

## 7.6. In Amphibia

The amphibian heart shows further advancement in specialization. The modification in the heart is correlated with the appearance of pulmonary respiration and the disappearance of gills.

The heart of amphibians (Figure 7.7) has five chambers namely (i) a sinus venosus, (ii) two auricles, (iii) a ventricle, and (iv) a truncus arteriosus. The heart is covered by a thin pericardium.

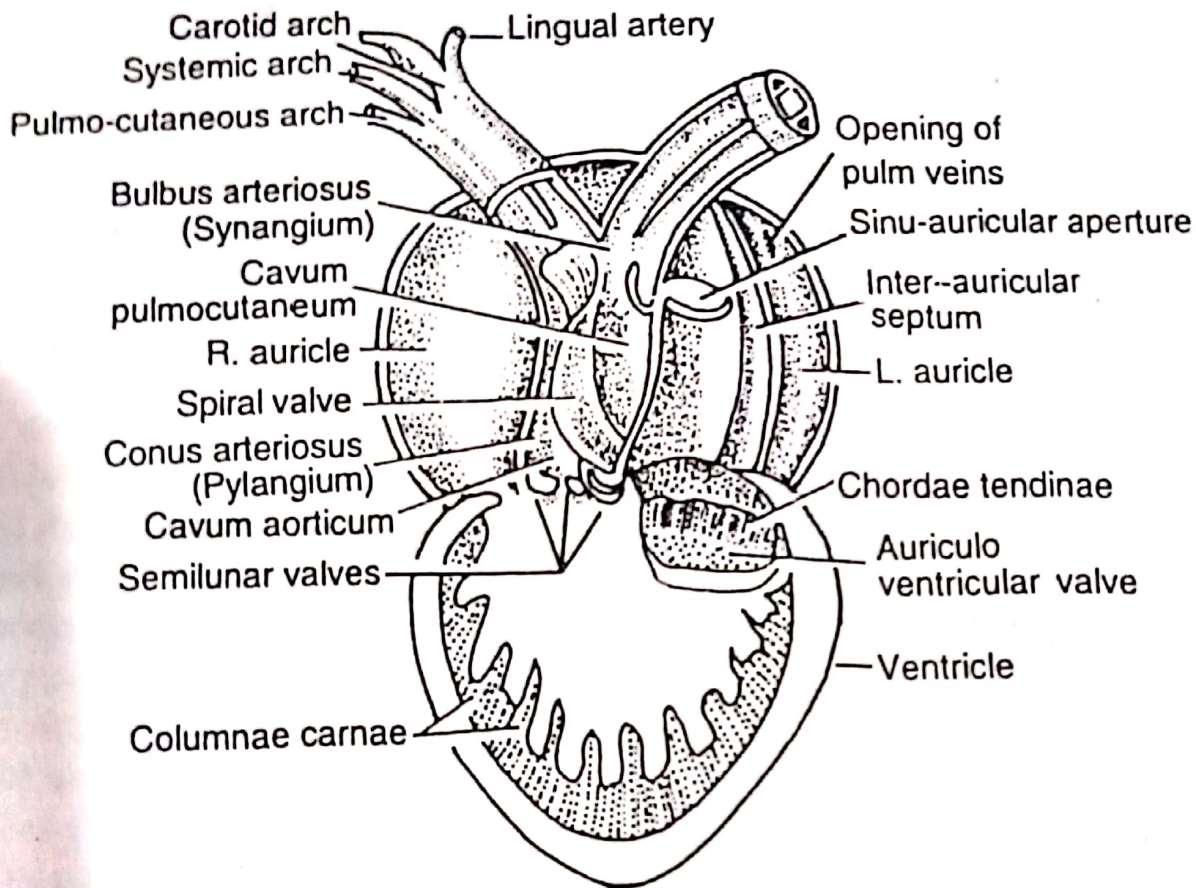


Fig. 7.7 Internal structure of heart of an anuran (Frog)

### (A) In Anura

- (i) The sinus venosus is a large triangular structure. It opens into the right auricle through a sinu-auricular aperture guarded by a pair of valves. Two pre-caval veins and a post-caval vein open into it.
- (ii) The pulmonary vein opens into the left auricle.
- (iii) The auricle is divided into a large right auricle and a smaller left auricle by a well-developed inter-auricular septum.
- (iv) There is a single muscular ventricle whose wall is spongy and with muscular columns.

