



Pavel Němec

IV. DÝCHACÍ SOUSTAVA

Evoluce dýchacích pigmentů

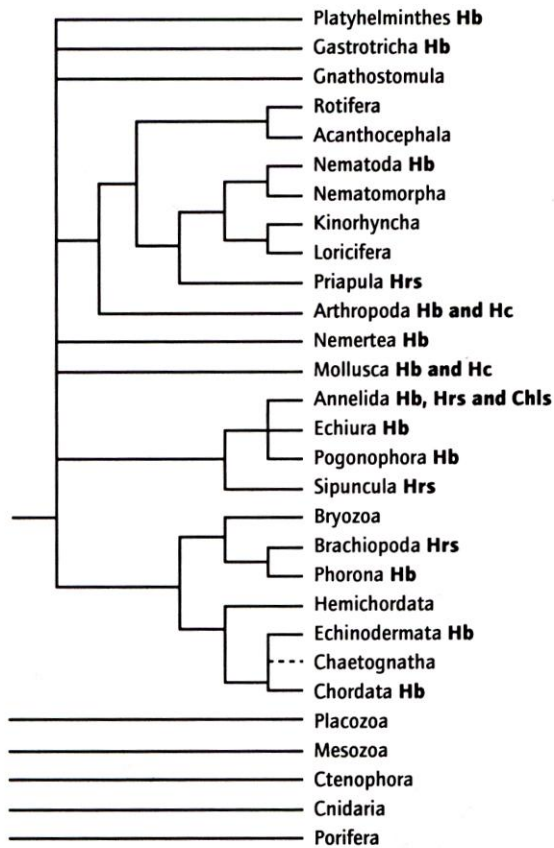


Fig. 11.7 Distribution of respiratory pigments across the animal phyla. Hb = haemoglobins; Hrs = haemerythrins; Hc = haemocyanins; Chls = chlorocruorins. Relationships between the phyla based on information presented in Figs 2.8 and 2.20.

✓ **hemolymfa / krevní plazma bez dýchacích pigmentů – omezená kapacita pro přenos O₂ (<0,3 mmol O₂/l)**

✓ **Specializované dýchací pigmenty zvýší kapacitu přenosu kyslíku 2x – 30x.**

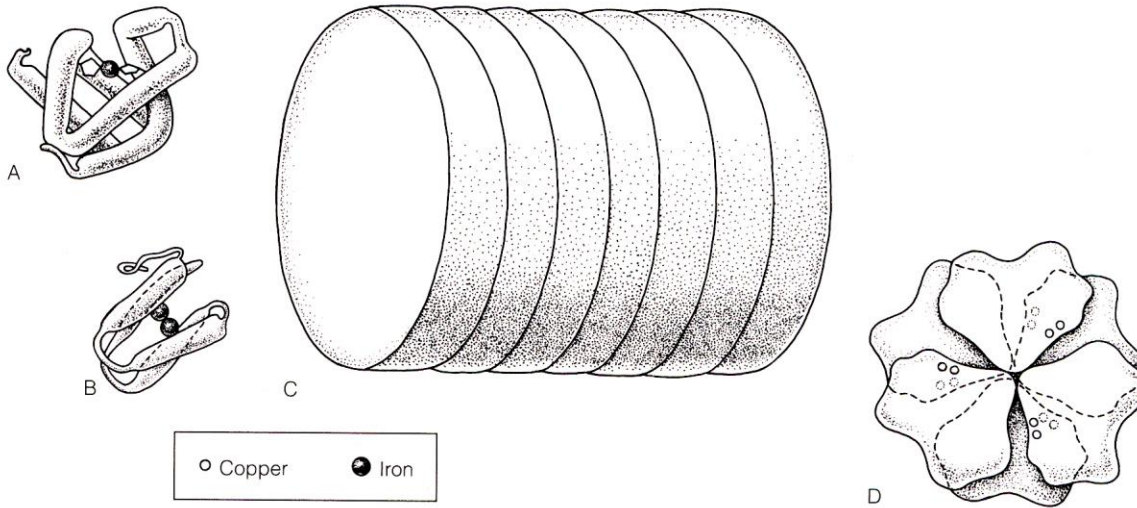
Výskyt u cca 1/3 kmenů mnohobuněčných živočichů. Pigmenty typu hemoglobin, hemerytrin patrně vznikly několikrát nezávisle

✓ **dýchací pigmenty se mohou vyskytovat:**
Intracelulárně (např. hemoglobin kroužkoců, některých měkkýšů a ostnokožců, hemerytrin ramenonožců a mnohoštětinatých kroužkoců)
Extracelulárně v krvi/hemolymfě (např. hemoglobin u některých měkkýšů a korýšů, hemocyanin členoců a měkkýšů, chlorocruonin kroužkoců)
Ve tkáních (ve stěnách těla, svalech, hltanu, nervové soustavě atd.).

Table 11.1 Structure and function of respiratory pigments.

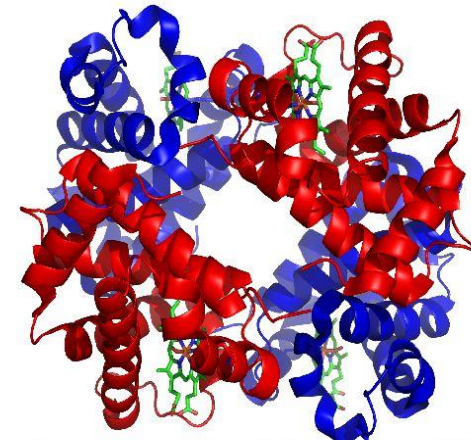
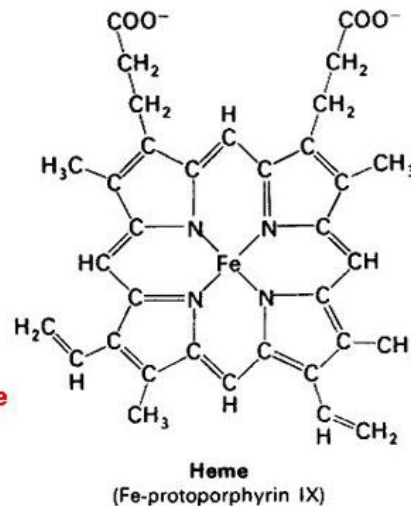
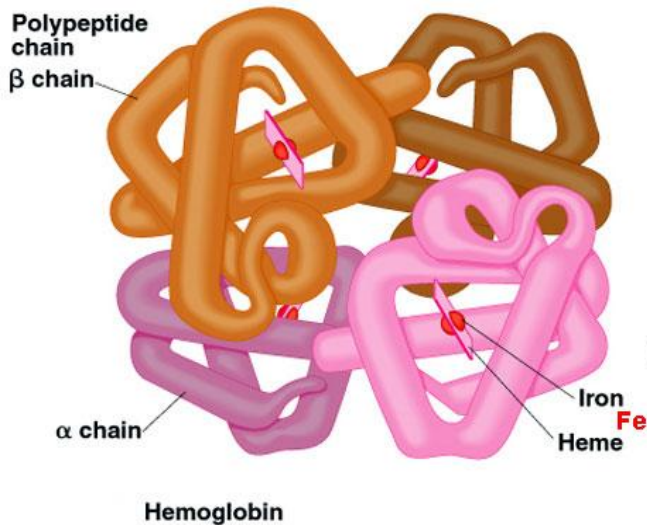
Name	Structure	Molecular weight range	Function
Haemoglobin	Prosthetic group is haem (a porphyrin), linked to one atom of ferrous iron. Found either in solution or in cells	17 000–3 000 000	Cooperative O ₂ binding. Red when oxygenated, blue when deoxygenated
Haemocyanin	Prosthetic group is a polypeptide linked to 2 atoms of copper Always found in solution, never in cells	25 000–6 680 000	Cooperative O ₂ binding. Blue when oxygenated, colourless when deoxygenated
Chlorocruorin	Like haemoglobin the prosthetic group is haem linked to one atom of ferrous iron. Always found in solution	3 400 000	Cooperative O ₂ binding. Green in dilute solution, red in concentrated
Haemerythrin	Non-porphyrin prosthetic group though it is attached to iron. Always found in cells	17 000–120 000	Violet when oxygenated, almost colourless when deoxygenated

Evoluce dýchacích pigmentů



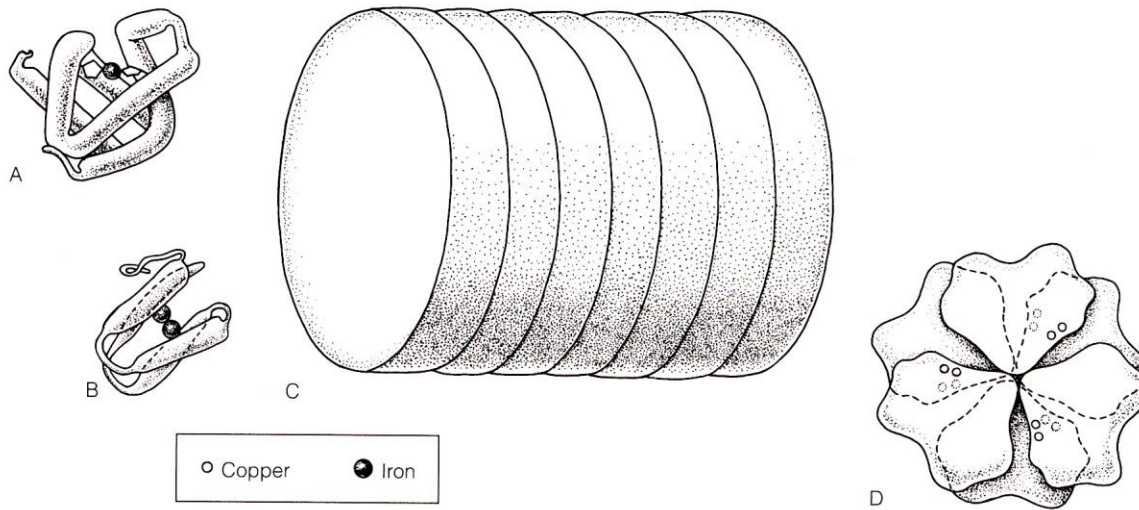
- A) Hemoglobin
- B) Hemerythrin
- C) Hemocyanin měkkýšů
- D) Hemocyanin členovců

A) Hemoglobin

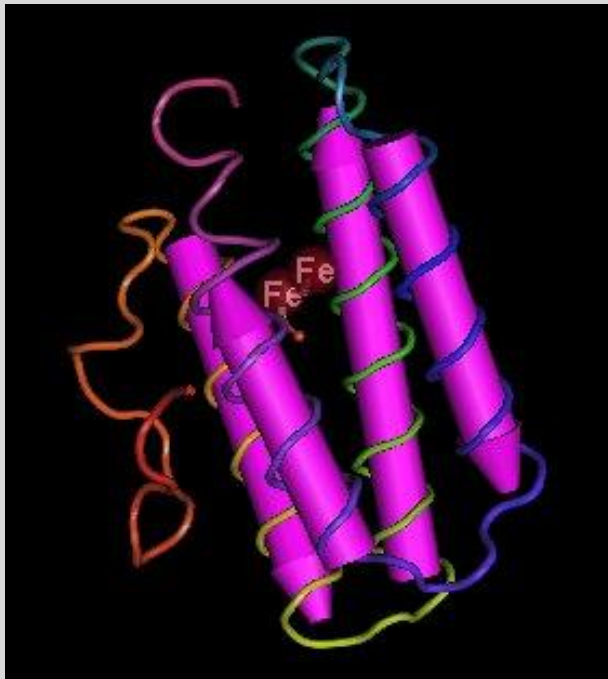


Three-dimensional structure of the vertebrate hemoglobin molecule. The globin subunits are in red and blue, with the heme moiety in green. From the Wikipedia entry on hemoglobin.

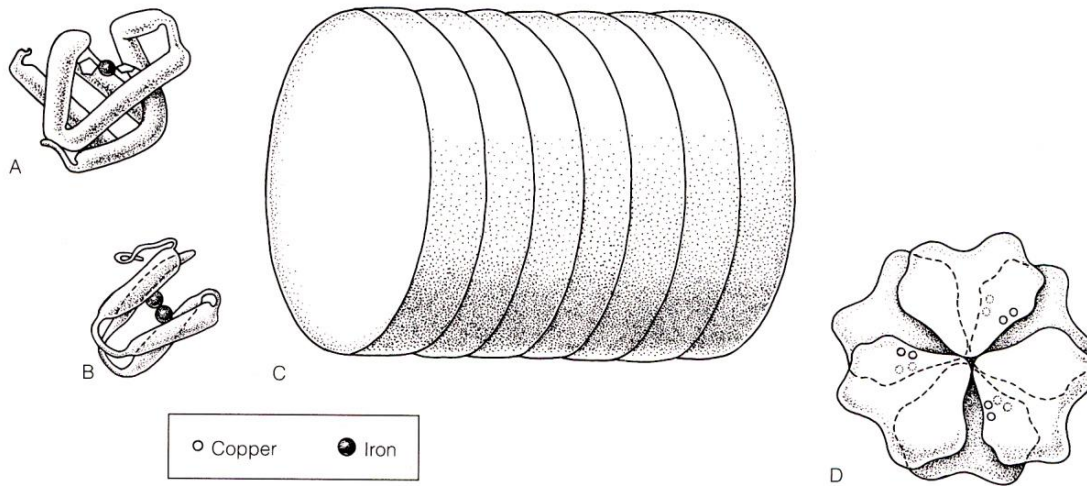
Evoluce dýchacích pigmentů



B) Hemerythrin



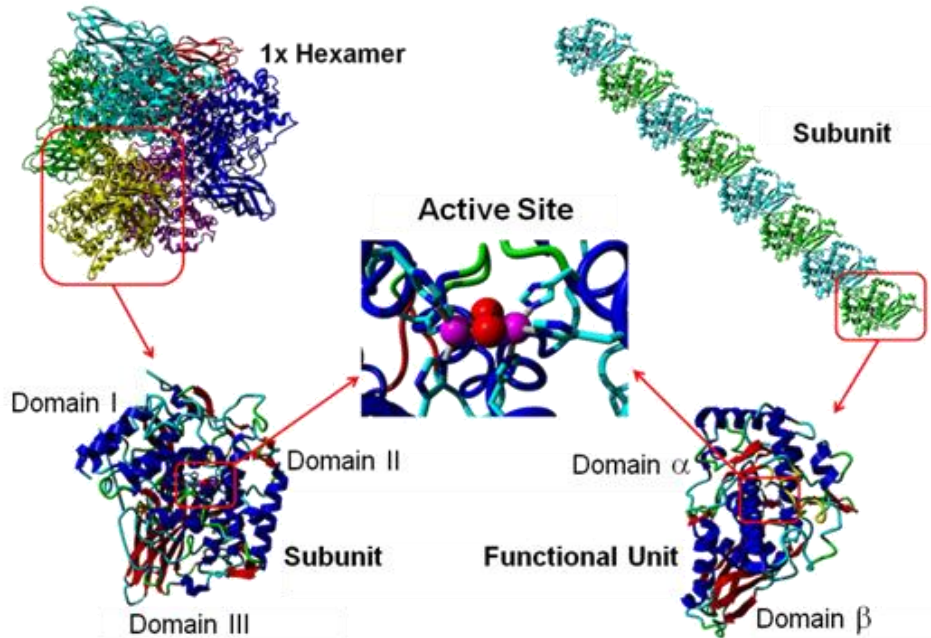
Evoluce dýchacích pigmentů



C) & D) Hemocyanin

Figure 3 Arthropod Hemocyanin

Molluscan Hemocyanin



Výměna plynů povrchem těla vs. specializované dýchací orgány

✓ U řady mnohobuněčných živočichů neexistují specializované, zvětšené povrchy určené k výměně plynů – příjem O_2 a výdej CO_2 pouze povrchem těla: **Houby (Porifera), žahavci (Cnidaria), většina ploštěnců (Plathyhelminthes) a kroužkvců (Anelida), hlístice (Nematoda), pásnice (Nemertini), chapadlovky (Phoronida), Ramenonožci (Brachiopoda), pláštěnci (Tunicata)**

Kožní dýchání má velký význam u řady ryb a žab, u člověka cca 2% z celkového množství kyslíku absorbováno kůží.

✓ **Specializované zvětšené povrchy**

Žábry – nejrůznější vaskularizované výchlípky vodních živočichů (dýchací povrchy vně)

mhohoštětinatci (Polychaeta), členovci (kromě hmyzu), většina měkkýšů, ryby, pulci obojživelníků.

