negroes, American Indians, Australian aborigines, certain natives of India (except Jews and Parsees) was rare or absent, but common in so-called civilized countries. He cited two studies that showed how Jewish schoolboys have vastly more myopia than English schoolboys and that Ashkenazi Jews have frequently higher rates of myopia than Gentiles. He speculated that

> . . . early man was subject to the most rigorous selection for distant vision acuity . . . defective vision would have led to speedy death . . . throughout the long dawn of man's cultural beginnings a slowly growing proportion of individuals may have found relief. Relaxation may have increased . . . as hunting may have been given up. With further developments of the Neolithic revolution, the trend towards relaxation probably proceeded more rapidly . . . Culture-habitats . . . supported specialists in industries which . . . were probably more tolerant of persons with slight refractive aberrations, particularly those who also possessed compensatory abilities. Some cultures may even have favored a mild myopia . . . provided support for them (and) lowered the selection standard for vision acuity even further.

It is interesting that the population genetecists H. Kalmus and R. Cruz-Coke suggest that the increase in color blindness from prehistoric hunting societies to the present is also due to a relaxation of selection.

CULTURAL PATTERNS AND MYOPIA

Generally speaking, and with exceptions, societies in the ancient world were such that people did not move around easily in order to resettle from one place to another. Indeed, forced resettlement was a dire punishment.

A great deal of rigidity existed within the class structure of ancient society. By and large there was relatively little social mobility. The crafts and craftsmen fitted well into this general scheme. Itinerant craftsmen were the exception, not the rule. Excavations from Ur to Athens have shown that the craftsmen's district was separate, distinguishable and often continually inhabited for generations. The neighbors of craftsmen were very likely other craftsmen, enhancing the likelihood of intermarriage. According to Loding,

> the Ur III text, (c. 2000 B.C.) represents the best example of a type of crafts establishment of similar professions existing from the earliest attested periods of Mesopotamian history.

According to Weisberg, there is philologic evidence for the word "guild" in Akkadian three hundred years earlier.

One of the most important factors to perpetuate social immobility was the hereditary nature of the crafts. According to Professor Samuel Noah Kramer, in the Sumerian religion,

> it is in accordance with the fate decreed by Enlil for man that a son follow the work of his father.

That this stricture was successful can be seen by the fact that philologists have traced the same family name in certain crafts in the ancient Near East for seven hundred years or about thirty generations.

According to Burford,

> Literary references . . . and numerous personal records show that throughout antiquity fathers trained their sons, who trained their sons after them in the practice of the craft into which they had been born. (By late Roman times these occupations which had been largely familial tradition were now compulsory by law) . . . Freedom to change one's occupation was denied; even the right to move to another part of the country was ruled out . . . Milder methods of retaining skilled workers in the community were tried by both Greek cities and the Roman state . . . The Roman collegium of craftsmen was primarily a cult organization with strong emphasis on social obligation . . . their main function was to serve *social* and funerary ends . . .

According to Weisberg,

> The full-blown system of guilds found during the Hellenistic period throughout the Near East cannot be explained merely on the basis of origin from Hellenistic Egypt. Such a system with its implications for religion, social life, economic development . . . is rather a product of slow growth over the centuries on native soil.

All of this suggests very strongly that craftsmen had their place and knew it. In ancient Greece, for example, this was reinforced by the pejorative attitude against manual work that existed on the part of the upper class. According to Burford,

> . . . association with the crafts could debar a man from participation in government . . . (and) throughout antiquity the aristocracy to a very large extent set the tone of public opinion.