- (v) The two auricles open into the ventricle by a single auriculo-ventricular aperture. This opening is also guarded by valves.
- (vi) The ventricle opens anteriorly into the truncus arteriosus by an aperture guarded by three or four semilunar valves.
- (vii) The truncus has a large spiral valve so that its cavity is subdivided into two channels—the cavum aorticum and the cavum pulmocutaneum.

### (B) In Urodela

The heart of urodela amphibians shows lower grade of organization as compared to that of anurans.

- (i) Heart is less compact.
- (ii) The inter-auricular septum is thin and usually perforated. In the aberrant lungless salamanders inter-auricular septum may be absent—a return to an almost fish-like condition.
- (iii) The truncus is much simpler with four or five proximal valves near its opening into the ventricle and a distal ring of valves (e.g., in *Cryptobranchus*). The spiral valve is either absent (e.g., in *Necturus*, *Cryptobranchus* etc.) or very small (e.g., *Salamandra*).

### (C) In Gymnophiona (Apoda)

- (i) Heart contains the same number of chambers as in anurans.
- (ii) A well-developed inter-auricular septum is present.
- (iii) In the truncus the spiral valve is absent.

## II. Heart in Amniotes

### 7.7.

The amniote heart reaches an altogether higher grade of specialization than the Amphibian. The sinus venosus is lost during development as a result of its merger into the wall of the right auricle. The disappearance of conus and truncus arteriosus is also noteworthy. Another very important feature of amniote heart is the formation of interventricular septum.

### 7.8. In Reptiles

The reptilian heart shows further advancement over the amphibian heart. It consists of two auricles and a partly or more or less completely divided ventricle. The sinus venosus is greatly reduced but not lost completely. It opens into the larger right auricle by the sinu-auricular opening which is provided with two almost transversely placed valves. The smaller left auricle receives the pulmonary vein. The two auricles are separated by a well-developed inter-auricular septum. The two auricles open separately into the ventricle by right and left auriculo-ventricular apertures (Figure 7.8).

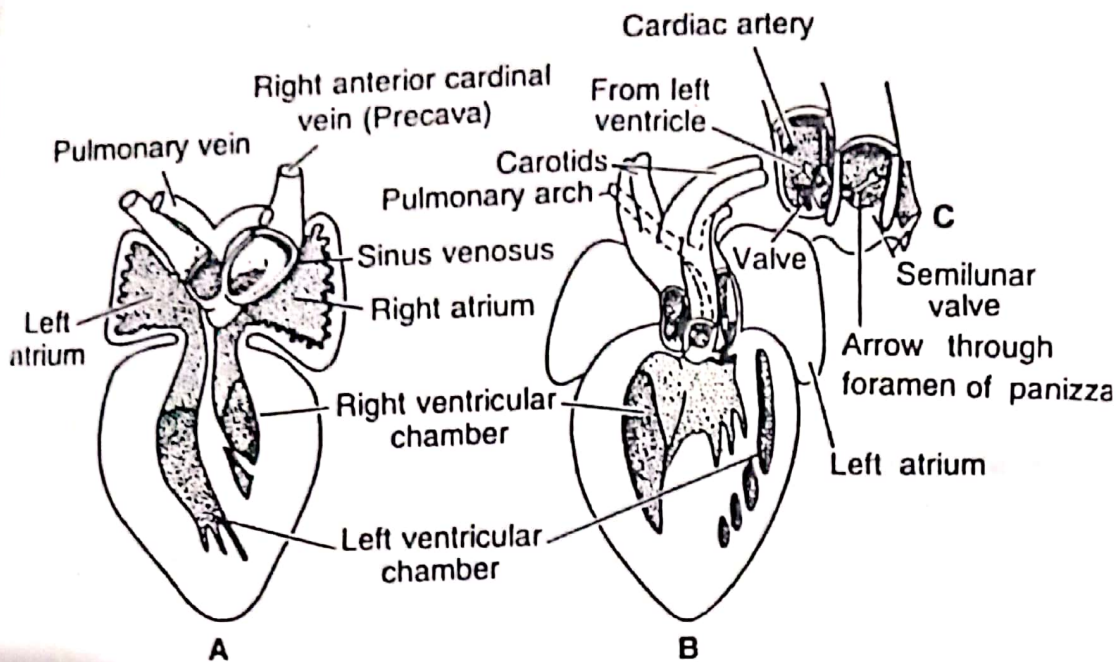


Fig. 7.8 Dorsal view of heart and main blood vessels of the alligator (A) as seen from below (B), and details of foramen of Panizza (C)