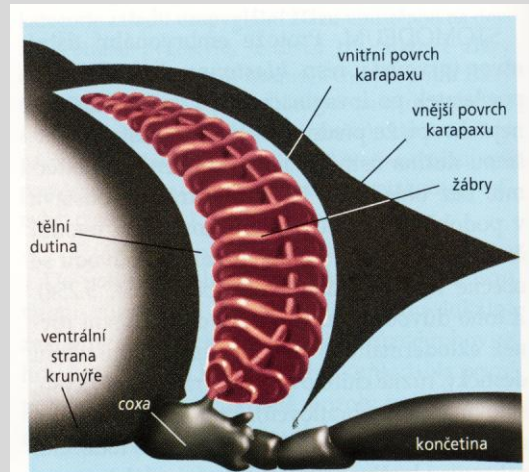
Plíce – dýchací povrchy uvnitř, typicky u suchozemských živočichů

Suchozemští plži, někteří klepítkatci (většina pavouků), bichiři, dvojdyšné ryby, suchozemští obratlovci (Tetrapoda)

✓ **Vzdušnice – systém trubiček rozvádějící plyny rovnou k tkáním, k přenosu nepoužívá tělních tekutin**

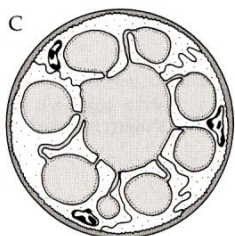
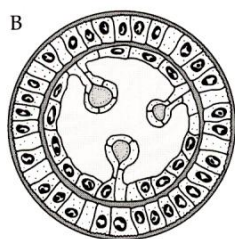
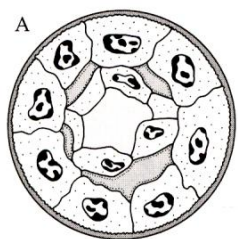
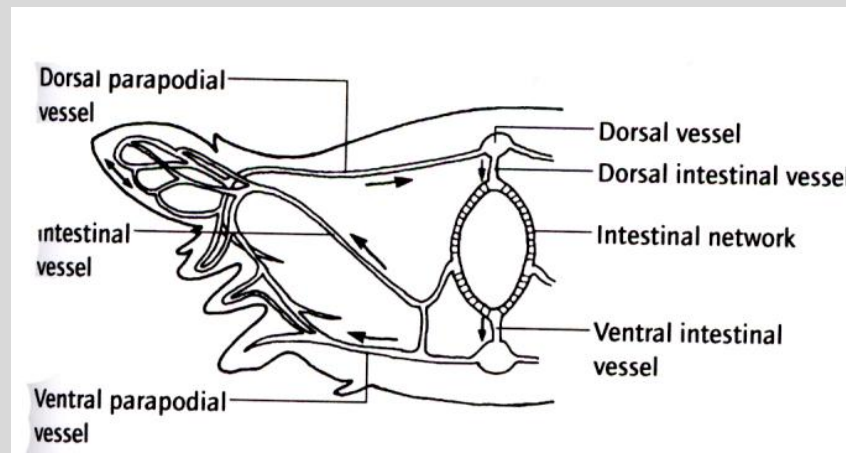
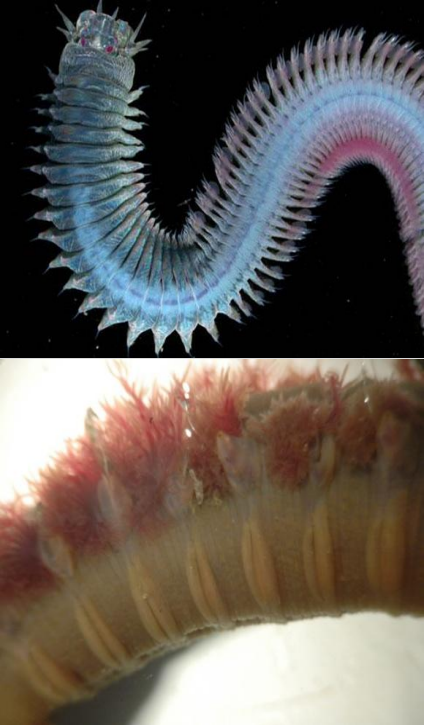
drápkovci (Onychophora), Hmyz (Insecta)

Vnější „žábry“



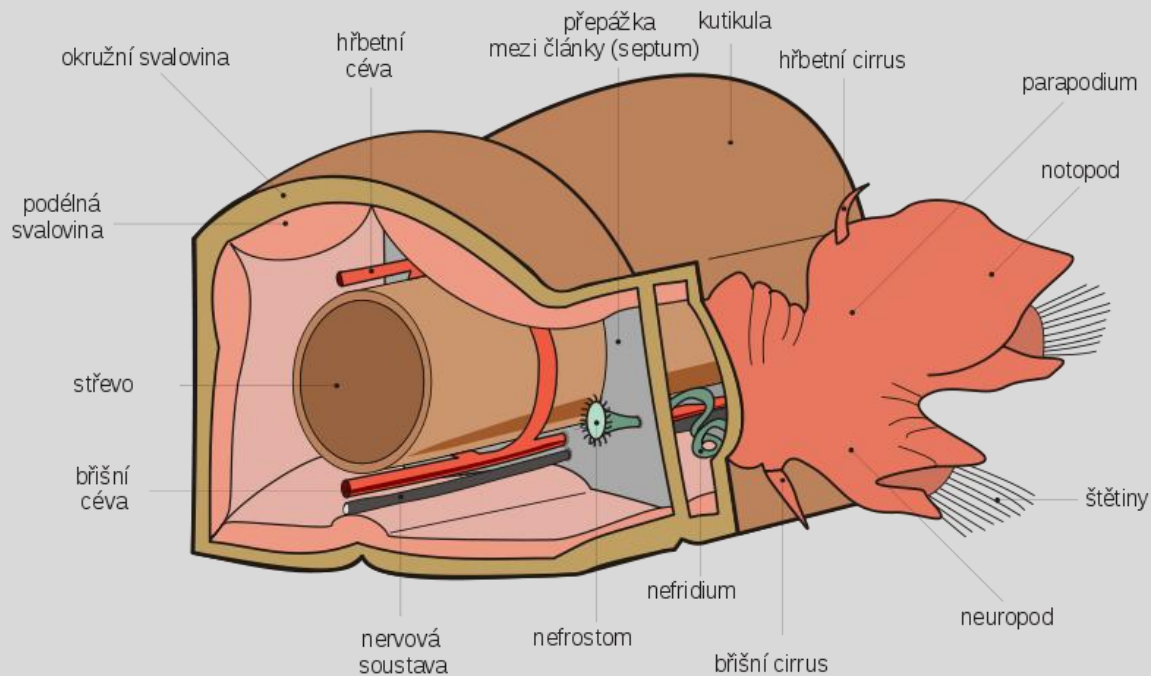
Obr. 5.255 Část končetiny (epipodit) kraba přeměněná na žábry.

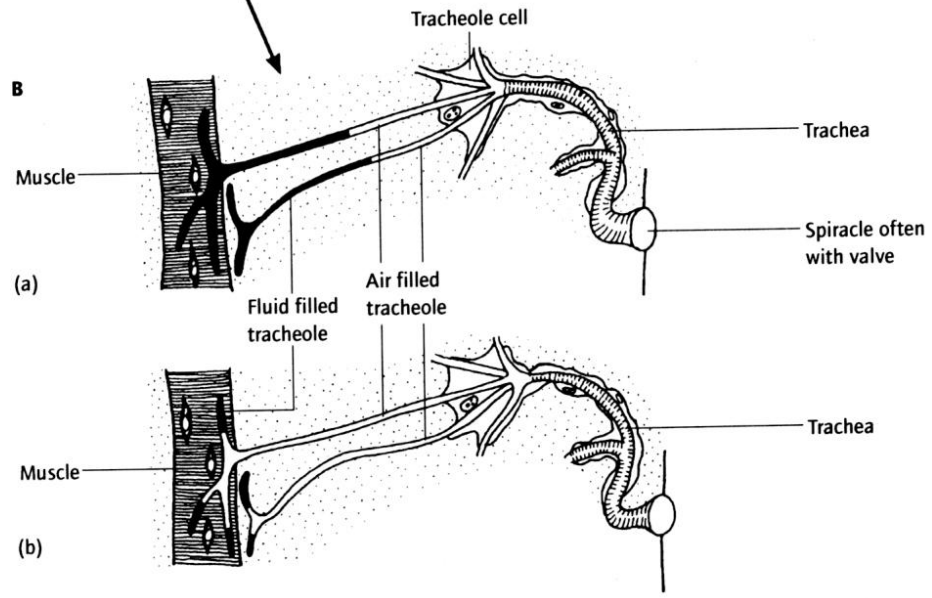
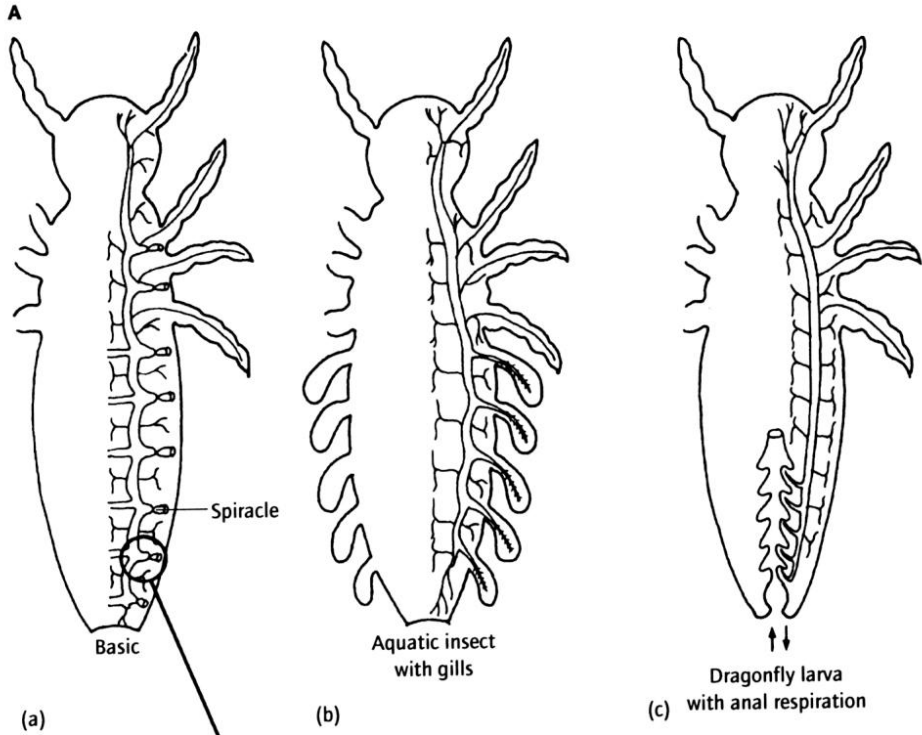
Mnohoštětinatci (Polychaeta) – žábry



- coelomic cavity
- hemocoel (primary body cavity)
- ECM, cuticle

Fig. 11.3. Different structures of annelid gills as seen in cross sections. A. *Malacoceros fuliginosus*, B. *Scalibregma inflatum*, C. *Dendronereides heteropoda*. After Storch and Alberti (1978).





Vzdušnice (tracheje)

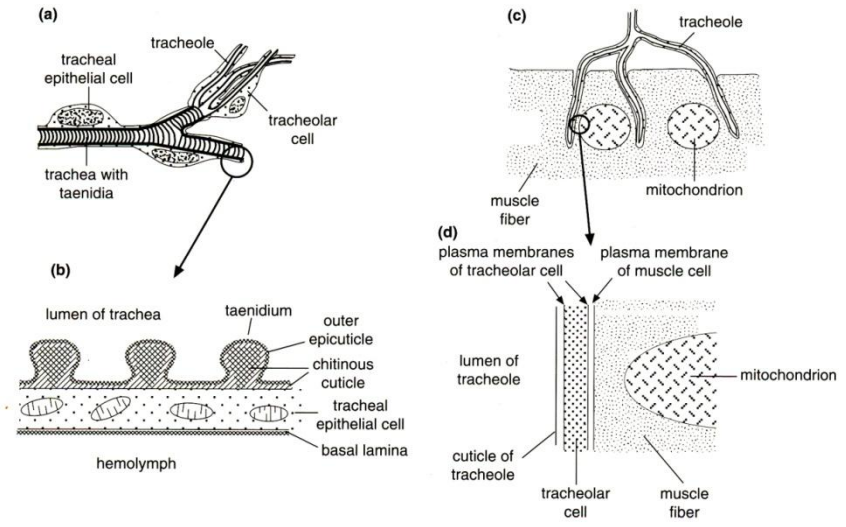


Figure 17.1 Tracheal system. (a) Diagram showing a trachea and tracheoles. (b) Longitudinal section of the tracheal wall; tracheal lumen above, hemolymph below. (c) Diagram showing tracheoles indenting a muscle fiber. (d) Enlargement of area circled in (c). Oxygen diffuses from the lumen of the tracheole (left) through the cuticle and the tracheolar cell to the mitochondrion in the muscle fiber.

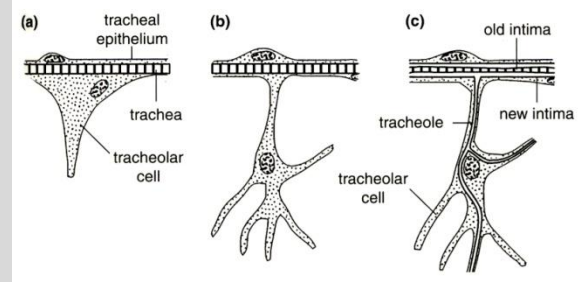
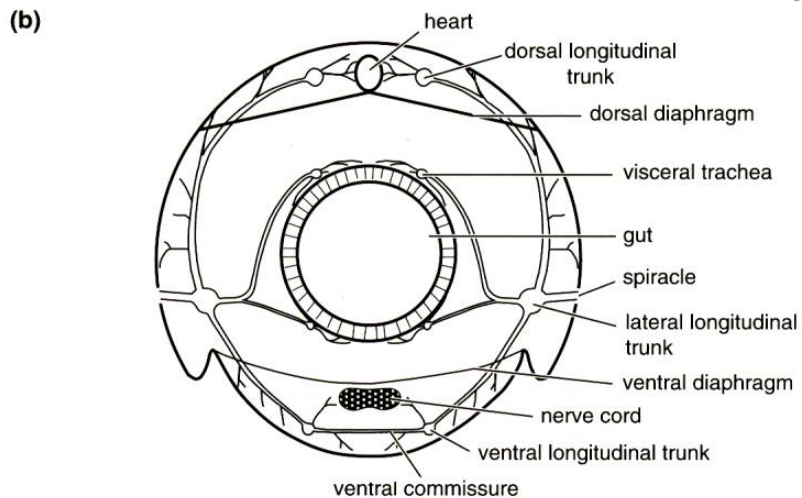
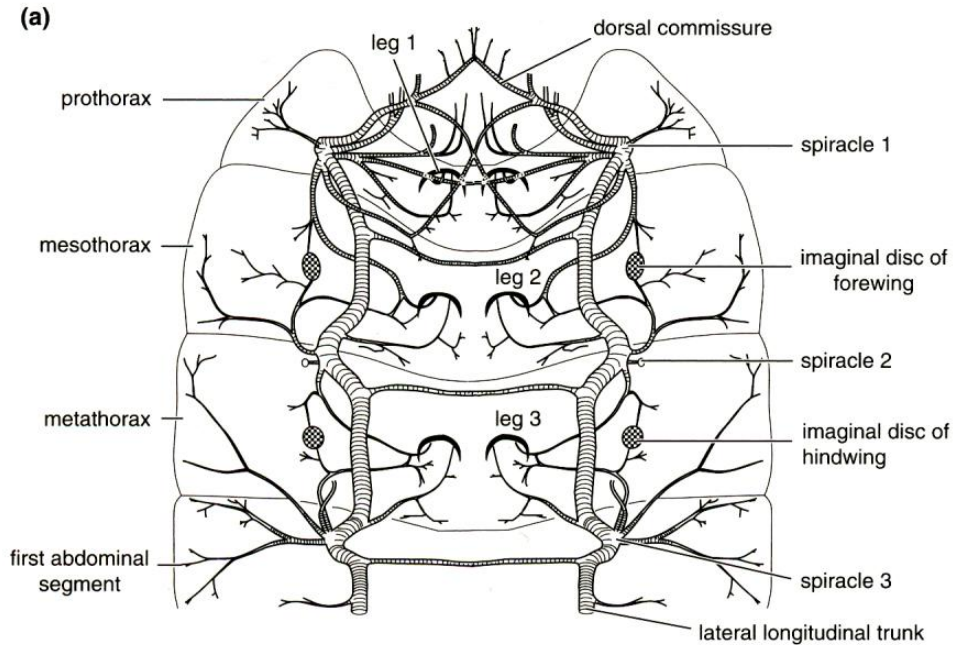


Figure 17.2 Development of a tracheole (after Keister, 1948). (a) Tracheolar cell developing from the tracheal epithelium. (b) Tracheolar cell with extensive cytoplasmic processes. (c) Tracheole within tracheolar cell and becoming connected to existing trachea at a molt.

