

MORPHOLOGICAL CHANGE AND EVOLUTION OF CARPS UNDER CULTIVATION

鯉科魚類的形態改變及演化

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The materials used in this study including three species of the carp family. They are *Carassius auratus* (the goldfish), *Cyprinus carpio* (the common carp) and *Hypophthalmichthys molitrix* (the bighead carp). All of them are very common fresh water food fishes in China and other Asiatic countries.

(A) The Goldfish (*Carassius auratus*) (Fig. 1 to Fig. 22)

Since many authors have interested in the fancy beautiful goldfish, many records, observations, and stories were published. One of the difficulty for the study of goldfish is nomenclature, because there are many local names, and many fanciful names, which caused confusions and ambiguity. In this paper, I tried to use as more morphological names as possible, so that it may be easily to know the shapes from the names. In order to avoid confusion or misunderstanding, The author describes the two important names clearly as follow.

- a. "Chi-Yu" or wildform goldfish—The ordinary common food fish in silver gray color, from which the colored goldfish was originated.
- b. Primitive goldfish—The earliest colored goldfish is called "Tsao-Chin-Yu" (means primitive goldfish) in China, "Watin" in Japan, or the common goldfish in some other countries. The morphology of this breed of goldfish is the same as the wildform fish, but in red, yellow red, white or spotted colors, instead of the ordinary silver gray color. The caudal fins of this fish are bilobed as the wildform or with trilobed short caudal fins.

Detail descriptions and history of the evolutionary changes of the goldfish will be published in another article, "Further studies on the evolution of goldfish". Following morphological units are going to be discussed in this paper.

1) Skeleton and body form. (*5, *6, *10)

A fossil *Carassius auratus* was found near Taiku, in Shansi province, in beds referred to the upper Pliocene. It was very interested to note that there were no marked differences in skeleton and body form between the fossil fish of millions years age and that of recent wildform food fish, and that of the early primitive red colored goldfish.

All of them, the fossil, the wildfish, and primitive goldfish are long body forms.

The slightly short body fishes were first recorded near the the end of the 16th century, while the extra short body types have been the productions of the 19th and the 20th century.

In the modern short body forms, besides the shortness in skeleton, the caudal vertebrae (the verterbrae after the trunk vertebrae with ribs) are usually fused. And there is a frontal furrow on the cranium. (*6)

2) Color

The first colored goldfish, which was recorded not later than 968-976, in Su-Shui District of Chekiang province of China, was but a common food fish in red color (*12, *13, *14, *15, *16). The multicolored and spotted fish was found in the 12th century (*7). So from the 10th to the 15th century, all the goldfishes were either in red or in yellow-red (golden red) colors or in white or multicolored forms, Further development of colors and color combinations were produced in later periods.

3) Caudal fins

The caudal fins of the goldfish are most variable and mutable. All the wild food fish, and the early primitive colored goldfish before the end of the 15th century, and primitive goldfish of present time have single vertical bilobed caudal fin with short fin rays. The first paired caudal fins recorded in the early of the 16th century, they were caudal fins with 3 lobes, while fishes with more lobes were originated in the later

foot-note *with number, refers to the number in the list of literaturatures referred.

periods.

Paired caudal fins formed by the splitting of the median fin rays into paired lateral halves. All the early paired caudal fins had short fin rays. But in the 18th century some forms had the tendency to lengthen the fin rays. And in the 19th and the 20th century, some of the forms have long or extra long caudal fin rays, sometimes longer than their bodies.

4) Anal fin

There are two types of the Anal fins, the single median anal fin and the paired anal fins. The paired anal fins also originated from the single median anal fins. It is also interested to note that there seemed some correlation between the anal fin and the caudal fin. All the fishes with single median vertical caudal fins or paired caudal fins with short fin rays have single median anal fin, while the fishes with long paired caudal fin rays have also paired anal fins.