The important new feature met with in the reptilian heart is the presence of an incomplete inter-ventricular muscular septum (complete only in Crocodylia). This septum tends to divide the cavity of the ventricle into right and left chambers. The most peculiar and characteristic feature of reptilian heart is the splitting of truncus arteriosus into three separate channels and therefore, three arteries leave the heart. One of these is the pulmonary artery carrying venous blood from the right chamber of the ventricle to the lungs. The remaining two are the systemic arteries, one of which comes from the right, and the other from the left chamber of the ventricle. A pair of semilunar valves protects the openings of each of the three trunks. Soon after leaving the heart the two systemic arteries cross each other. These two are connected by a foramen of Panizza. Since in Crocodylia there is complete separation of right and left auricles and ventricles, the only connection between the two sides of the heart is through the foramen of Panizza. Due to the presence of incomplete inter-ventricular septum in reptiles, the separation of venous and oxygenated blood is not complete. Even in Crocodylia some mixing of venous and arterial blood occurs through the foramen of Panizza.

### 7.9. In Birds

In the history of vertebrate evolution, the birds have succeeded in completely separating the venous and oxygenated blood.

In avian heart (Figure 7.9) the sinus venosus is lost so that the two pre-cavals and the post-caval vein open separately into the right auricle. The left auricle receives the pulmonary veins. The interauricular septum is well developed. The ventricle is completely divided into a right and a left ventricles

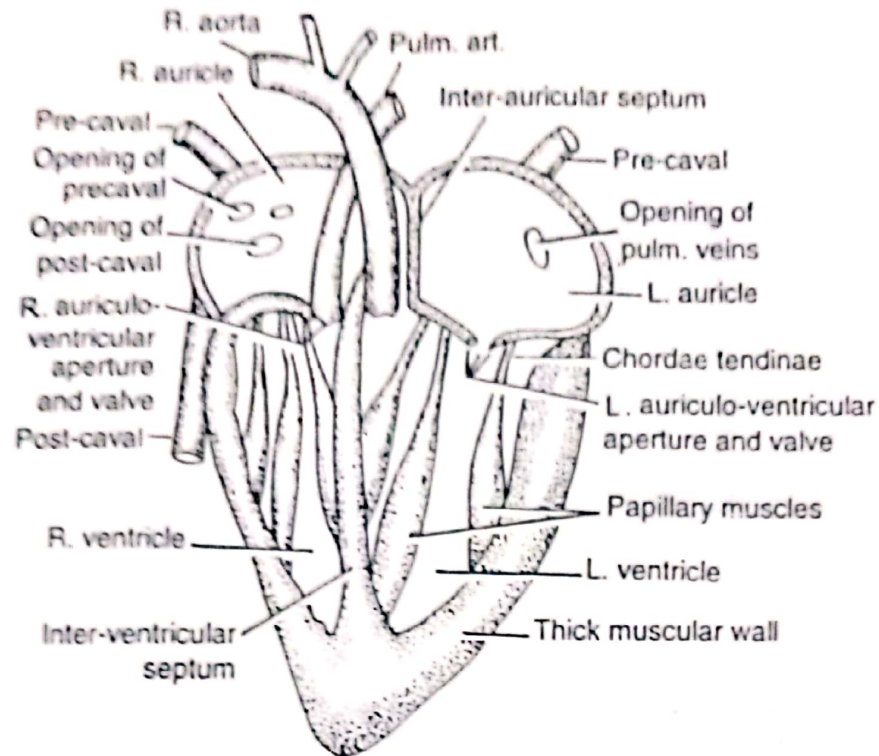


Fig. 7.9 L. S. of heart of a bird

by the inter-ventricular septum. The two auricles open separately into the right and left ventricles by right and left auriculo-ventricular apertures. The right ventricle is guarded by a single large muscular valve while the left auriculo-ventricular aperture is guarded by two membranous valves. Unlike reptiles, the only trunk issuing from the right ventricle is the pulmonary, whose opening is guarded by three semilunar valves. Similarly, the only trunk issuing from the left ventricle is the carotico-systemic which also has three semilunar valves at its base.