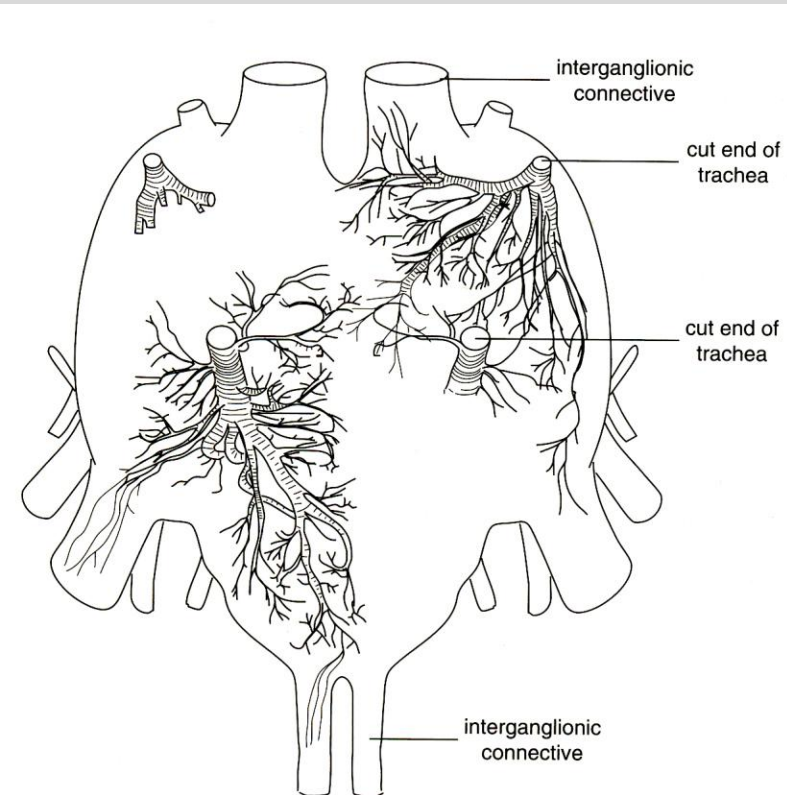
Vzdušnice (tracheje)



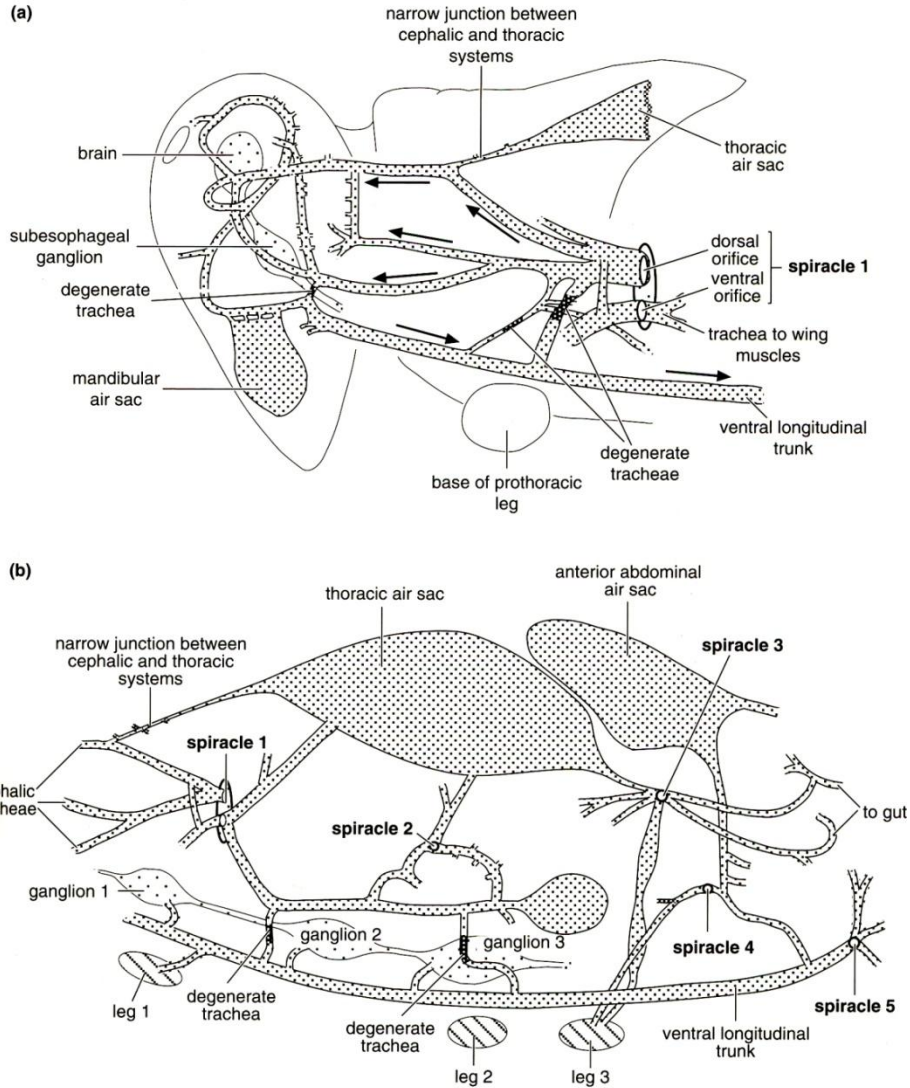
A) Tracheální systém housenky

B) Schématický řez zadečkem sarančete – hlavní tracheální kmeny

C) Tracheální větvení v hrudním nervovém gangliu sarančete



Vzdušnice (tracheje)



Vlevo: Tracheální systém sarančete

Dole: Vliv reverze pumpování srdce na velikost vzdušných vaků a směr proudění vzduchu ve vzdušnicích

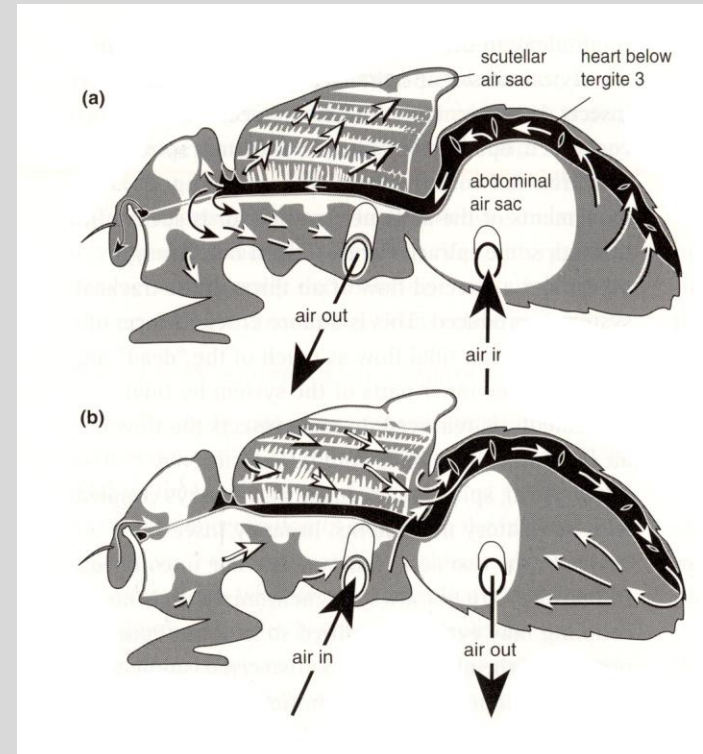


Figure 17.4 Tracheal system of a locust (*Schistocerca*) (after Miller, 1960b). (a) Supply to the head from spiracle 1; arrows indicate the probable direction of airflow resulting from abdominal ventilatory movements. (b) Supply to the pterothorax; notice that the thoracic air sac is largely isolated from other parts of the tracheal system by narrow or degenerate tracheae.

Póry vzdušnic – spiracula, stigmata

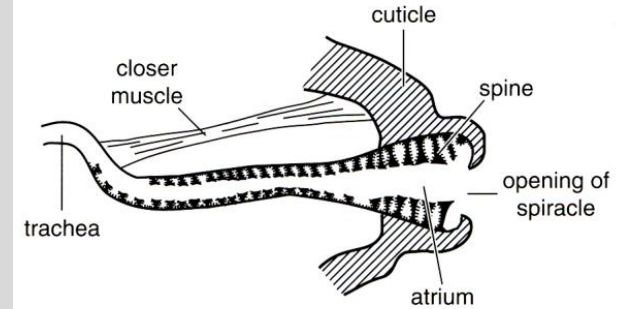
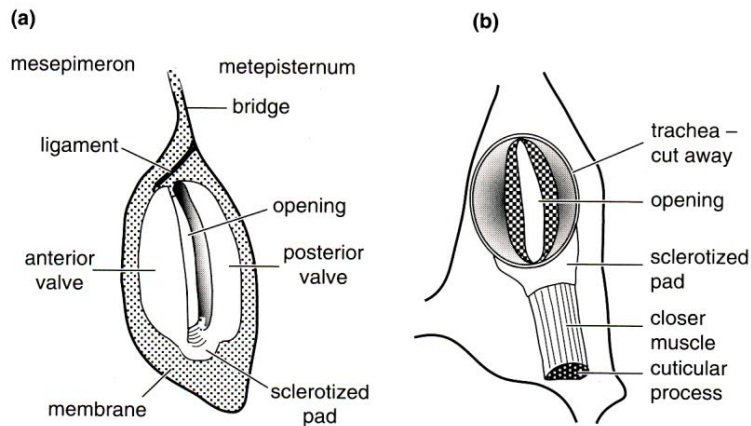


Figure 17.10 Section through a spiracle of a louse, *Haematopinus*, showing the atrium and branched spines in which dust accumulates (after Webb, 1948).

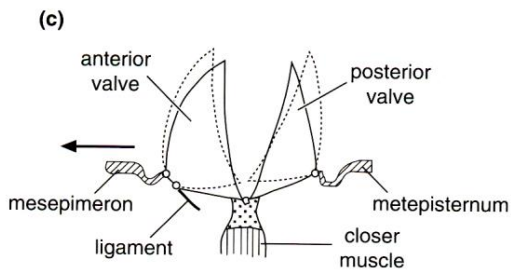


Figure 17.11 A one-muscle spiracle; second thoracic spiracle of a locust (*Schistocerca*) (after Miller, 1960a). (a) External view; (b) internal view; (c) diagrammatic section through the spiracle showing how movement of the mesepimeron (arrow) causes the valves to open wide (dotted).

Vodní hmyz – alternativní řešení dýchání

Vnější tracheální žábry

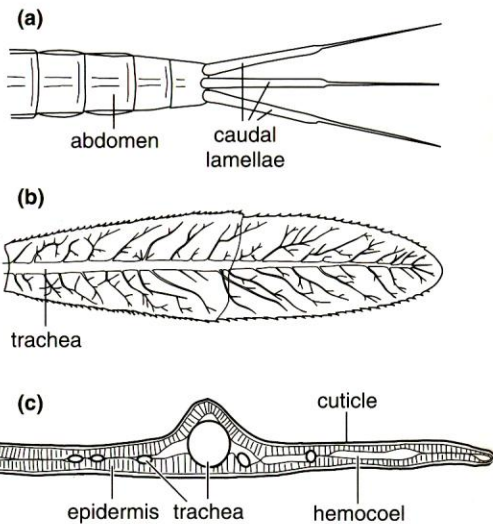


Figure 17.28 Tracheal gills (caudal lamellae) of a damselfly larva (Zygoptera). (a) Dorsal view of the posterior end of the abdomen. (b) One lamella showing the tracheae; only the major branches are shown (after Gardner, 1960). (c) Transverse section of a lamella (after Tillyard, 1917).

Anální tracheální žábry

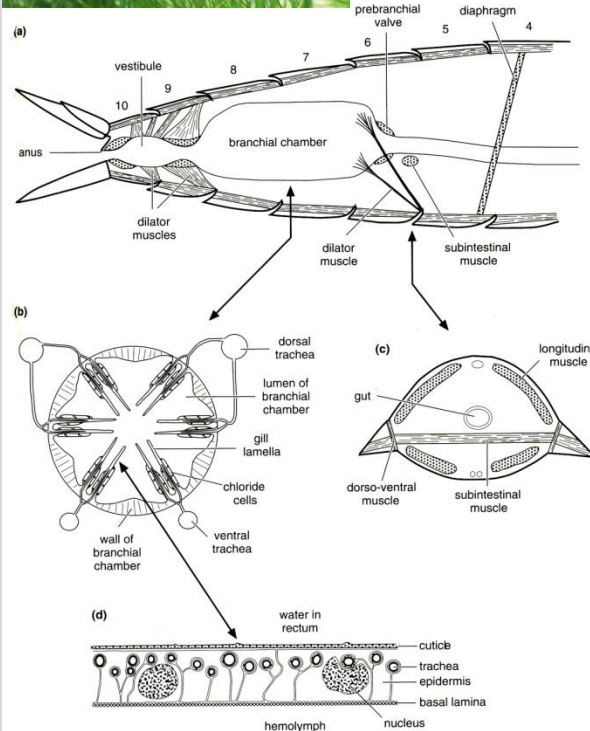


Figure 17.29 Tracheal gills in the rectum of a dragonfly larva (after Tillyard, 1917; Mill and Pickard, 1972). (a) Longitudinal section through the abdomen; numbers indicate abdominal segments. (b) Transverse section through the branchial chamber. (c) Transverse section through abdominal segment 6 showing the subintestinal muscle. (d) Detail of gill epithelium showing the tracheae close beneath the cuticle (after Schmitz and Konnick, 1976).

Nesmáčivé chloupky na plastronu

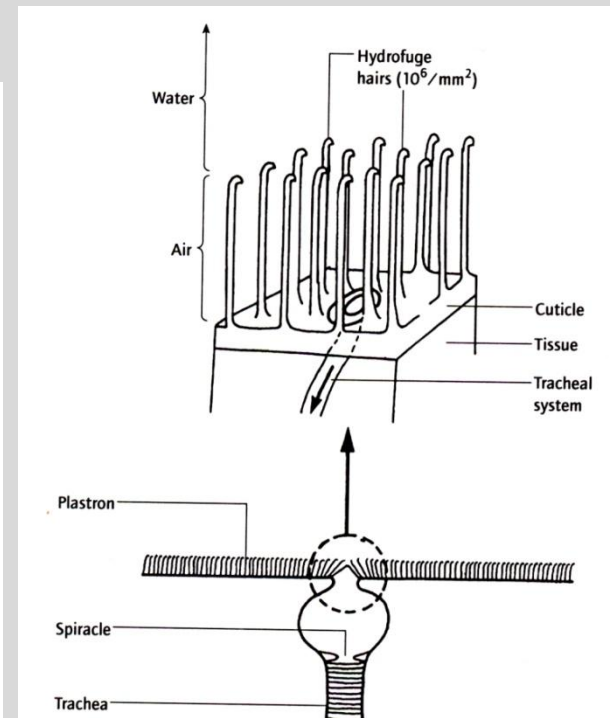
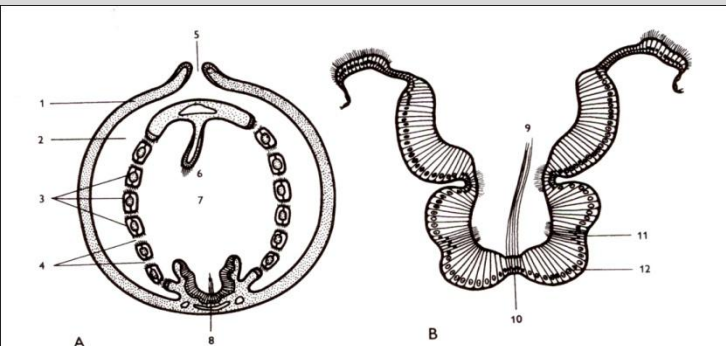
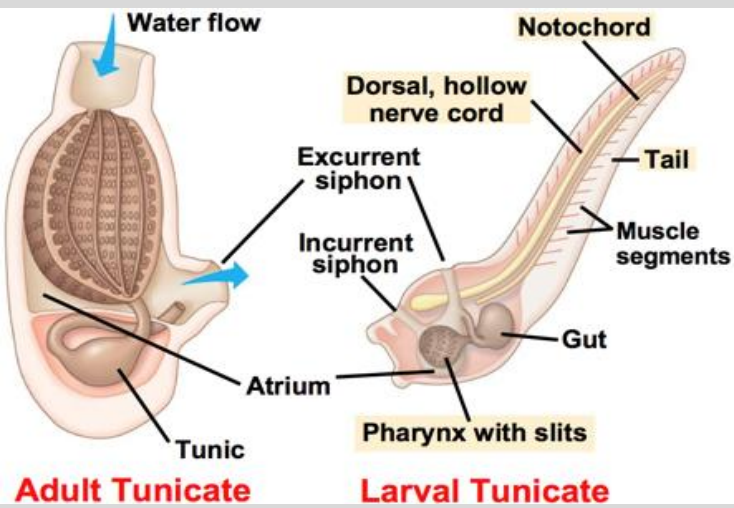


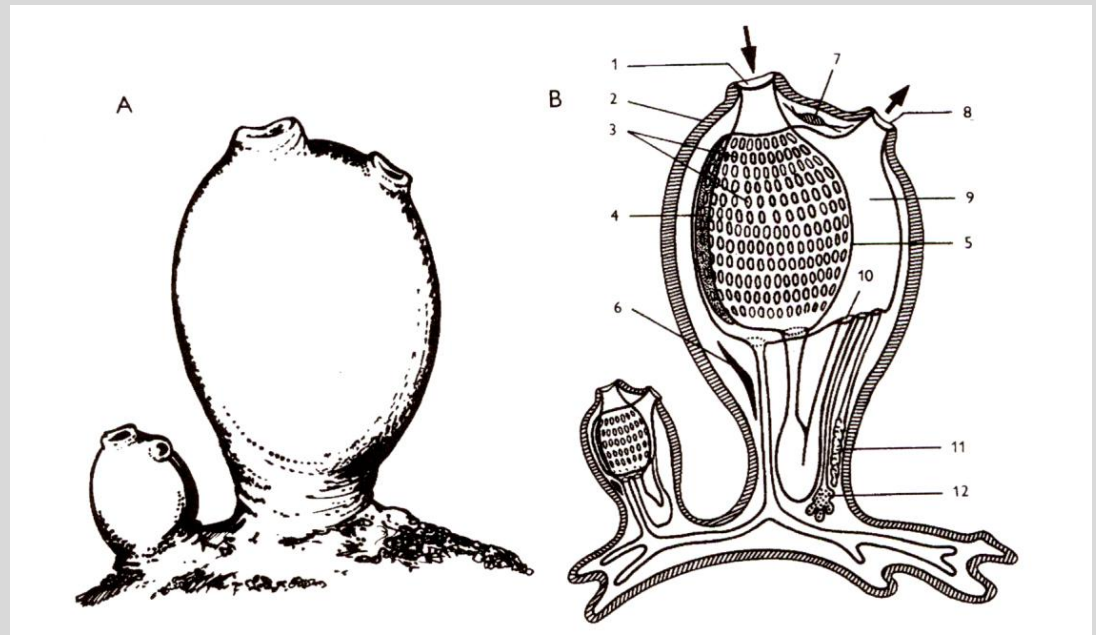
Fig. 11.13 A plastron. Part of the body surface is covered with hydrophobic hairs providing a non-wettable surface, where air remains permanently. It thus acts as a non-compressible gill into which O_2 diffuses from the water; i.e. as O_2 is withdrawn the thick pile prevents intrusion of water, so the volume remains constant and P_{O_2} must fall causing O_2 to diffuse in from the aquatic environment. In the aquatic insect *Aphelocheirus* the plastron can withstand pressures of several atmospheres before collapse. (After Ramsay, 1962 and Randall *et al.*, 1997).