5) Dorsal fin

Dorsal fin is also very variable. Dorsal fin in the wild food fish, or primitive goldfish, and most modern forms have single complete dorsal fin, with short fin rays. Dorsalfinless fishes were recorded in the 18th century, their back are smooth and round and no trace of dorsal fin. Between the complete dorsal fin and dorsalfinless type there were intermediate forms, with incomplete dorsal fin, or with two tubercles on back only (*2).

The modern "Lion-head" and "egg fish" have developed this dorsalfinless character in perfection.

In the 19th and the 20th century some modern forms have the tendency to extend and lengthening the rays of dorsal fins (*1, *4).

6) The Pectoral and pelvic fin

The pectoral and pelvic fins of the Wildform and the early primitive goldfish are simple and with short fin rays. But some fancy forms in the 18th century had longer fin rays, and the extra long fin ray forms have been production in the 19th and the 20th century.

7) Eye

All the early goldfish and most of the varieties have simple and normal eye, same as that of the wildform. The protruding eyes, called "dragon eye" in Chinese or "Telescope" fish by some authors were first recorded in the 16th century, while the "Skyward-eye" or "Celestial" by some authors, was first recorded near the end of the 19th century. The "Water-bubble-eye" fish was originated in the early score of the 20th century.

8) Head

The head of the early goldfish and most of the breeds of goldfish have simple and normal head as the wildform. Due to some extra growth of the cranial bones, muscles, and skin, "lion-head" (buffalo head, or toad head) fish was first recorded in the middle of the 19th century, and the "goosehead" or "Oranda" was produced near the end of the 19th century. The "Lionhead" is a short body fish with short or median long caudal fin rays, but without dorsal fin, while the "Goosehead" or "Oranda" is a short body type with long or moderate long caudal fin rays, but with a complete dorsal fin.

9) Nasal septum-

All the wildfish and most varieties of the goldfish have simple and normal septum. One kind of fish has an extra growth on the nasal septum to form a ball shaped bouquet. This character is called as "Narial ball" or "Narial Bouquet" or "Pompom" by some authors. It was first recorded in early decades of the 20th century.

10) Operculum

Besides the simple and normal operculum of the wildform and most kinds of the goldfish, a kind of an extra growth on the operculum is called "outfolded operculum." This was first recorded in the early score of the 20th century.

11) Scale

All the early goldfish and most kinds of the goldfish have normal scales as the wildform. Transparent scale fish (or crystal fish, or "Scaleless" fish by some authors) was first recorded in the early decades of the 17th century. And the "Pearl scale" was first produced in the beginning of the 20th century.

For convenience, the evolutionary history of the colored goldfish may be summarized into three periods.

- I. Early period (from the 10th century to the 15th century), the period of the beginning of change—The first red colored goldfish was originated from the silver gray wild food fish in the 10th century from Chekiang province of China. Besides the red color, the early primitive goldfish was exactly the same as the wild food fish, and there were no remarked differences between the fossil specimen of millions years ago in strata of upper Pliocene, and recent wild goldfish.

All the fishes in this period had long bodied forms as the wildform.

- II. Middle period (from the 16th to the 18th century), period of moderate change—The paired caudal fin types of 3 lobes and more lobes were recorded in the early of the 16th century. The protruding eyes and slightly short bodied fish were recorded near the end of the 16th century. Transparent scale fish was first recorded in the early of the 17th century, and the dorsalfinless types and vestigial dorsal fin were observed in the 18th century. During this period, more colors and color combinations were found (*3, *8, *9, *11).

- III. Modern period (from the 19th century to present date), period of rapid change—The short bodied, dorsalfinless "egg fish" had its perfection in from, and the Lionhead character were recorded in the first half of the 19th century, while the "Goosehead" or "Oranda" fish and "Skyward eye" fish were found in the later half of the 19th century. The "Pearl scale" "Outfolded operculum" and "Narial bouquet" and "Water bobble eye" were the modern production in the early decades of the 20th century (*1).

Besides the above mentioned special characteristics, there are common tendencies of the lengthening of fin rays and the shortening of the bodies in many breeds.

From the above data it indicated that the rate of the mutational changes was slowly at the early age, but more rapidly at the later periods.