### 7.10. In Mammals

Like birds, mammals also have succeeded in separating the oxygenated and venous blood. The heart is completely four-chambered as in birds consisting of two auricles and two ventricles (Figure 7.10). The sinus venosus is absent and the three caval veins open directly into the right auricle. The semilunar valves are, however, represented by the Eustachian and Thebesian valves. The pulmonary veins open separately into the left auricle. The right auriculo-ventricular aperture is provided with three tricuspid valves while the left auriculo-ventricular aperture is guarded by two mitral valves. The right ventricle leads into the pulmonary trunk while the left ventricle leads into the carotico-systemic trunk.

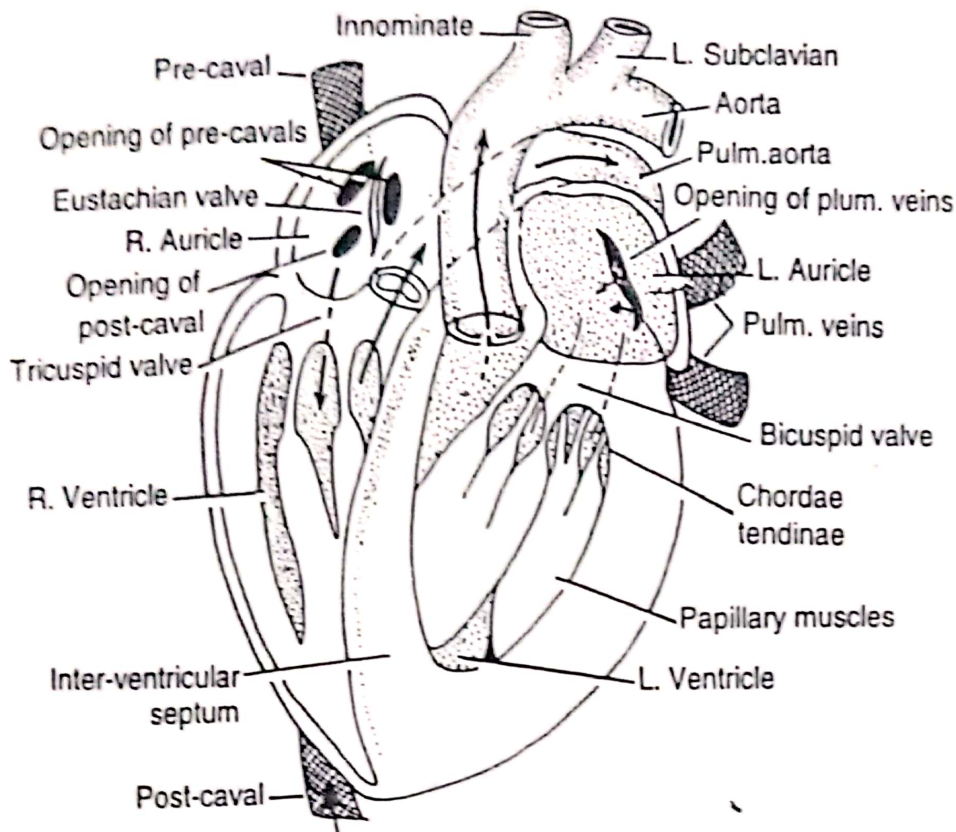


Fig. 7.10 L. S. of the heart of rabbit

### 7.11. Summary

The main changes which the heart has undergone in its evolutionary history may be summarized as follows. It will be evident that the aim and trend in the evolution of heart was to keep the venous and oxygenated blood streams separate (Figure 7.11).

