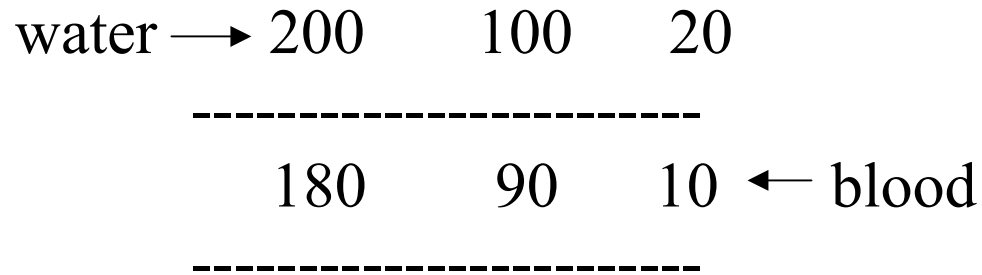


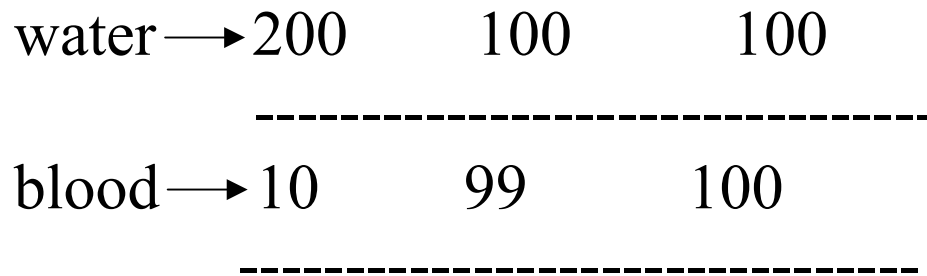
Adapted from Eckert et al. 1988.

Blood flow is opposite the direction of water flow over the gills
(countercurrent flow)



results in greater extraction of oxygen than parallel flow because blood passing through the lamellae is continually being exposed to water with a higher oxygen concentration

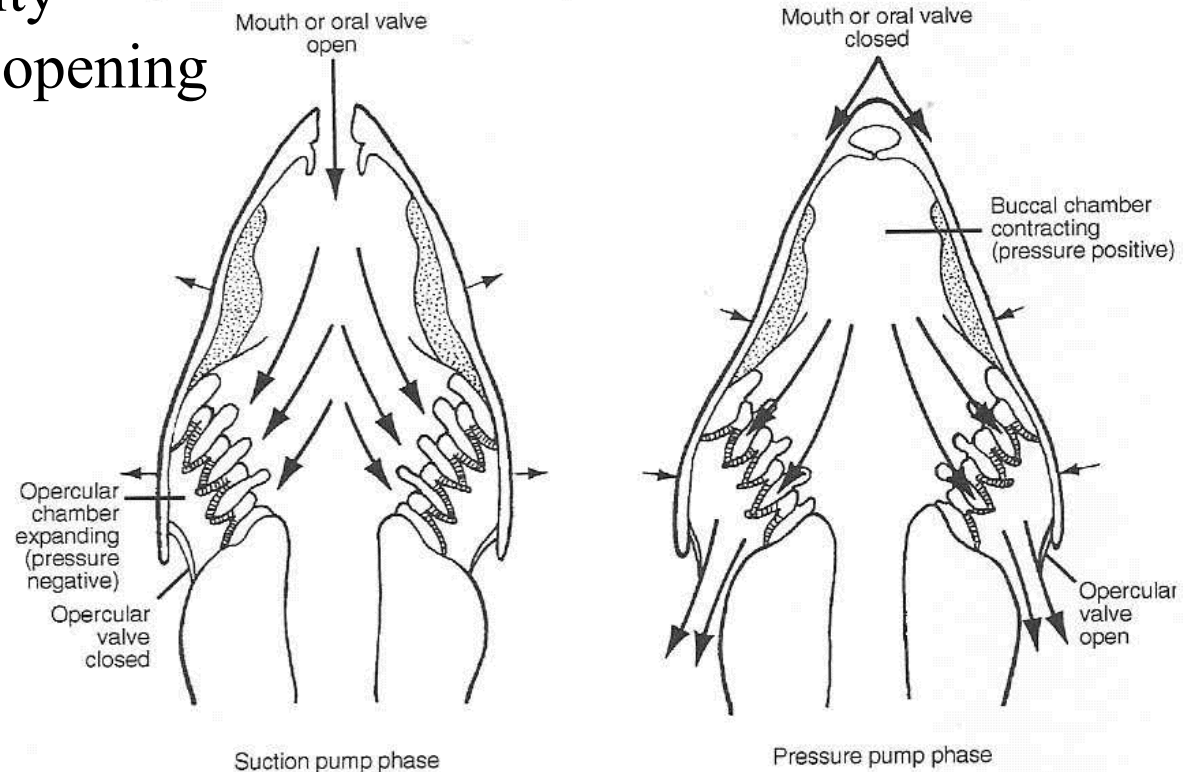
(parallel flow)