(B) The Common carp (*Cyprinus carpio*) (Fig. 23)

The common carp is also a kind of very popular food fish in China and

other oriental countries. There are many records of this species in ancient Chinese literatures. In some cities people considered the common carp not only as a popular food fish, but as a "noble" species, the "leader" in fishes families. The red colored common carp, or the golden carp, had been recorded not later than 709 AD (further searches in the ancient Chinese fish literatures are required to trace earlier records).

After the red colored mutation in the common carp, the spotted red and white colors followed at later time. Besides the color changes of the common carp, no marked changes on fins, eyes, head, or scales, or other structures were observed or recorded.

(C) The bighead carp (*Hypophthalmichthys molitrix*) (Fig. 24)

The bighead carp has had also a long history of fresh water cultivation in China, but no marked change in color or form was found or recorded.

Discussion

From the records of the mutational changes occurred in the history of the goldfish and the golden carp, there are many points of interesting.

1. *Carassius auratus* from upper pliocene to the 10th century was rather stable, and it has become more mutable after the later scores of the 10th century. Its rate of changes in recent one thousand years was slower at the beginning, but more rapidly at later periods. The common carp in recent one thousand and two hundred years has been in a state of slow changes in colors, while the bighead carp is in a state comparatively stable.
2. Since the goldfish and the common carp are closely related species, it is very interested to note that the common carp had somewhat parallel changes in color mutations similar to those occurred in the goldfish. Closely related species may have similar pattern of mutational changes, it is possible that they have some similarity in the molecular arrangement and the structure of genes and cell proteins.
3. As the history of the evolutionary changes of the goldfish, from the fossil form in the upper pliocene to the modern varieties is rather complete, it is the best material, or at least one of the best materials for studies on experimental evolution. It would be possible, by x-ray, isotopes, or other radiation methods, to produce artificial mutations in laboratory. If we success to

produce artificial mutations similar to those occurred in its history in nature, it would open a new field for experimental evolution. It would help to solve some basic problems both in the theoretical and practical biological sciences.

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Explanation of Plates and Figures

- Fig. 1 Fossil *Carassius auratus*, Taiku, Shansi
 - Fig. 2 Wildform goldfish, the common food fish
 - Fig. 3 The Primitive goldfish
 - Fig. 4 The primitive goldfish without dorsal fin, but with two tubercles on back
 - Fig. 5 The primitive goldfish with vestigial dorsal fin
 - Fig. 6 Primitive goldfish without a dorsal fin
 - Fig. 7 Primitive goldfish with dragon eye, the protruding eye (dragon eye, telescope eye)
 - Fig. 8 Primitive goldfish with dragon eye, but without dorsal fin
 - Fig. 9 Short bodied goldfish with dragon eye
 - Fig. 10 Short bodied fish with dragon eye, but without dorsal fin
 - Fig. 11 Modern short bodied goldfish, with bilobed caudal and long fin ray
 - Fig. 12 Modern short bodied goldfish with trilobed caudal
 - Fig. 13 Modern Lion head fish without dorsal fin
 - Fig. 14 Modern Goose head fish with long dorsal and caudal fins
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 - Fig. 17 Modern egg fish
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 - Fig. 19 Modern short bodied goldfish with narial ball
 - Fig. 20 Modern short bodied goldfish with pearls scales
 - Fig. 21 Ancient wildform goldfish picture printed 1726
 - Fig. 22 Ancient primitive colored goldfish picture printed in 1726
 - Fig. 23 Ancient wild common carp picture printed in 1726
 - Fig. 24 Ancient bighead carp picture in 1726
- Fig. 21, 22, 23 and 24 were reproduced from Tu Su Chi Chen (or Imperial Encyclopedia) printed in 1726, Peking

Some of the drawings were modified from Axelrod (1958), Baster (1765), Inns (1949) and Sauvigny (1780).