- (i) Primarily, the heart consisted of a two-layered tube with a muscular wall and an endothelial lining. The tube was devoid of valves.
- (ii) The cardiac tube later on became subdivided into chambers—the sinus venosus, atrium, ventricle and conus. These chambers contract in a series from behind forwards, and are separated by valves ensuring one way flow of blood.
- (iii) From the primitive condition, the heart of cyclostomes diverged with some important specializations.
- (iv) In fishes a valvular conus arteriosus developed. In higher teleostomes the conus was replaced by a non-contractile bulbous arteriosus.
- (v) In Dipnoi and Amphibia, the atrium became divided by an incomplete septum into a right (larger) and a left atria. The ventricle, however, remained undivided. Thus at this stage the heart became

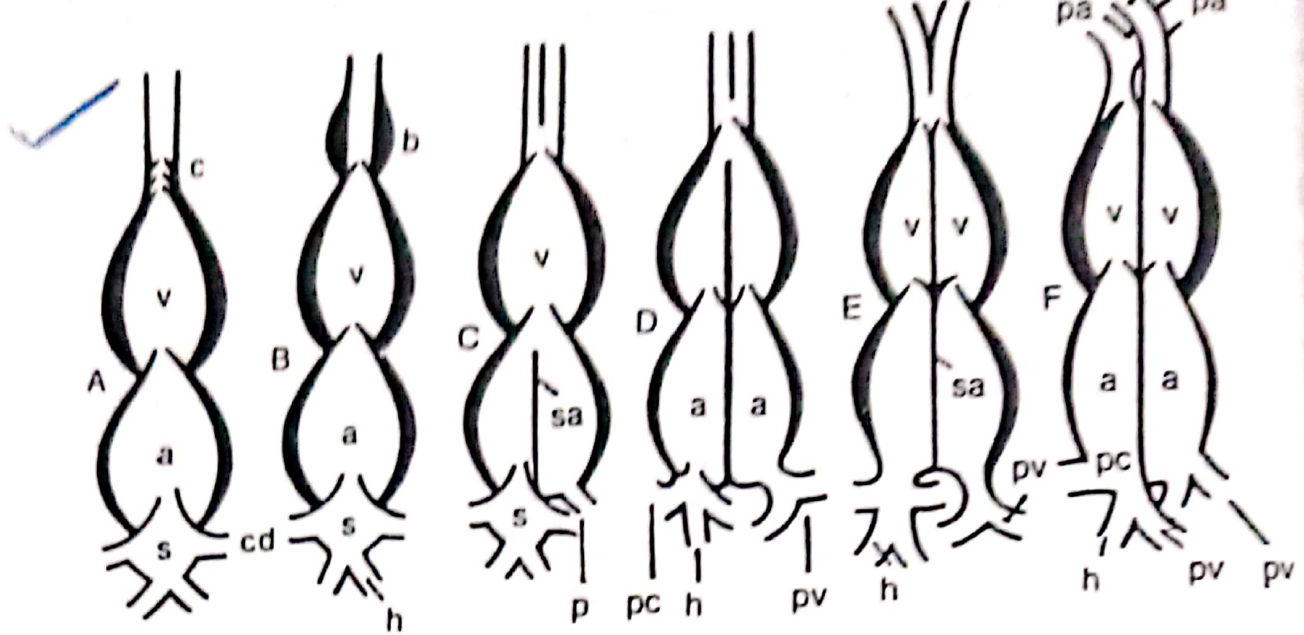


Fig. 7.11 Different stages in the differentiation of the parts of the hearts, ventral view. A, elasmobranch; B, teleosts; C, amphibia; D, lower reptiles; E, alligator; F, birds and mammals *a*, atrium; *ao*, aorta; *b*, bulbus arteriosus, *c*, conus; *cd*, Cuvierian duct; *h*, hepatic veins; *pa*, pulmonary artery; *pc*, pre-and postcaval veins; *pv*, pulmonary veins; *s*, sinus venosus; *sa*, inter-auricular septum; *v*, ventricles.

longitudinally subdivided into right venous and left arterial channels. The sinus established its connection with the right atrium.

- (vi) Further subdivision of heart lumen occurred in amniotes (reptiles, birds and mammals), In reptiles, for the first time, the atrioventricular aperture becomes divided into two, so that the two atria or auricles open separately into the ventricle. A definite inter-ventricular septum appeared in Amniota to divide the ventricle into right and left arterial chambers. This subdivision of ventricle was achieved for the first time in Crocodilia (Reptilia). However, the beneficial effects of this separation in Crocodilia are partly neutralized by the mixing of venous and arterial blood in the dorsal aorta (through the foramen of Panizza).
- (vii) The two most progressive vertebrate classes, the birds and mammals have completed the division of heart into right venous and left arterial half. Thus complete separation of two types of blood has been achieved. This division has obviously been brought about independently in the two groups (birds and mammals) as they have evolved independently from primitive reptiles.