Pláštěnci (Tunicata)

- ✓ **Otevřená cévní soustava**
- ✓ **Jednoduché srdce + cévy, které vedou krev k orgánům a do pláště**
- ✓ **Dýchání povrchem těla a pomocí žaberního vaku**
- ✓ **Krevní buňky (améboциты podobné lymfocytům, u některých krevní barviva (např. Phallusia – hemovanadin))**



Obr. 9 Šikmý řez krajinou hltanu přes vyvřovací otvor (A) a příčný řez endostylem (B) pláštěnců (Urochordata). 1 – tělní stěna, 2 – obžaberní prostor, 3 – žaberní přepážky, 4 – žaberní štěrbiny, 5 – vyvřovací otvor (*atrioporus*), 6 – epibranchiální lišta, 7 – dutina hltanu, 8 – hypobranchiální rýha (endostyl), 9 – bičíky endostylu, 10 – bičíkaté buňky, 11 – postranní obrvené buňky, 12 – žlázové buňky.

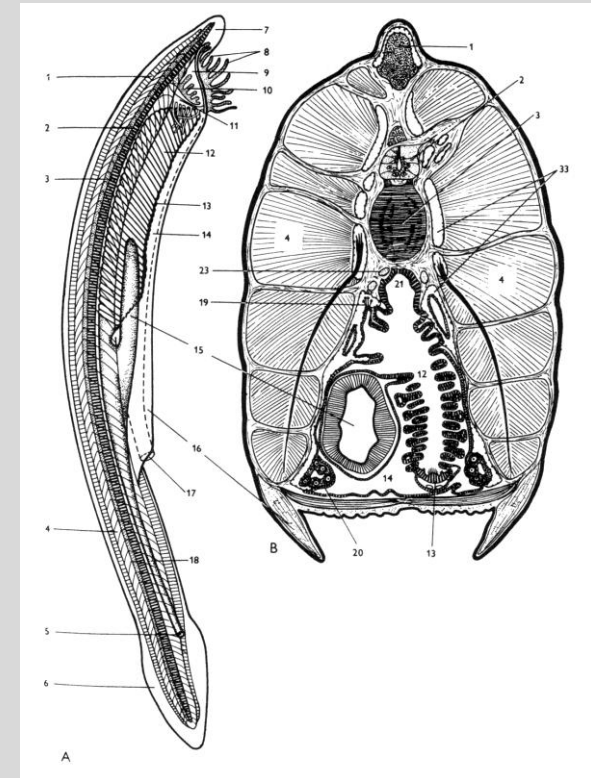
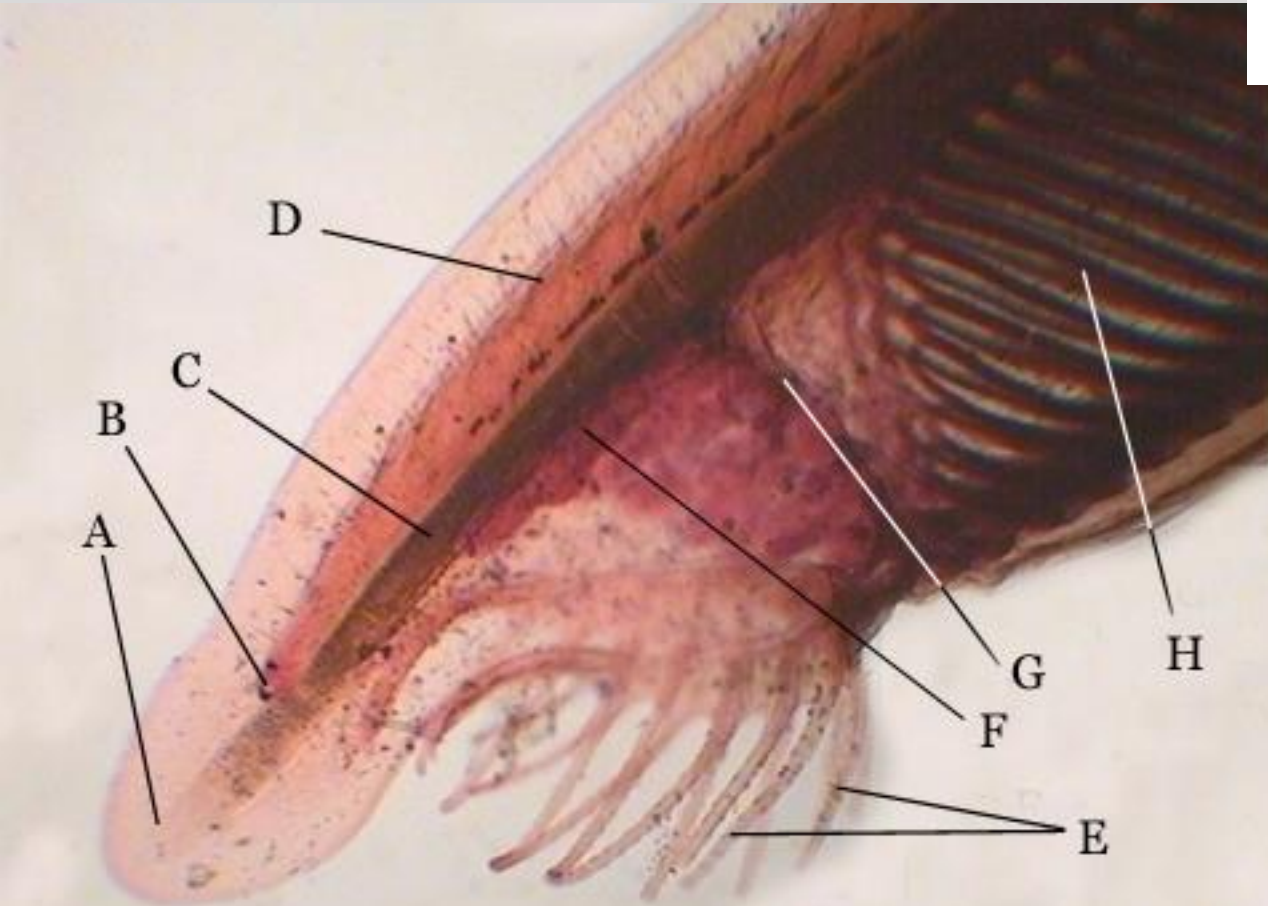
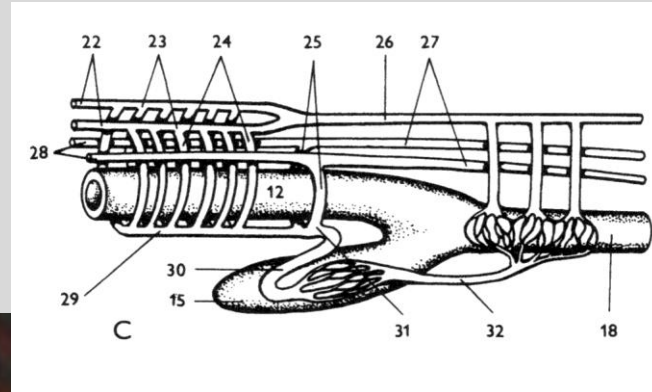


Obr. 12 Vzhled a morfologie dospělých sumek. A – dva jedinci rodu *Halocynthia*, B – schéma jejich anatomie. 1 – přijímací otvor, 2 – tělní stěna a pláště, 3 – žaberní štěrbiny, 4 – endostyl, 5 – hltan, 6 – srdce, 7 – cerebrální ganglion, 8 – vyvřovací otvor (kloakální sífon), 9 – kloakální dutina obžaberního prostoru, 10 – vyústění střeva (řitní otvor), 11 – varle, 12 – vaječník.

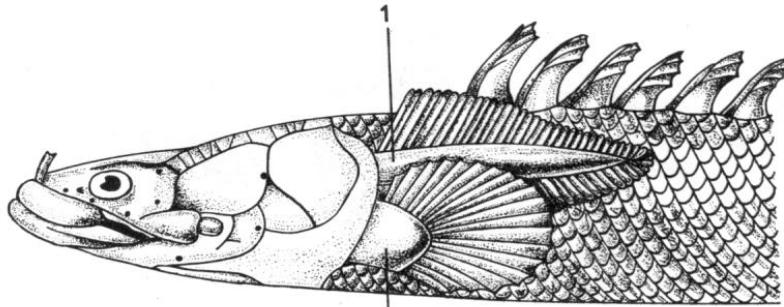
Kopinātec (Branchiostoma)

✓ **Žábry endodermálního původu, ale hlavně jednovrstevná pokožka**

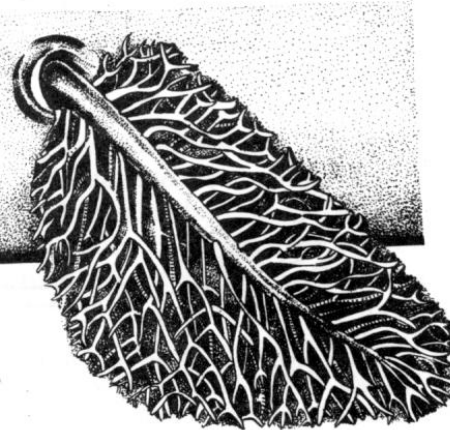
✓ **Krevní plazma neobsahuje respirační pigmenty**



Vnější žábry ryb



A



B

Obr. 71: Vnější žábry larvy bichira rodu *Polypterus* (A) a samečka bahníka amerického rodu *Lepidosiren* (B), jemuž tyto žábry narůstají na břišních ploutvích v období péče o potomstvo, kdy bahníci nepřijímají atmosférický kyslík. 1 - vnější žábry, 2 - hrudní ploutev. A - podle Romera, 1971, B - podle Ihleho et al., 1971.

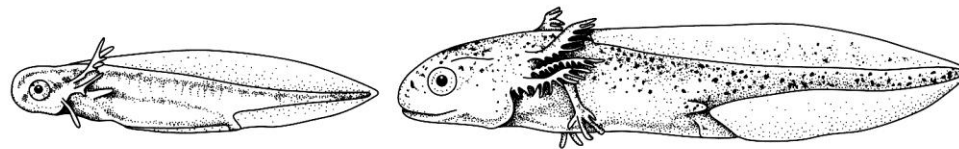


Vnější žábry obojživelníků

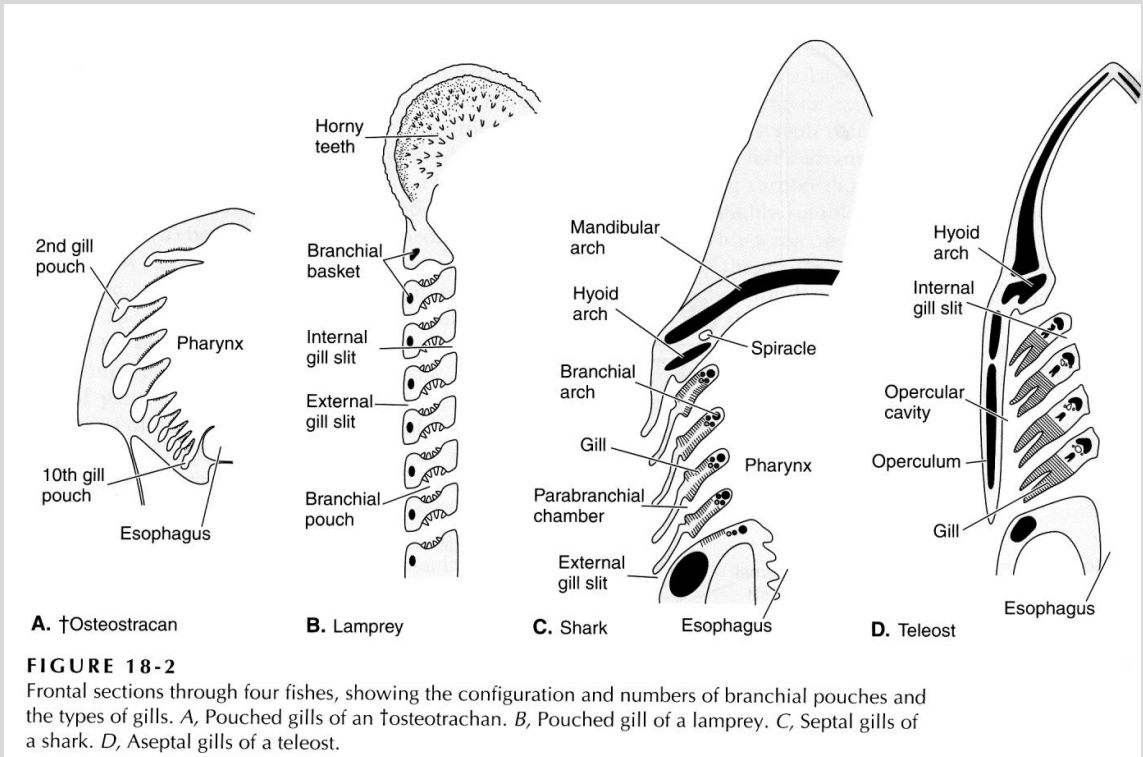
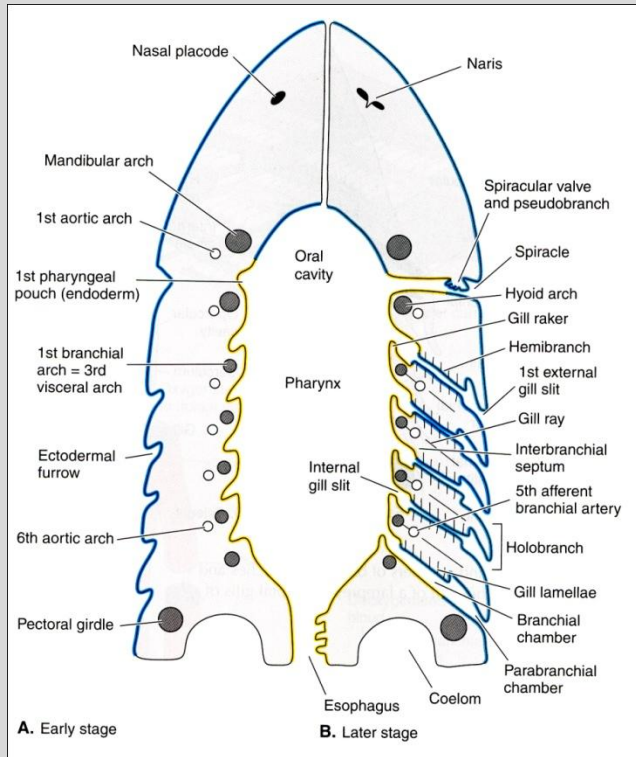


FIGURE 18-12

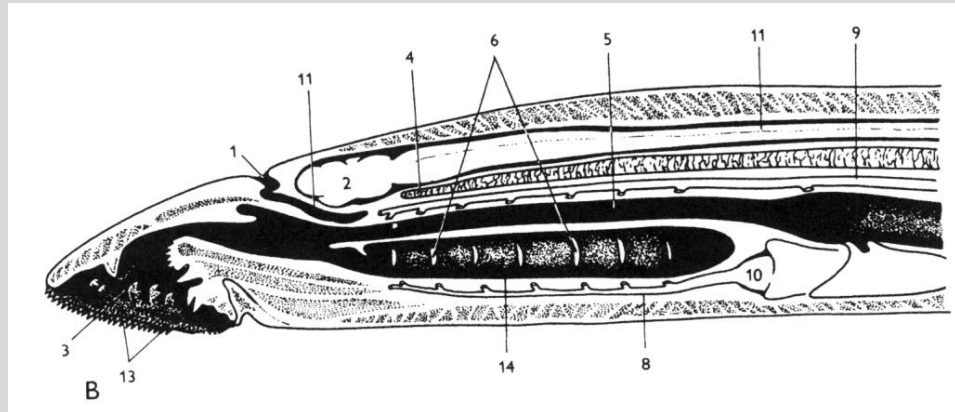
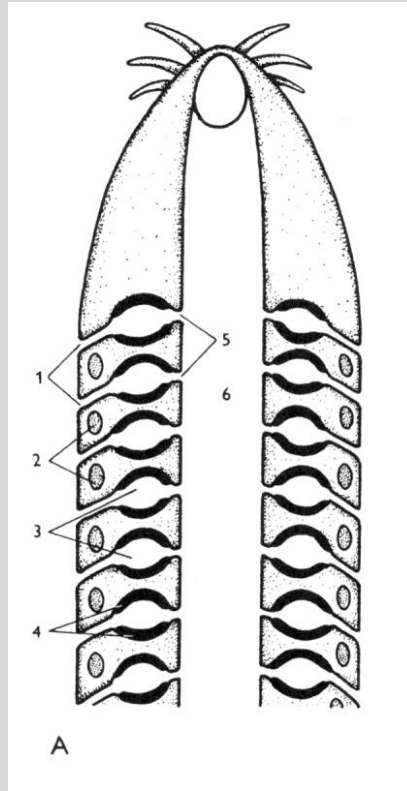
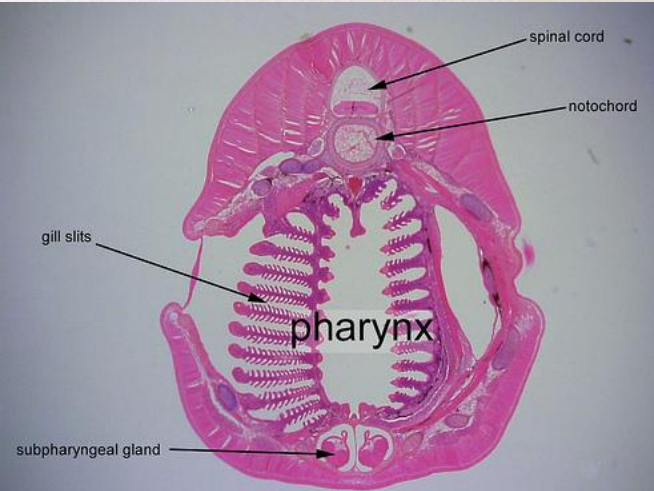
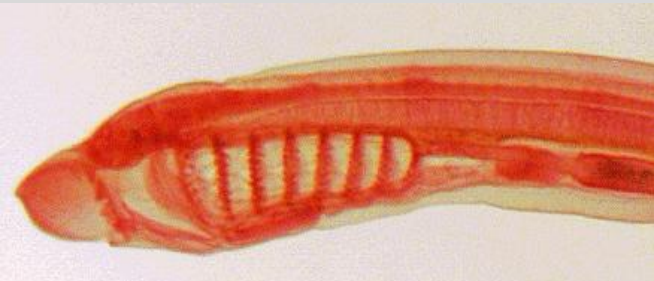
The development of the external gills in the larva of a salamander. (After *Glaesner*.)