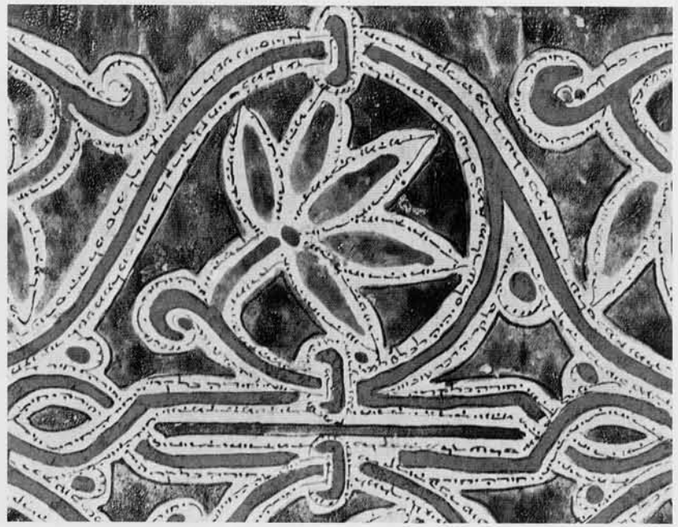
Forced and self-perpetuated segregation in our own time makes the social immobility in the ancient world easy to understand. Social immobility, consanguineous intermarriage, the genetic nature of myopia, plus the familial craft pattern would lead to an increase in the proportion of the dominant myopic trait as the previously cited data of Wold suggests.

The clearest example of the separation and isolation of crafts and, indeed, pressure to insure intermarriage within a craft comes from the caste system in India. Here too, the occupations were determined from father to son. However, in many instances, only certain castes practiced particular occupations.

Navrant in *Art in Industry* described the following about nineteenth century India:

> Three classes of metal workers (gold and silver, brass and copper, iron and steel) . . . differentiated themselves into three separate castes, with the invariable injunction against inter-eating and intermarrying.

Wulff as recently as the 1960's, in *Traditional Crafts of Persia,* states that



> certain crafts especially metal crafts are traditionally exercised by members of ethnical groups. Significant in the jeweler's craft are the Sobbi gold and silversmiths of Huzistan (Khuzistan). They are all members of the agnostic religious group of Mandaeans . . . and have a language of their own.

The Bible also provides similar and interesting testimony. This begins with Exodus 35:30-33 in which Moses states that God has endowed Bezaleel of the tribe of Judah with special knowledge "in all manner of workmanship" including the cutting, setting and engraving of stones. Bezaleel engraved the twelve stones of Aaron's breastplate with the names of the twelve tribes. According to the *Interpreters Dictionary of the Bible,* people of a single craft often occupied a special quarter in an

6
This example of micrographia is from the Damascus Keter . . . described by Bezaleel Norkiss in *Hebrew Illuminated Manuscripts.* It is dated at A.D. 1260. The scale of the above photo is slightly less than 1:1. Other examples of micrography are even smaller.

Israelite town. In 1 Chronicles 4:1 which gives the lineage of the sons of Judah, it is stated that Joab of Judah is

> the father of the valley of Cha-ra-shim; for they were craftsmen.

The term Cha-ra-shim means craftsmen. The same Valley of Craftsmen was resettled by Benjaminites following the restoration from exile.

The Judaic tradition contains additional evidence, not only of craftsmen who worked together but who were probably myopic as well. These craftsmen were the creators of the Hebrew illuminated manuscripts (Fig. 6) which began long before the invention of spectacles in the thirteenth century. Significant and relevant to our hypothesis, is the distinctive use of micrography or "minute writing" in these manuscripts as compared with Christian illuminated manuscripts. The purpose of micrography was to circumvent the stricture against the "graven image." It was used to create geometrical and floral designs as well as animals and grotesques. According to Narkiss in *Hebrew Illuminated Manuscripts,*

> the most common examples are the marginal lists of irregularities in writing and spelling and reading in the Bible which constitutes the masorah magna. In accordance with tradition, the masorah apparatus though *not necessarily legible* . . . had to be written in the Bible codices.