## 7.12. Comparison of Hearts of Fish And Amphibia

(Figs. 7.4, 7.5, 7.6 and 7.7)

Heart of Fish	Heart of Amphibian (e.g., Frog)
1. Heart is roughly S-shaped and is enclosed in a spacious pericardial cavity.	1. Heart is roughly triangular pear-shaped and is enclosed in not so spacious pericardial cavity.
2. Heart is of primitive type consisting of four chambers: (i) a sinus venosus (ii) an atrium or auricle (iii) a ventricle and (iv) a conus arteriosus (in elasmobranchs) or a bulbus arteriosus (in teleosts)	2. Heart shows advancement over fishes which is correlated with the disappearance of gills and appearance of pulmonary respiration. It consists of five chambers: (i) a sinus venosus (ii) a pair of auricles (iii) a ventricle, and (iv) a truncus arteriosus
3. The sinus venosus and auricle are dorsally placed while the ventricle and conus are ventrally placed.	3. Only the sinus venosus is dorsally placed, the rest like auricles, ventricle and truncus are ventrally placed.
4. Auricle or atrium is a single chamber placed on the dorsal side of the ventricle. In Dipnoi (lungfishes) only the atrium becomes partially divided by incomplete longitudinal septum.	4. Auricle is divided into a large right auricle and a smaller left auricle by a well-developed interauricular septum in Anura and Gymnophiona. In Urodela (tailed amphibians), however, the interauricular septum is thin and usually perforated. In the aberrant lungless salamanders this septum may even be absent.
5. The auriculo-ventricular aperture is guarded by a pair of obliquely set (bilabiate) valves.	5. The auriculo-ventricular valve is semilunar.
6. Ventricle is prominent, single and highly muscular.	6. Same

7.13. Comparative Account of Hearts in Vertebrates

<p><i>Fish</i> (Scoliodon) (Fig. 7.4)</p>	<p><i>Amphibia</i> (Frog) (Fig. 7.7)</p>	<p><i>Reptilia</i> (Lizard) (Fig. 8.4 &amp; 8.5)</p>	<p><i>Bird</i> (Pigeon) (Fig. 7.9)</p>	<p><i>Mammalia</i> (Rabbit) (Fig. 7.10)</p>
<p>1. Heart is situated midventrally below the pharynx in pericardial cavity separated from the peritoneal cavity by <b>septum transversum</b>. 2. Heart is enclosed within a <b>two-layered pericardium</b>. 3. Heart consists of a linear series of four chambers namely a <b>sinus venosus</b>, an <b>auricle</b>, a <b>ventricle</b>, and a <b>conus arteriosus</b>. The presence of a single auricle and ventricle makes it a <b>two-chambered heart</b>. 4. Dorsally-placed <b>sinus venosus</b> receives venous blood from different parts of the body by two <b>ducti cureri</b> veins and a pair of <b>hepatic sinuses</b>. 5. Single undivided atrium or auricle is somewhat triangular.</p>	<p>1. Heart is situated midventrally in the thoracic cavity. <b>Septum transversum</b> is absent. 2. Same as fish 3. Heart is <b>3-chambered</b>; two auricles and a single ventricle. Besides these, a <b>sinus venosus</b> and a <b>truncus arteriosus</b> are present. 4. <b>Sinus venosus</b>. Receives venous blood from body by 3 major veins—one postcaval and two pre-cavals. 5. Auricleis divided into right and left auricles by an <b>interauricular septum</b>.</p>	<p>1. Same as Amphibia 2. Same as fish 3. Heart consists of two auricles and a <b>partially divided ventricle</b>. <b>Sinus venosus</b> is also present. 4. <b>Bilobed sinus venosus</b> receives venous blood through two pre-caval and a post-caval veins. 5. Same as Amphibia</p>	<p>1. Same as Amphibia 2. Same as fish 3. Heart is <b>4-chambered</b> made up of two auricles and two ventricles. 4. <b>Sinus venosus</b> absent and hence the three caval veins open into the right auricle. 5. Same as Amphibia</p>	<p>1. Heart lies midventrally enclosed in <b>pericardium</b> in the thoracic cavity. 2. Same as fish 3. Heart chambers similar to bird 4. Same as bird 5. Same as Amphibia</p>