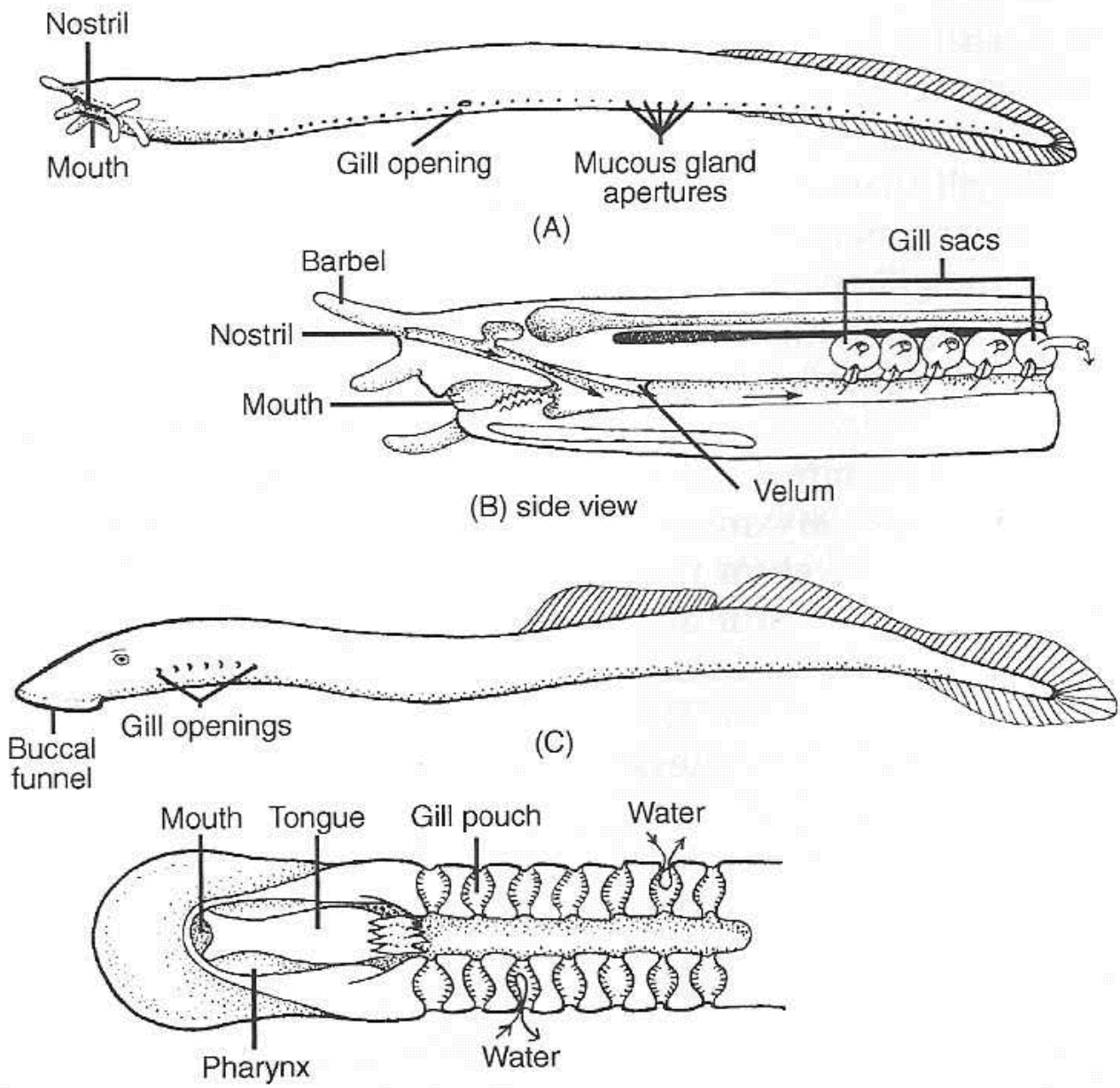
up to 90% efficient under favorable conditions

stages in pumping:

- close opercles, open mouth
- expand buccal and opercular cavity - to pull water into mouth
- close mouth, open opercles (more negative pressure in opercular cavity)
- contract buccal cavity - to push water over gills
- contract opercular cavity to force water out gill opening



Adapted from Hildebrand 1988.