In keeping with the tradition of subspecialties within crafts, the micrography was the responsibility of a special craftsman called, according to Narkiss, a "vocalizer." He is sometimes named in the colophon together with the scribe, who did the overall layout of the carpet page. The desirability of the magnified, close vision of myopia for the "vocalizer" is self-evident. The tradition of micrographia suggests that the need and use of myopic craftsmen continued until the invention of eyeglasses and magnification. Whether such eyeglasses were used subsequently in this craft is unknown. The previously cited data (Post) about an increased frequency of myopia in Ashkenazi Jews would appear to be relevant to micrography. While eyeglasses were known in the thirteenth century, according to Duke-Elder, they were both scarce and expensive. It was not until the fourteenth and fifteenth centuries that they became more common.

Probably the oldest example of a minute form of notation is that analyzed by Alexander Marshack in *The Roots of Civilization.* He describes a bit of bone worked by the early Cro-Magnon man from the Aurignacian layer that is about 25,000 years old. In a small one and three-quarter inch area of the bone, he found engraved marks that appeared as

> . . . chaotic, haphazard pitting obviously made by man . . . (it required) a hand magnifier and a jeweler's eyepiece . . . and the beam of a powerful lamp to distinguish between these marks and to group them. (It required) higher magnification . . . and many hours (to realize that) the pattern was not random . . . (but) made on purpose . . . and, therefore, notational.

After much study he concluded that

> this was a visual record and recall of the seasons and moons of the past year.

Although Marshack's emphasis was on interpretation, since it required a microscope, lenses and special light to see these notations clearly, it would seem reasonable that innate, unusual, magnified, clear close vision was required to make them. Why not a myopic craftsman? Perhaps he too, like Bezaleel, was considered to be God endowed.

It is of interest that the famous archaeologist, Sir Arthur Evans, was myopic. His half-sister, Dr. Joan Evans, in her biography wrote,

> Evans was extremely short sighted and a reluctant wearer of glasses. Without them, he could see small things held a few inches from his eyes in extraordinary detail, while everything else was a vague blur. Consequently, he saw details with microscopic exactitude.

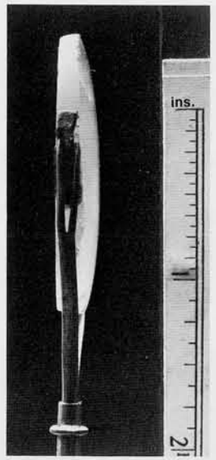
Another biographer, Leonard Cottrell, wrote,

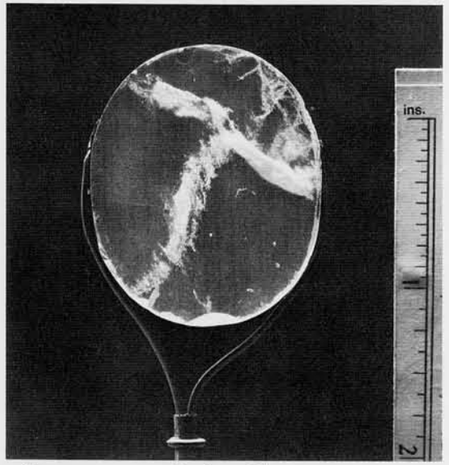
> . . . this seeming handicap of short sight . . . eventually led Sir Arthur Evans to Crete . . . because of his minute, almost microscopic vision of the tiny Cretan bead seals and signet rings.

DISCUSSION AND ARGUMENTS AGAINST THE HYPOTHESIS

While a strong case can be made for the familial tradition in the crafts, this relationship was not exclusive. There were exceptions. The apprenticeship system which has been recorded in much of antiquity is such an example. However, it is questionable that this was extensive enough to dilute the effect of the hereditary genetic pattern. Indeed, some of the best apprentices may have been myopes themselves. It is not difficult to imagine situations in which an apprentice could not be taught close work at all because he was a hyperope. The likelihood of this can be seen by apprenticeship contracts delineating responsibility for an apprentice who did not learn his trade.

Another relevant argument is related to the age of the craftsmen. The early age of some of the craftsmen is shown on Roman epitaphs. According to Weisberg, however, the apprenticeship period ranged from fifteen months to eight years. For a seal cutter it was five years, according to a text translated by Oppenheim and reported by Porada.