Žábry – rybovití obratlovci



Žábry mihulí a sliznatek



Žábry paryb

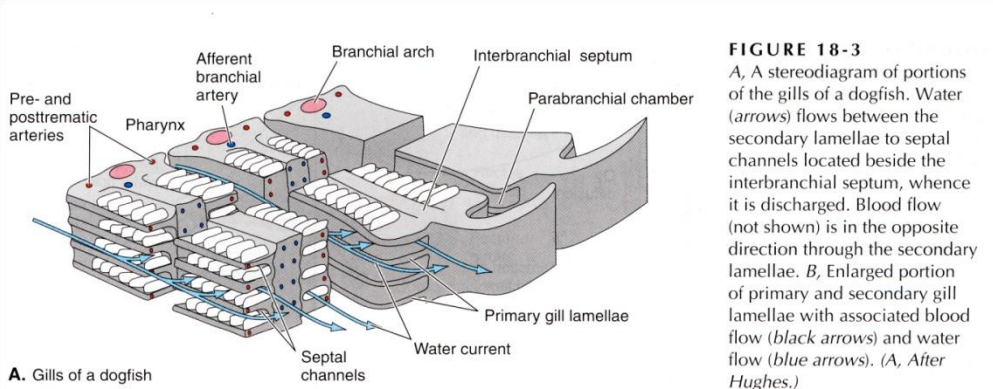


FIGURE 18-3
A, A stereodiagram of portions of the gills of a dogfish. Water (arrows) flows between the secondary lamellae to septal channels located beside the interbranchial septum, whence it is discharged. Blood flow (not shown) is in the opposite direction through the secondary lamellae. *B*, Enlarged portion of primary and secondary gill lamellae with associated blood flow (black arrows) and water flow (blue arrows). (*A*, After Hughes.)

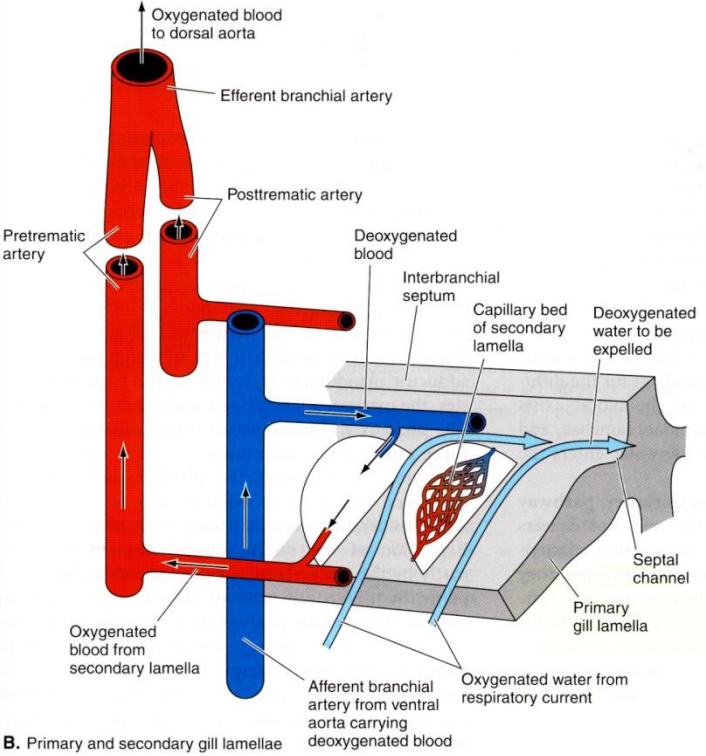
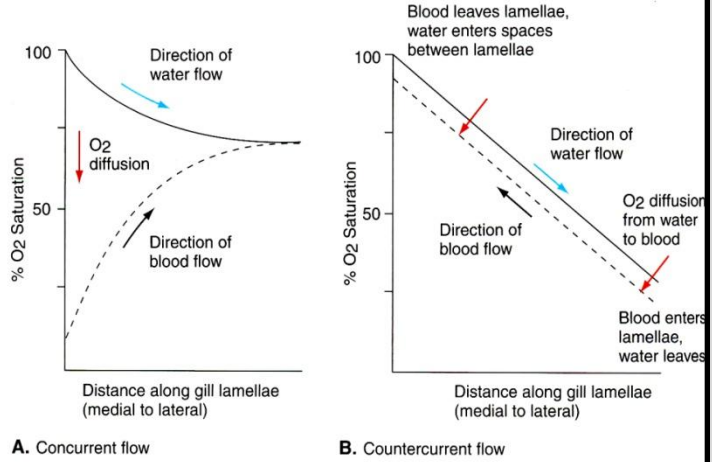
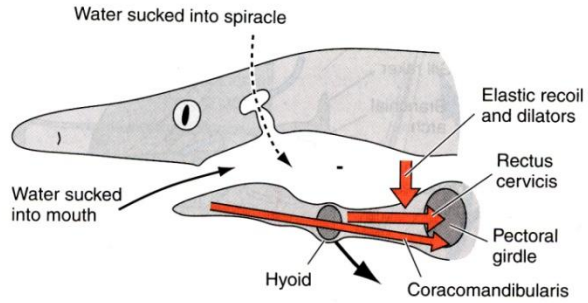


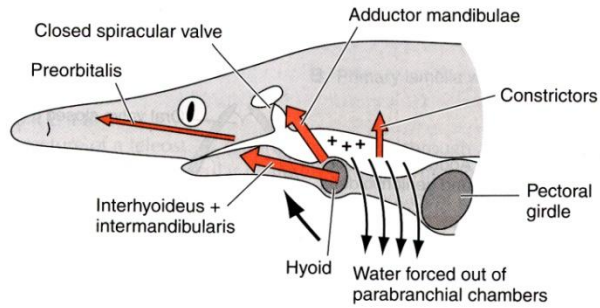
FIGURE 18-4
 Graphs showing the changes in oxygen content of blood and water during concurrent flow (left) and countercurrent flow (right).



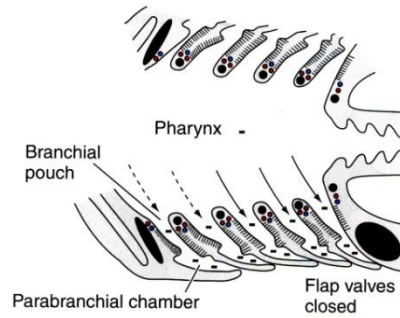
Ventilace žaber u paryb



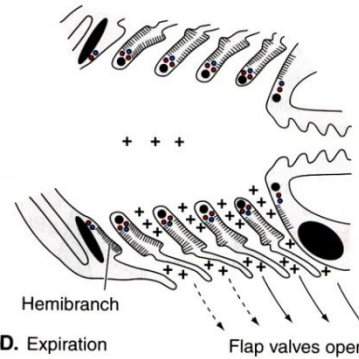
A. Suction pump



C. Force pump



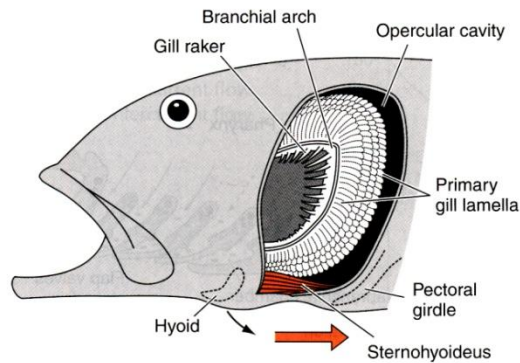
B. Inspiration



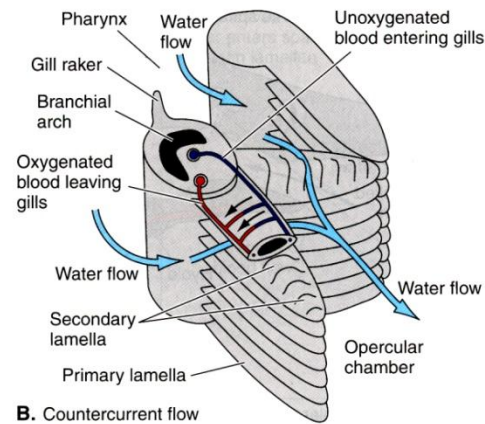
D. Expiration



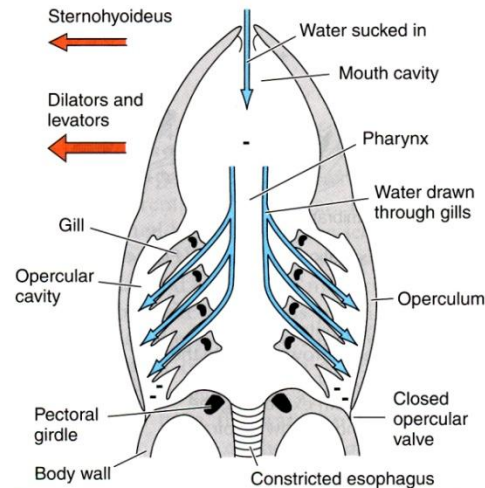
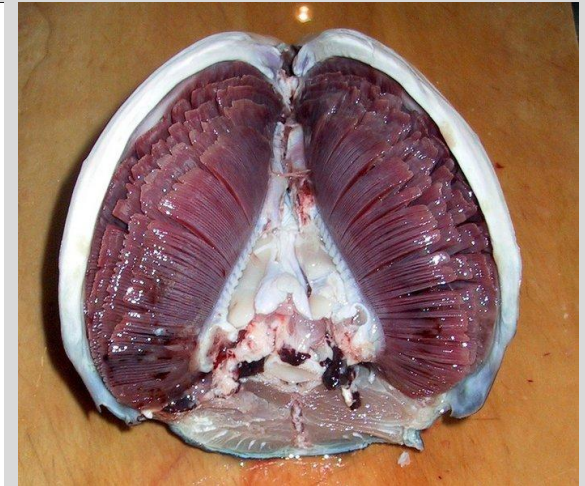
Žábry kostnatých ryb



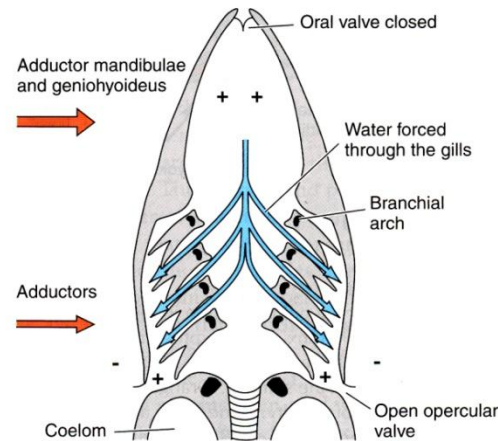
A. Lateral view



B. Countercurrent flow



C. Inspiration (expansion stage)



D. Inspiration (compression stage)

FIGURE 18-6

The gills in a teleost. *A*, A lateral view of the opened opercular chamber. The black arrows indicate the movements of the hyoid. *B*, The countercurrent flow of water and blood in a gill. Blue arrows indicate the flow of water across the gills; black arrows indicate the flow of blood within the gills. *C*, Mechanics of inspiration. Blue arrows show the direction of water movement. *D*, Mechanics of inspiration. (*B*, After Dorit et al.)

Žábry kostnatých ryb

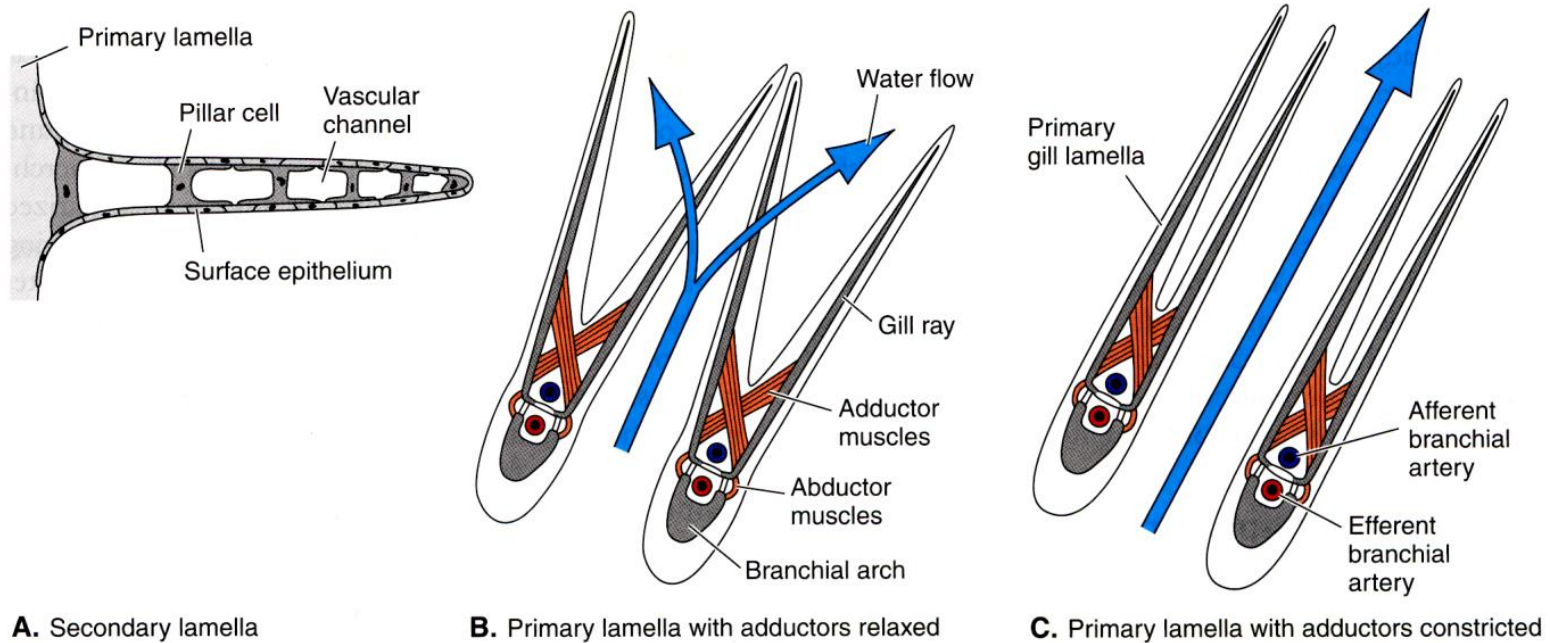
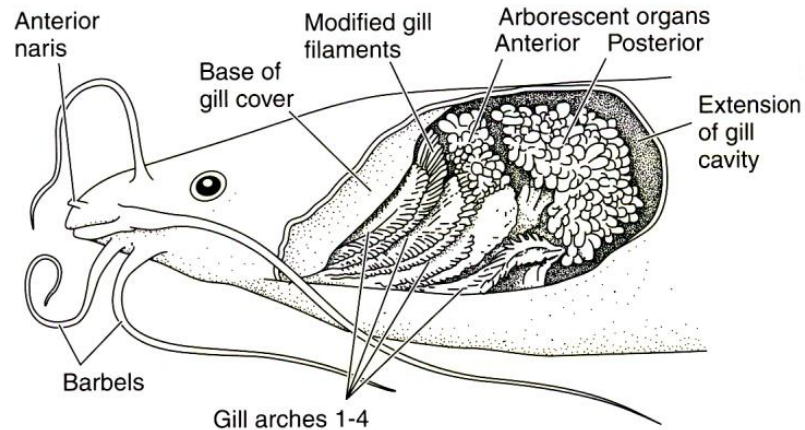
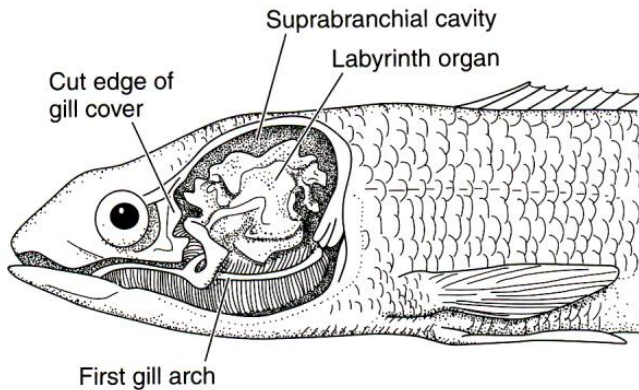
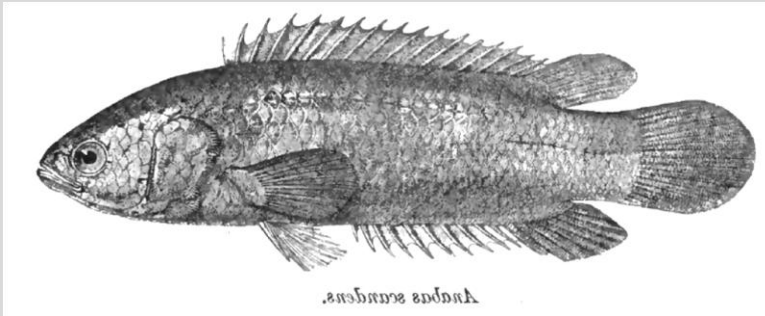


FIGURE 18-7

Gill structure of a teleost. *A*, A transverse section through a secondary lamella, showing the close proximity of the vascular channels through which blood flows and the surface across which water flows. *B*, Primary gill lamellae of adjacent gills meet when adductors relax, so water must cross the secondary lamellae. *C*, Primary gill lamellae of adjacent gills separate when the adductor muscles constrict, and much water leaves the opercular chamber without crossing the secondary lamellae. (*A*, After Hughes; *B* and *C*, after Bijtel.)