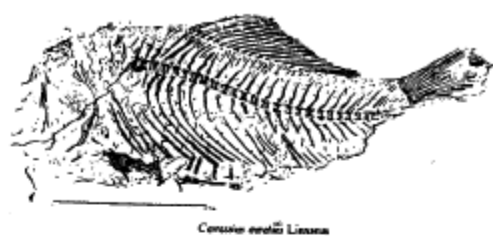


Fig. 1

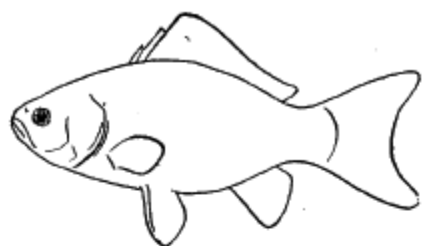


Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9



Fig. 10



Fig. 11

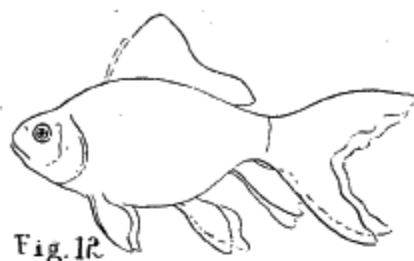


Fig. 12



Fig. 13

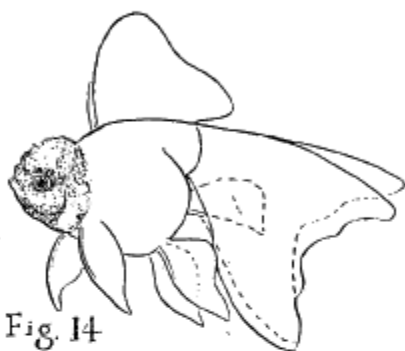


Fig. 14

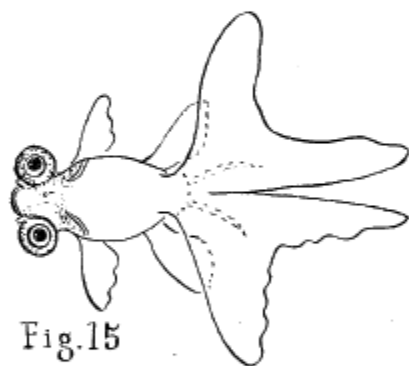


Fig. 15

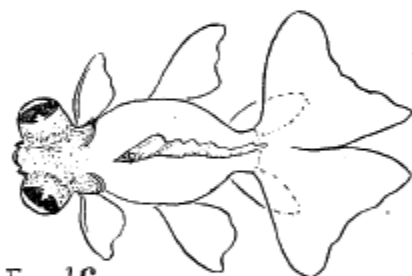


Fig. 16



Fig. 17

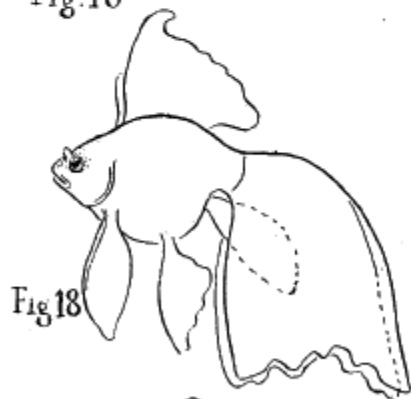


Fig. 18



Fig. 19



Fig. 20

金魚圖



Fig. 22

鯽魚圖



Fig. 21

鯉魚圖

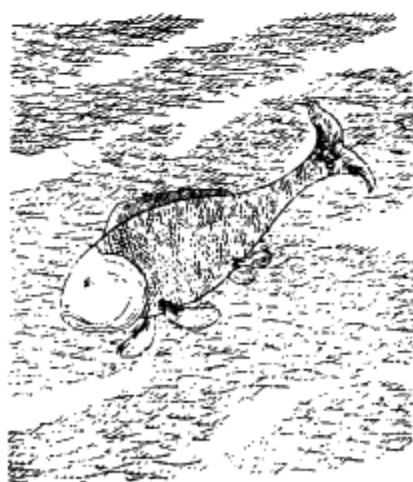


Fig. 24

鯉魚圖



Fig. 23