7a, b
The photographs are of a rock crystal artifact, plano-convex in shape, that was excavated by Layard at Nimrud about 1850. It is reprinted with permission of the Trustees of the British Museum (BM 90959). Thought by some to be a lens and others an ornament, we requested an expert lapidary, Mr. Martin Walter, to copy it in rock crystal since the measurements were given. This piece was then refracted by an optician who reported "a magnification of 2 diopters but significant distortion."

These young craftsmen offer an alternative explanation to the stated hypothesis, since the near vision of a youth with keen eyesight might be sufficient for close work. However, this would falter with age, due to loss of accommodative ability. In addition, would it not seem reasonable that the more difficult engraving on a cylinder seal, gem stone or die for a coin would have been reserved for the older, more experienced engraver? According to Wulff in *Traditional Crafts of Persia,* in gem cutting, it was the master craftsman who did the skilled work while his assistants did the grinding and polishing. According to Dr. Yale Solomon, a clinical ophthamologist, prolonged strained accommodation even in the young person would produce blurred vision as well as eye pain and headache. Lorenzo Natter, a noted and talented gem engraver of the eighteenth century A.D., described this problem as follows:

> The art of engraving gems is too difficult for a young man to be able to produce a perfect piece and when he arrives at a proper age to excel in it, his sight begins to fail.

No such strain occurs in the myope; consequently, he could work for long periods without negative effects. According to Dr. Solomon,

> it is a fallacy that close vision may be improved by continual close work, nor are there exercises that can accomplish such an improvement.

Another argument against the hypothesis is that longevity in the ancient world was much shorter than in our own times and therefore, death occurred before presbyopia. Is it not possible, however, that part of this earlier mortality was due to environmental factors such as poor nutrition and that early aging included an equally early loss of accommodation? The question of longevity is obviously quite complicated. There are laboratory experiments to show that the longevity of laboratory animals can be affected by changes in nutrition and caloric intake. Neither the youthful craftsmen nor shortened longevity necessarily negate the stated hypothesis.

The contention that magnifying lenses were made and used requires further evidence; however, one must grant the possibility (Fig. 7). Not only would excavated

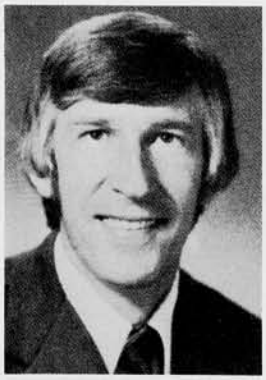
examples be needed, but also evidence of widespread knowledge or use as well, since the numbers and types of small objects requiring magnification are fairly ubiquitous. The lack of evidence is not only in the ancient world but through medieval times as well. The technical ability to make some things does not prove their use. The wheel could surely have been made and used by the ancient Maya and Inca, but there is no evidence that it was.

Does the stated hypothesis exclude the other two explanations, namely the existence of magnifying lenses and of young craftsmen with excellent eyesight and unusual accommodative ability? Not necessarily. Theoretically the three could coexist. However, proof for the existence and relative significance of each would still be necessary. One of the purposes of this paper is to stimulate such a quest.

CONCLUSION

For thousands of years ancient craftsmen have produced thousands of artifacts of such minutiae, skill and beauty that they have inspired both awe and puzzlement. They have produced puzzlement because logically they required the use of magnifying lenses to aid in their manufacture. However, there is virtually no evidence for the existence of magnifying lenses from either archaeological or literary sources. There is general agreement, however, that lenses and eyeglasses were invented around A.D. 1250.

In this paper an alternative explanation has been elaborated that this kind of close work could have been done by particular people with excellent close vision, namely nearsighted craftsmen or myopes. Evidence has been presented from the scientific disciplines of ophthamology, medical genetics, population genetics, archaeology and art history as to how and why myopes could have done such work without the need for magnifying lenses.



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