Přídavné dýchací orgány ryb



A. Climbing perch

B. Walking catfish

FIGURE 18-8

Air-breathing adaptations in teleosts. A, Climbing perch. B, Walking catfish.

lezoun rodu Anabas

Plíce

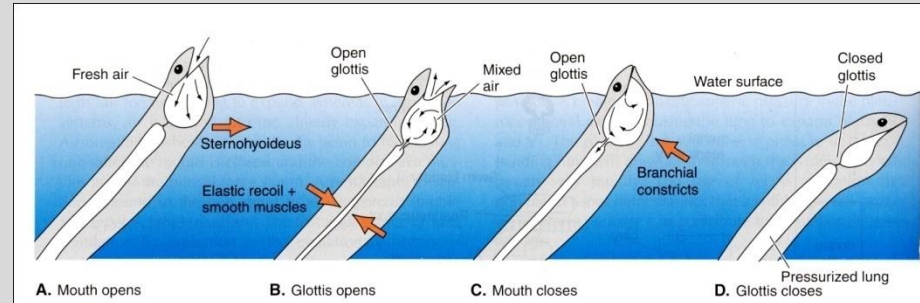
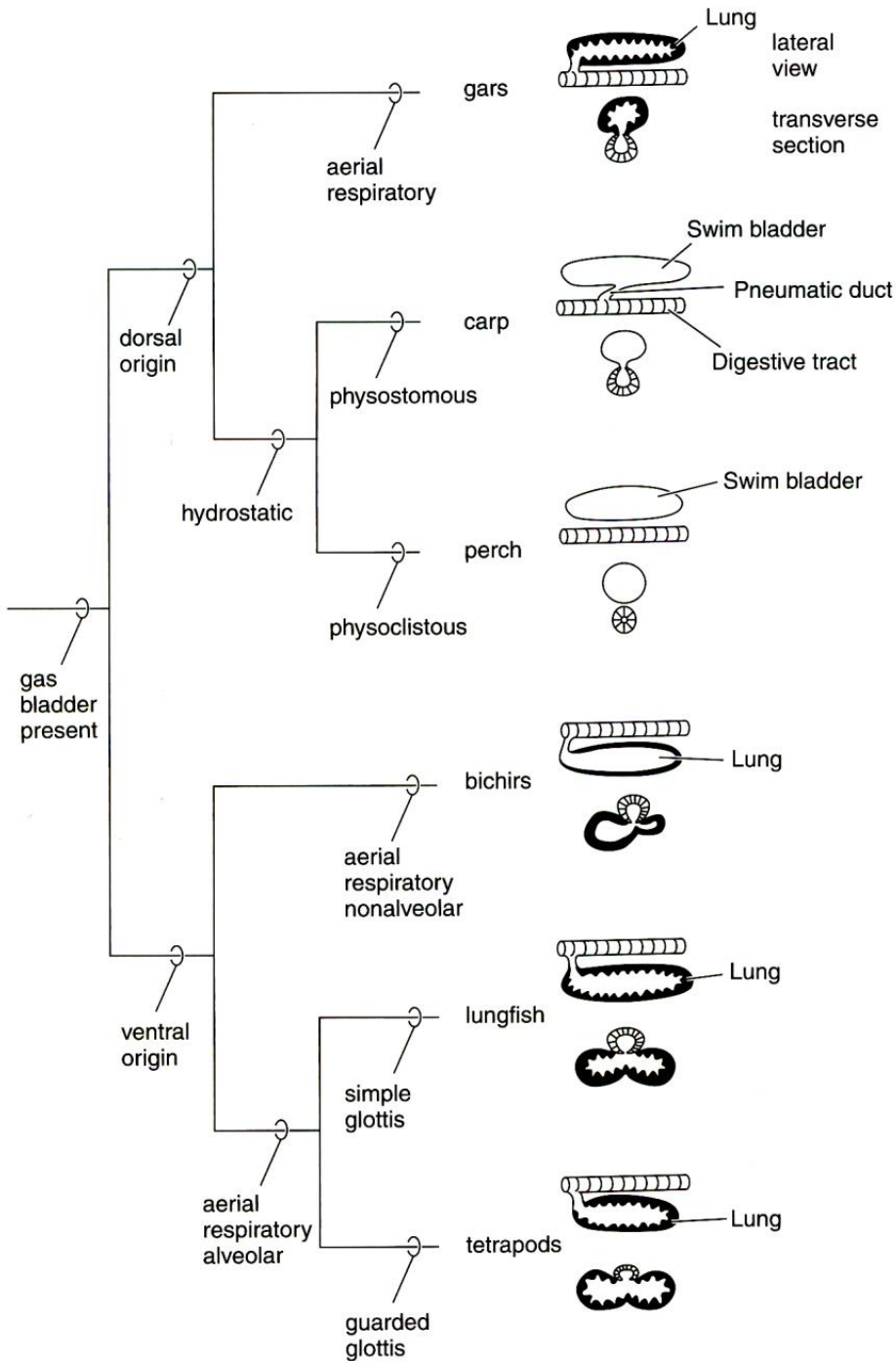
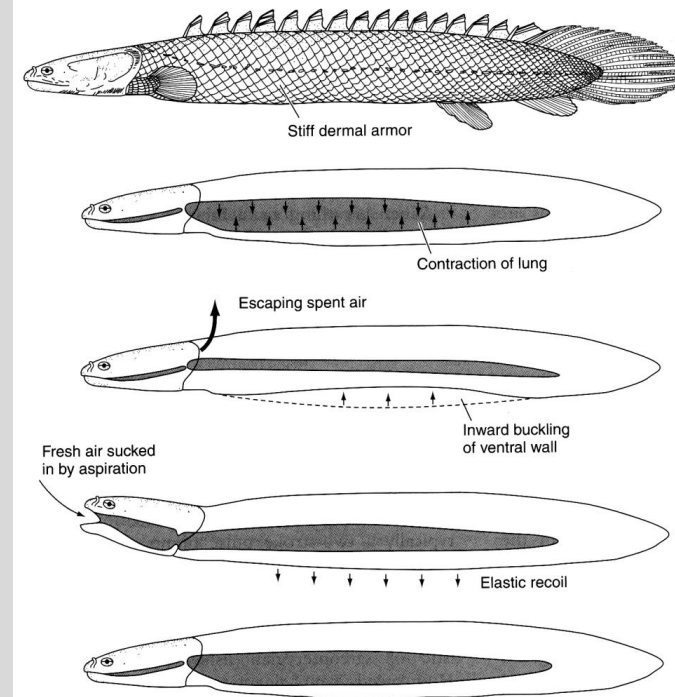


FIGURE 18-10
Ventilation of the lung by a buccal pulse pump in the South American (*Lepidosiren*) and African (*Protopterus*) lungfishes. Black arrows indicate air flow; orange arrows indicate muscle action. A, A lungfish at the surface opens its mouth and takes fresh air into its oropharyngeal cavity. B, The glottis opens, and spent air expelled from lungs mixes with fresh air. Excess air escapes through the mouth. C, The mouth closes, and mixed air is forced into the lungs. D, The glottis closes, and air is held in the lungs.



Plynový měchýř

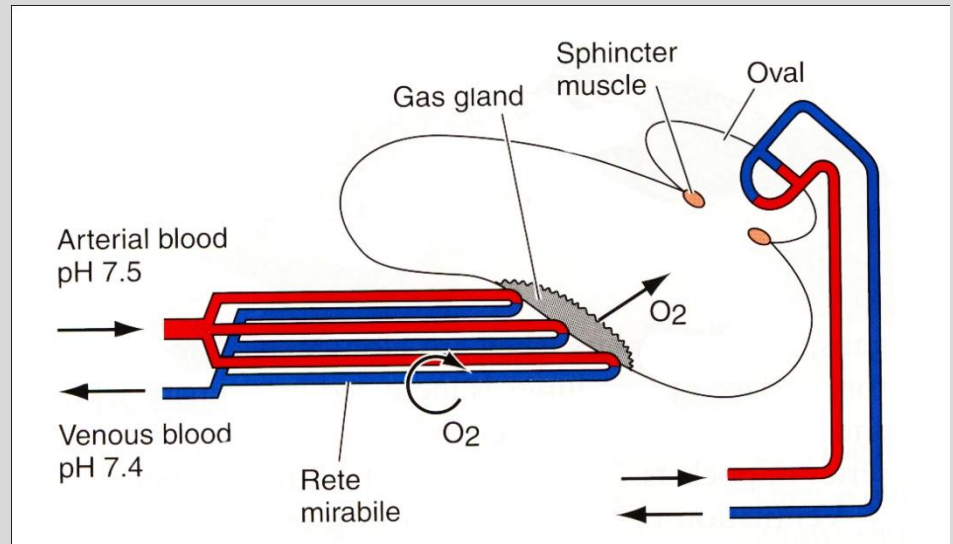
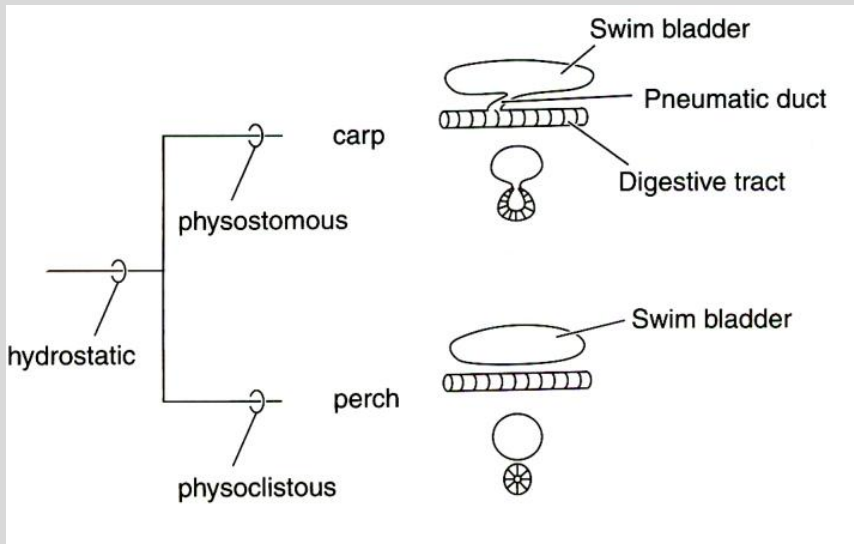
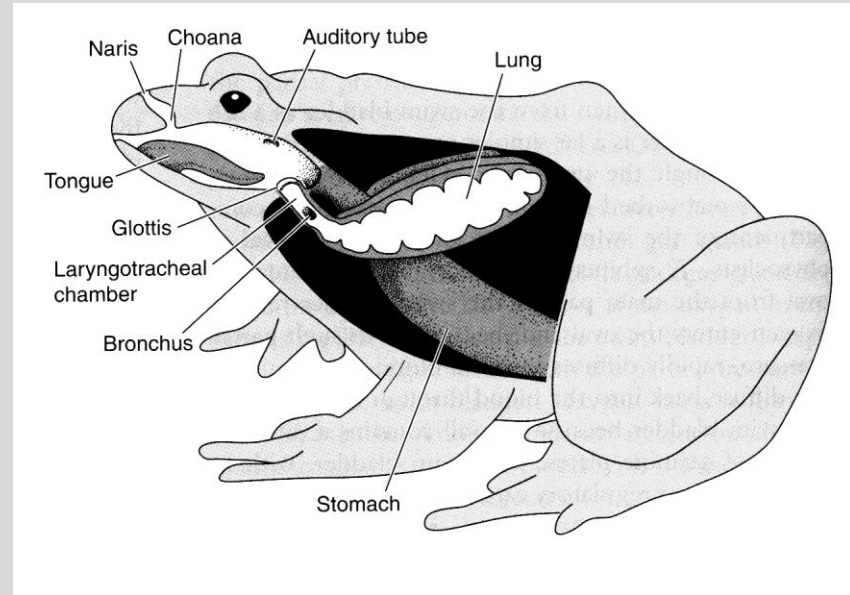
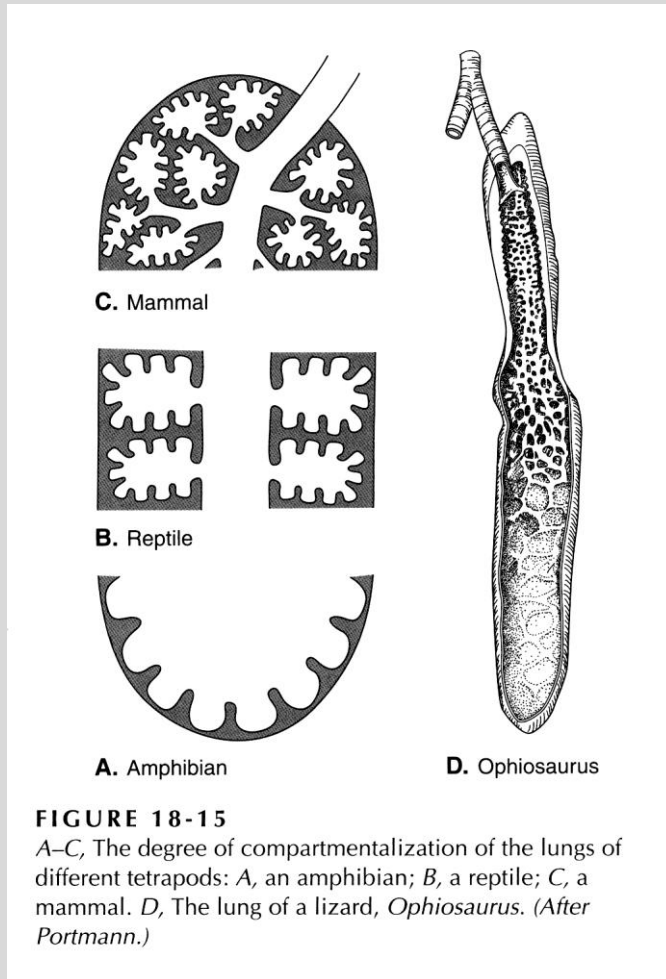
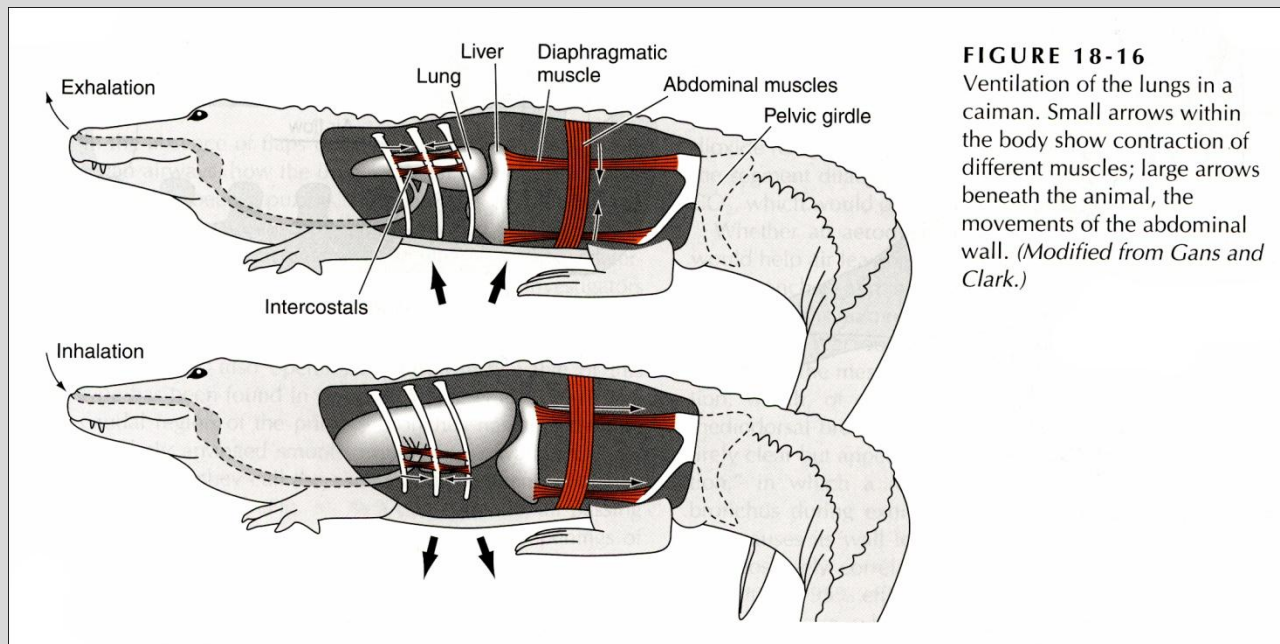
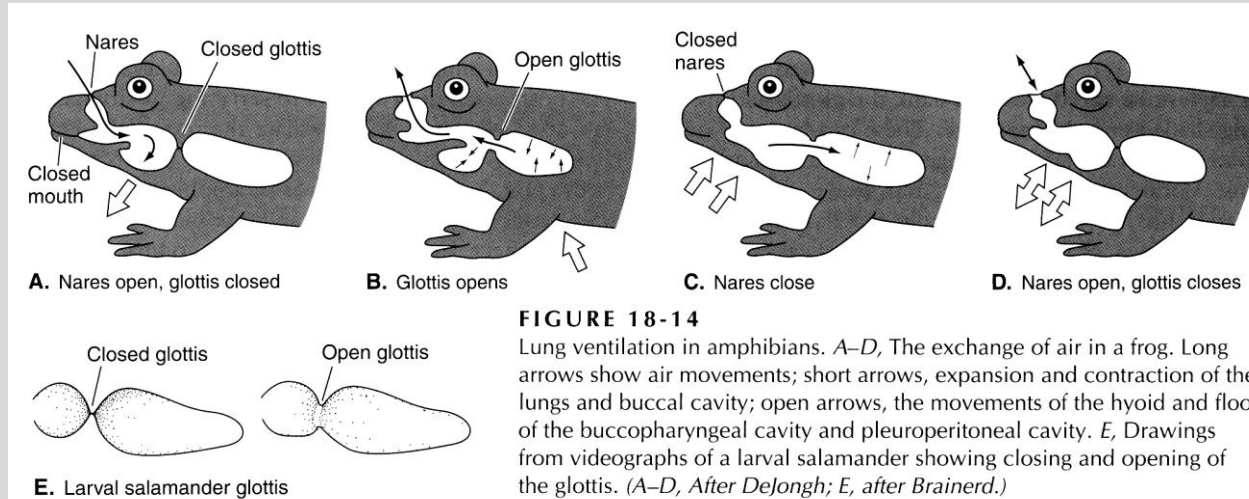


FIGURE 18-11

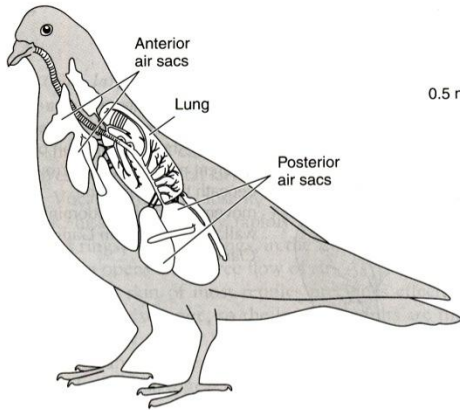
The operation of the swim bladder in a physoclistous teleost. (Modified from Alexander.)



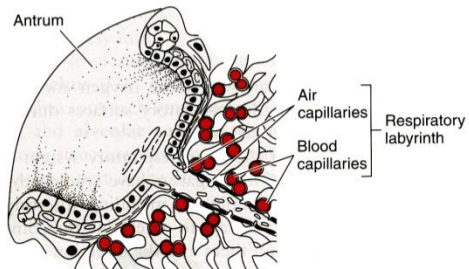
Ventilace plic u obojživelníků a plazů



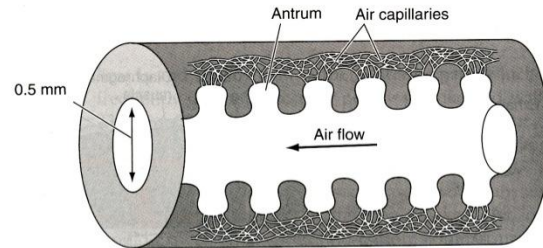
Plíce ptáků



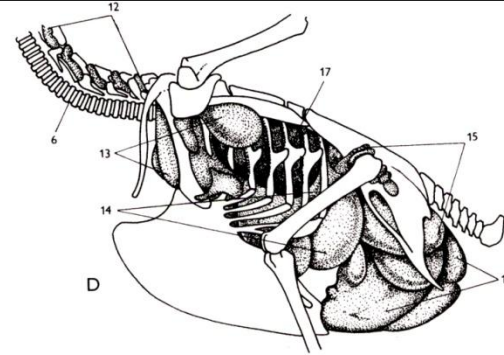
A. Lungs and air sacs



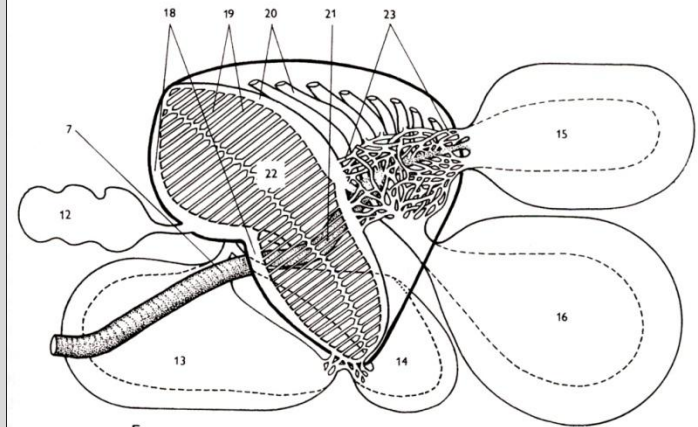
C. Antrum and respiratory labyrinth



B. Parabronchus and air capillaries



D



E

FIGURE 18-17

The anatomy of the respiratory system of a bird. A, A lateral view of the lungs and major air sacs. B, A lateral view of a parabronchus and air capillaries. Arrows show the unidirectional flow of air across the respiratory surfaces. C, A small portion of the wall. (A, After Salt; B and C, modified from Smith et al.)

Ventilace ptačích plic

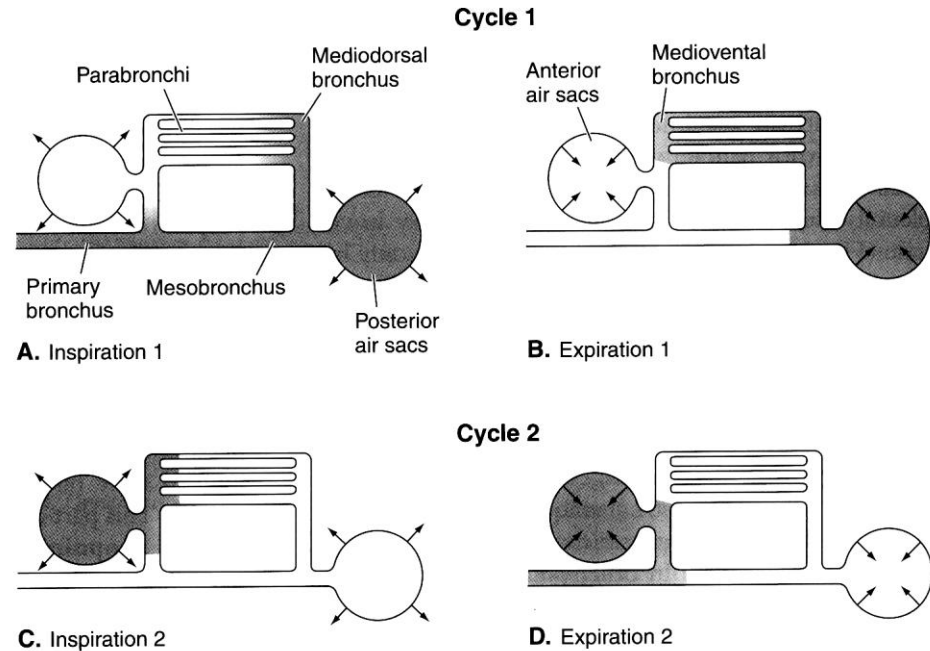
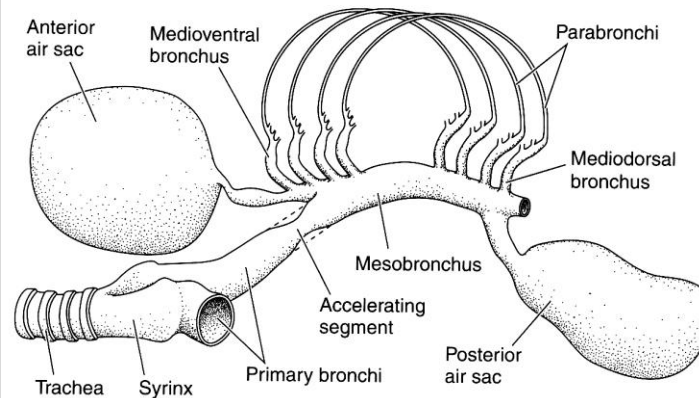


FIGURE 18-18

The movement of a volume of air (*shaded*) through the lungs and air sacs of a bird. Two cycles of inspiration and expiration are needed to move a specific mass of air through the system. (After Bretz and Schmidt-Nielsen.)



A. The principal airways in the lung of a goose, showing the contracting segment during inspiration. Its diameters during expiration are shown by the dashed lines. (Modified from Wang et al.)

Mechanismus okysličování krve

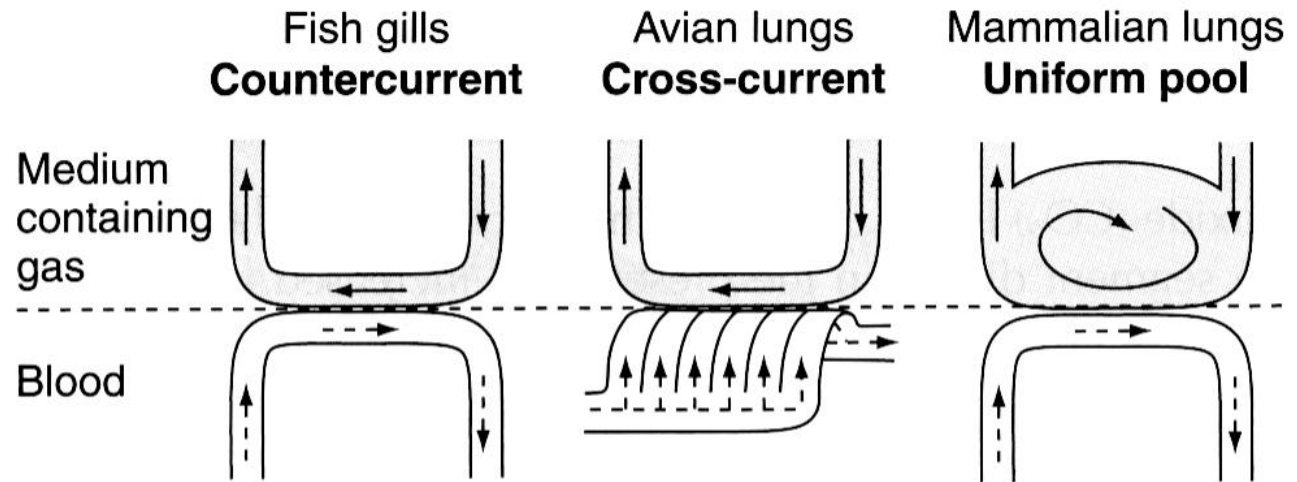


FIGURE 18-19

A comparison of the movement of blood and the external medium (water or air) across the respiratory surface of a fish, bird, and mammal. (After Piiper and Scheid.)

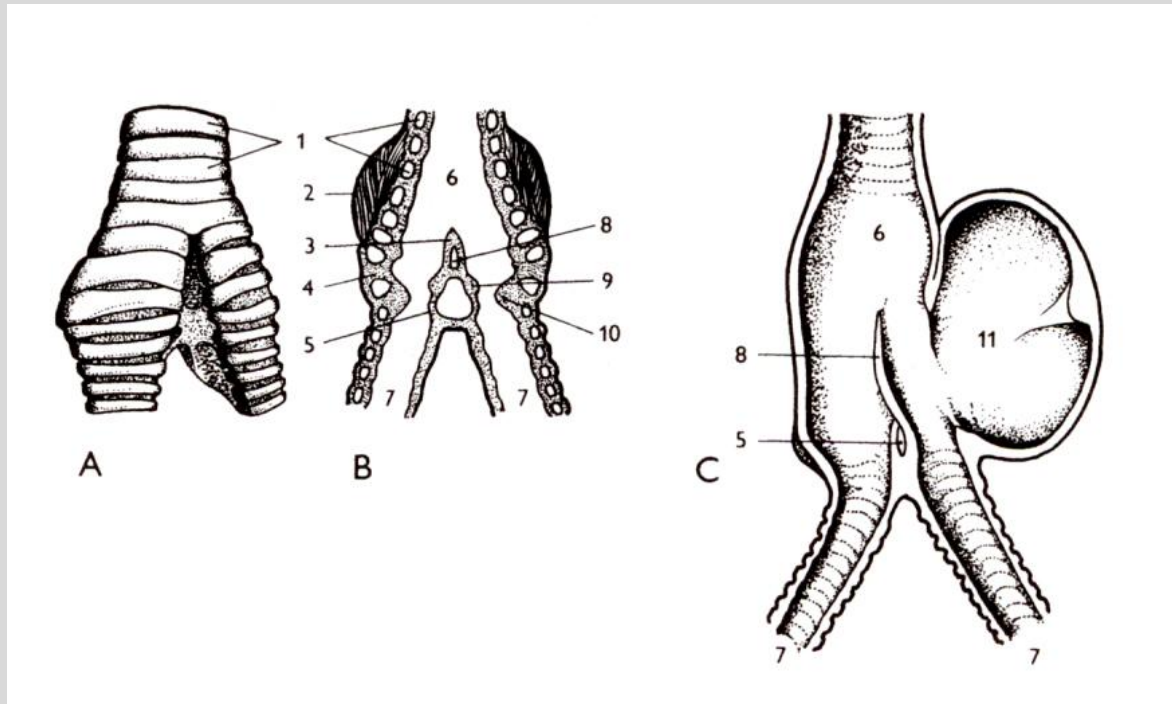
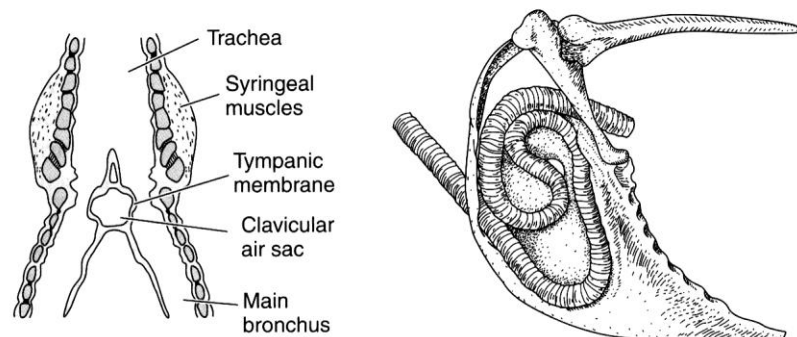


FIGURE 18-20

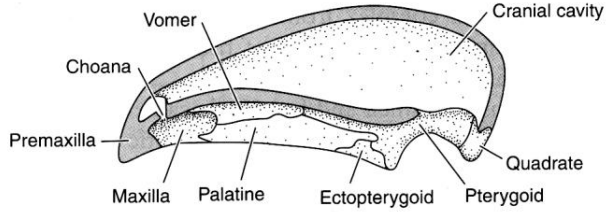
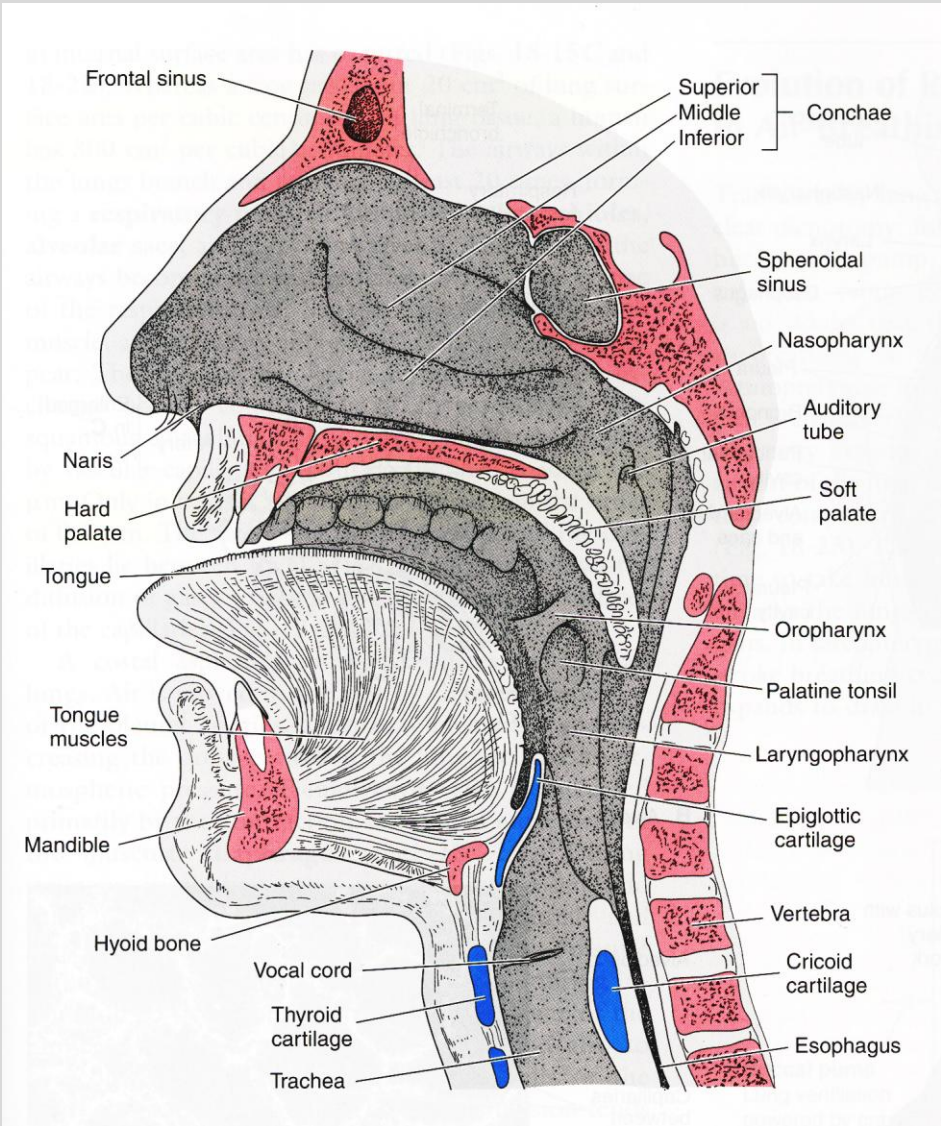
Vocalization in birds. *A*, A frontal section through the syrinx of a male blackbird, *Turdus merula*. *B*, A lateral view of a dissection of the sternum and trachea of a whooping crane. (*A*, After Pettingill; *B*, after Portmann.)



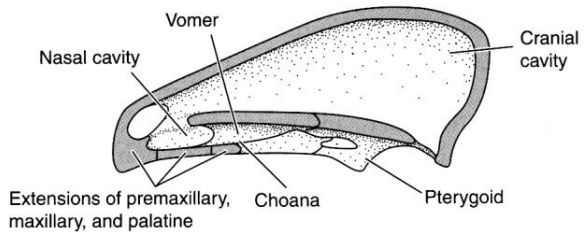
A. Syrinx of a blackbird

B. Sternum and trachea of a whooping crane

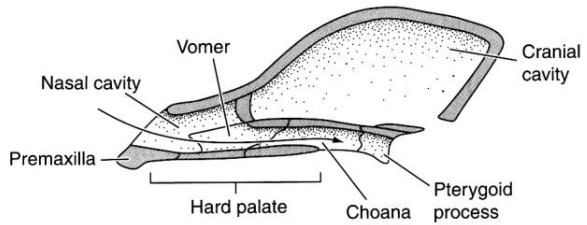
Dýchací cesty savců



A. Early synapsid (†*Dimetrodon*)



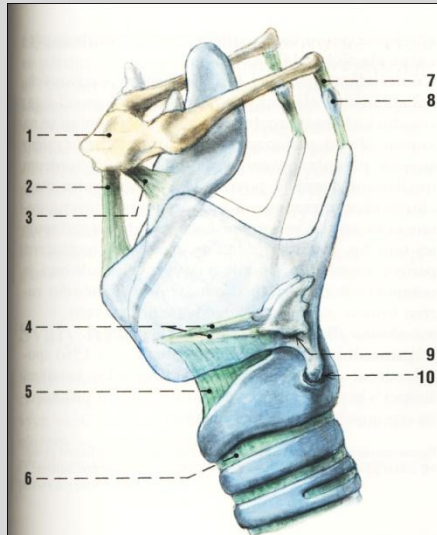
B. Therapsid (†*Probainognathus*)



C. Mammal (*Canis*)

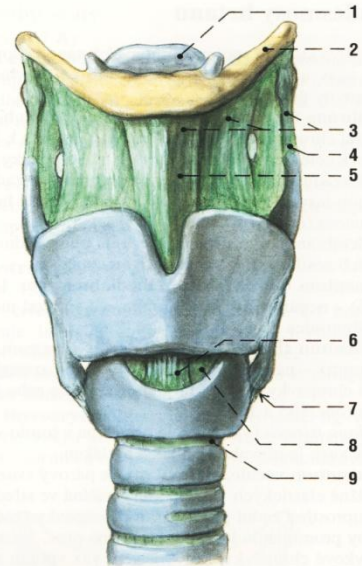
FIGURE 7-27
Sagittal sections through the skull of representative vertebrates to show the evolution of the mammalian hard palate. *A*, An early synapsid. *B*, A therapsid. *C*, A mammal. (Modified after Romer and Parsons.)

Hrtan (larynx)



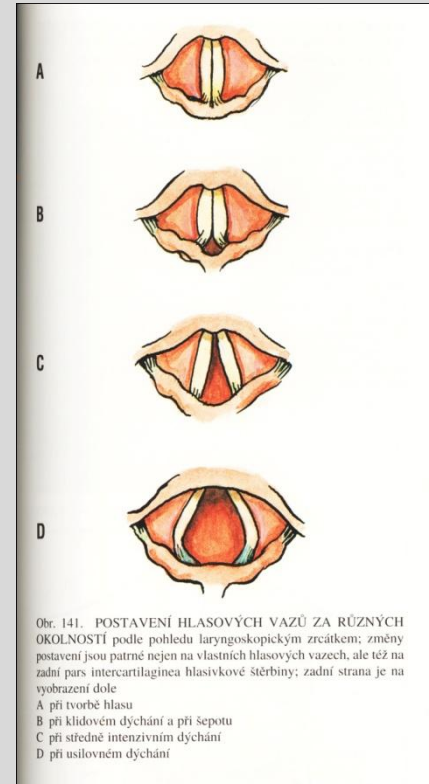
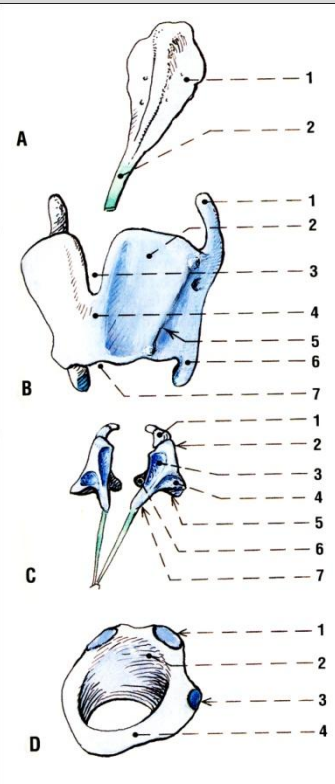
Obr. 135. SPOJENÍ CHRUPAVEK HRTANU; klouby a vazy; kloubní pouzdra odstraněna, odstraněna zevní vrstva vazů; pohled zleva; poloschematické znázornění

- 1 jazyka
- 2 lig. thyrohyoideum medianum
- 3 lig. hyoepiglotticum
- 4 ligg. vocalia
- 5 conus elasticus
- 6 lig. cricotracheale
- 7 lig. thyrohyoideum laterale (sinistrum)
- 8 cartilago triticea
- 9 articulatio cricoarytenoidea
- 10 articulatio cricothyroidea



Obr. 136. LIGAMENTA HRTANU; pohled zředu; poloschéma

- 1 cartilago epiglottidis
- 2 jazyka
- 3 membrana thyrohyoidea
- 4 lig. thyrohyoideum laterale (sinistrum)
- 5 lig. thyrohyoideum medianum
- 6 lig. cricothyroideum (medianum)
- 7 articulatio cricothyroidea
- 8 conus elasticus
- 9 lig. cricotracheale

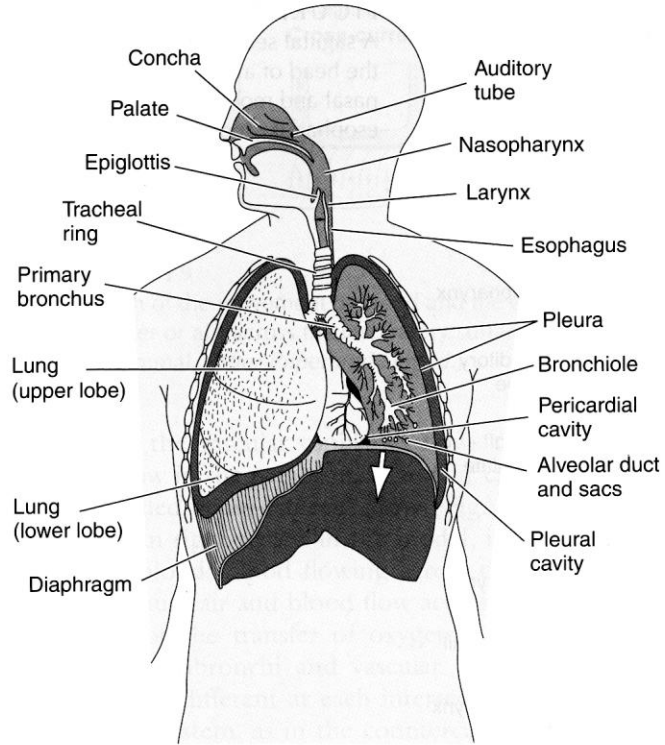


Obr. 141. POSTAVENÍ HLASOVÝCH VAZŮ ZA RŮZNÝCH OKOLNOSTÍ podle pohledu laryngoskopickým zrcátkem; změny postavení jsou patrné nejen na vlastních hlasových vazech, ale též na zadní pars intercartilaginea hlasivkové štěrbině; zadní strana je na vyobrazení dole

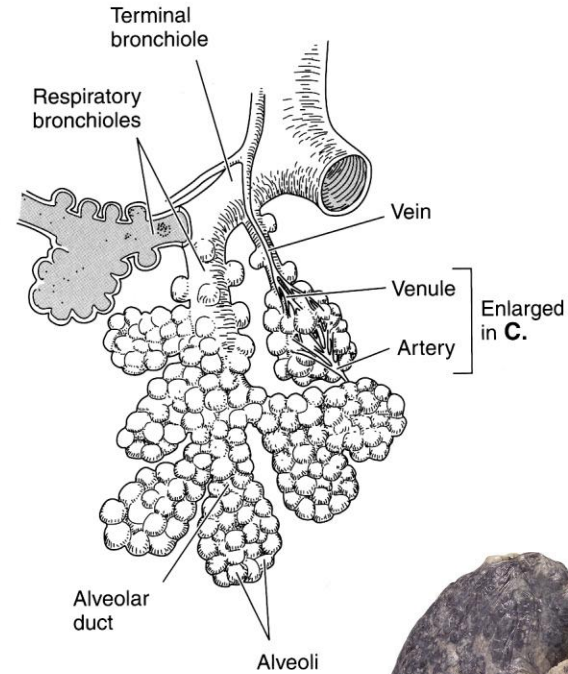
- A při tvorbě hlasu
- B při klidovém dýchání a při sepotu
- C při středně intenzivním dýchání
- D při usilovném dýchání

Cartilagine epiglottica, thyroidea, arytenoidea, cricoida

Plíce savců



A. Airways and lungs

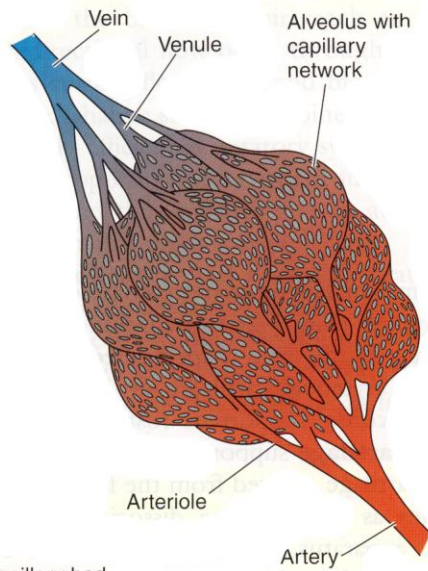


B. Alveoli

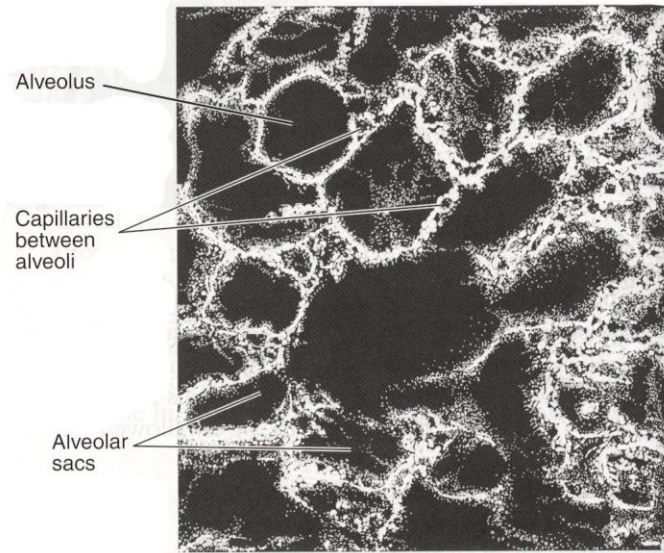


Plíce kuřáka

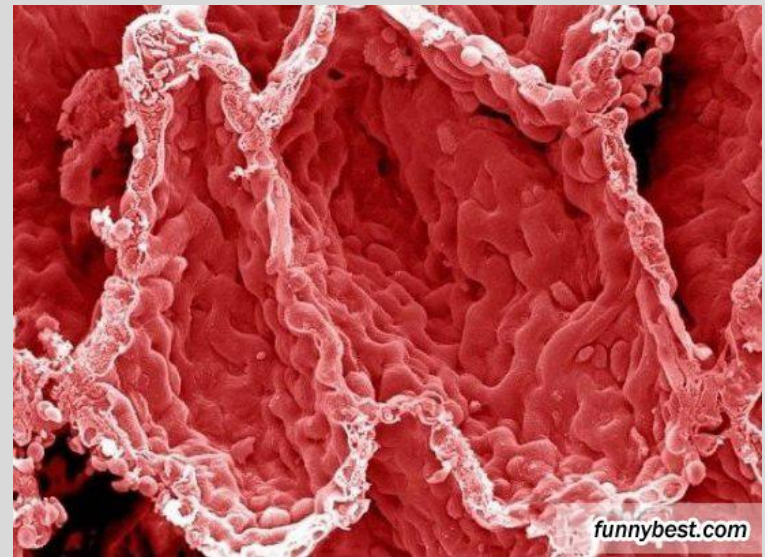
Plíční sklípky a jejich cévní zásobení



C. Capillary bed



D. Portion of human lung



Evolve mehanizmu ventilace plic

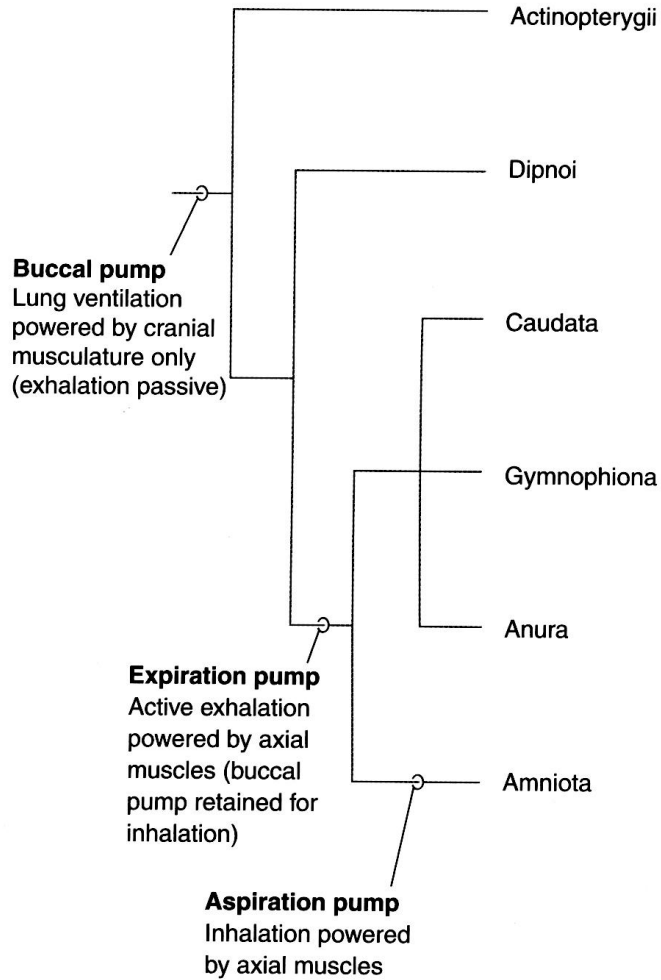


FIGURE 18-23

A cladogram showing major stages in the evolution of lung ventilation. (After Brainerd.)