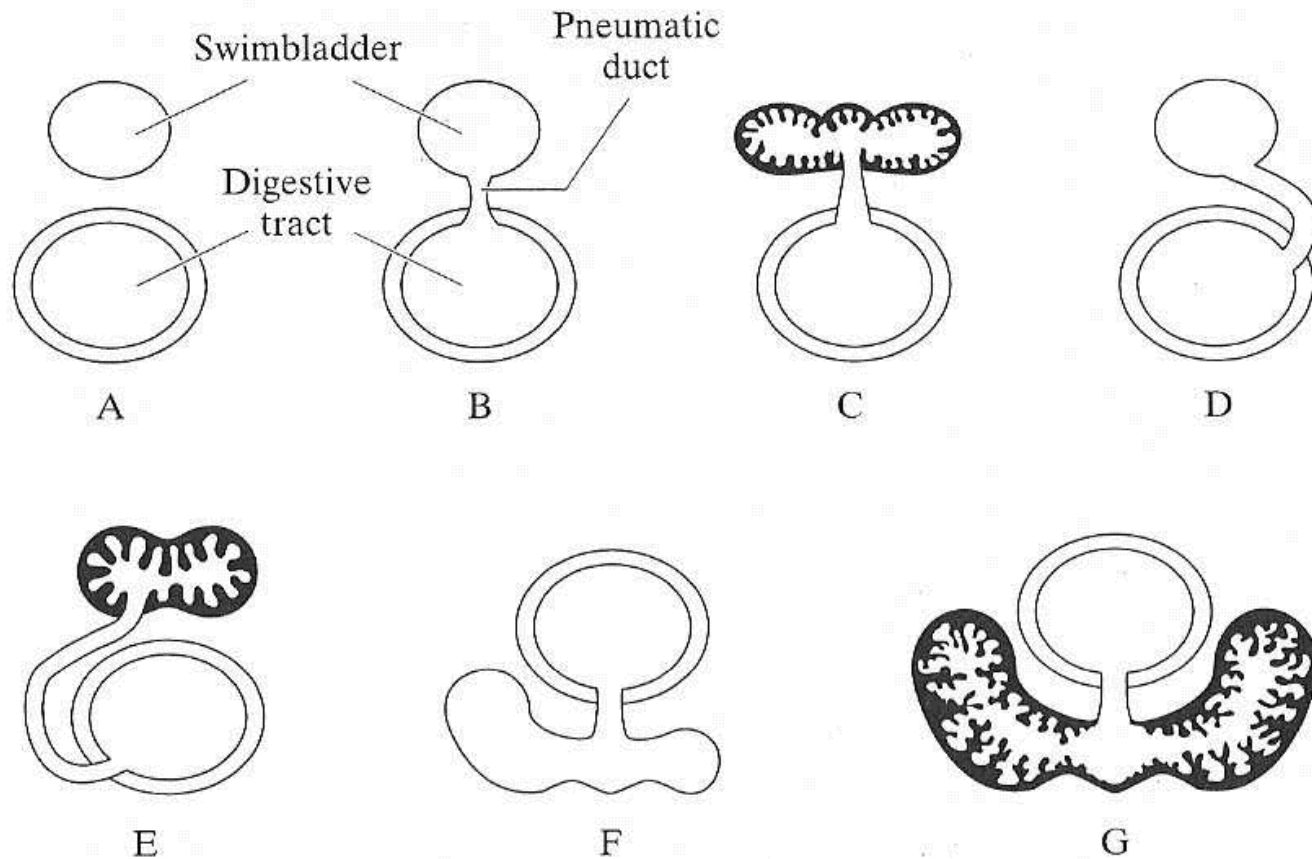
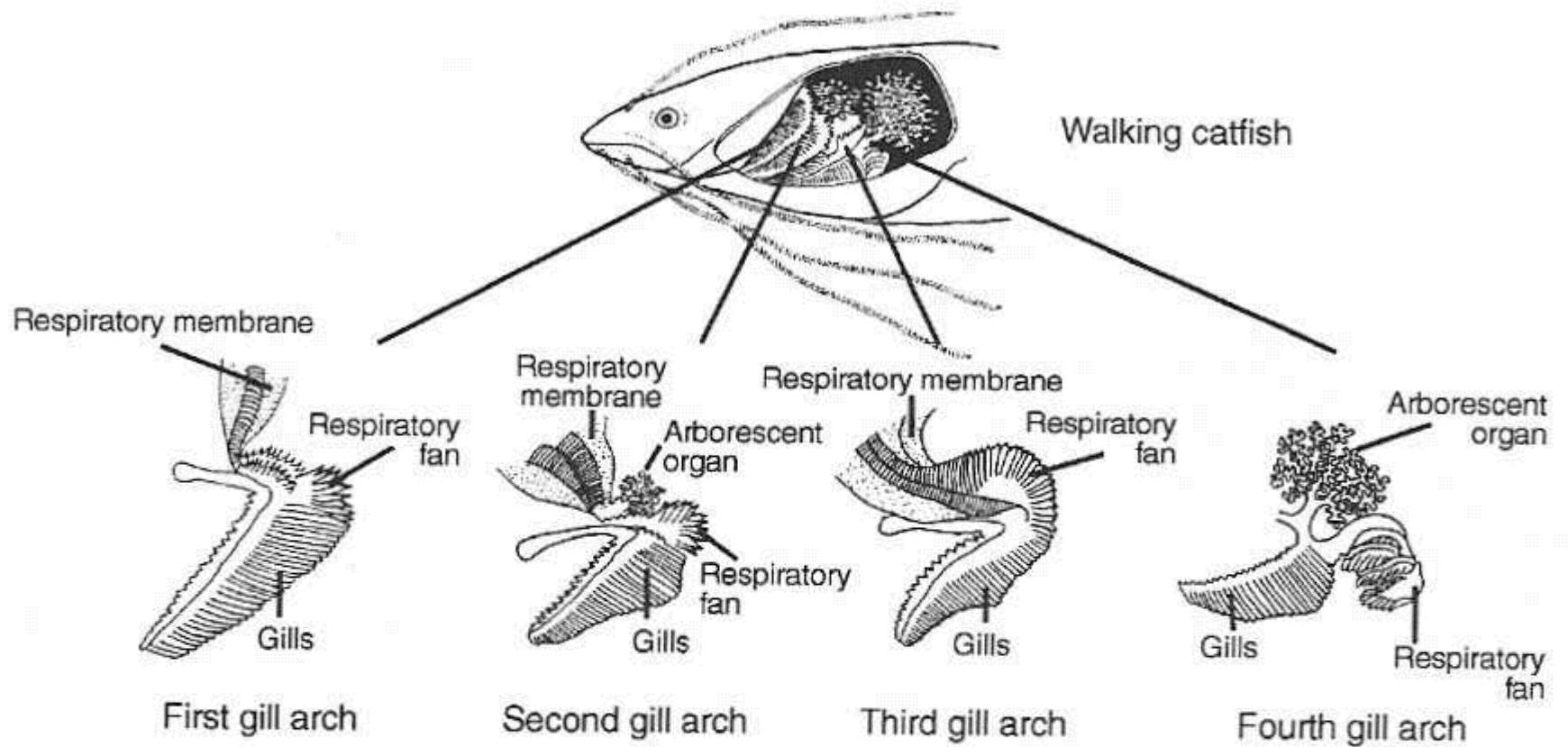
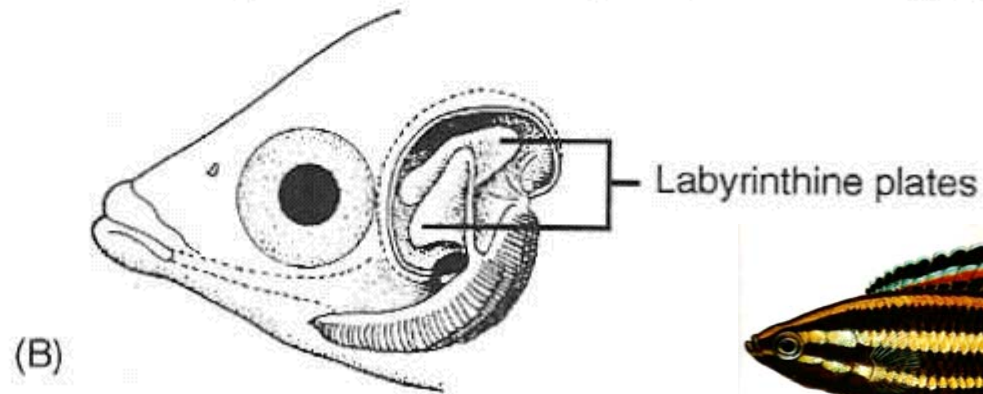


FIGURE 5.1 Cross-sections of swimbladders or lungs (as viewed from the anterior end) showing relationships to the digestive tract in various fishes. Many of these fishes (C–G) can use the swimbladder or lung as an air-breathing organ (see Chapter 3). **A.** Typical (water-breathing) phystoclistous species. **B.** Typical (water-breathing) phystostomous species. **C.** Gars (*Lepisosteus* spp.) and bowfin (*Amia* sp.). **D.** Climbing perches (*Erythrinus* sp.). **E.** Australian lungfish (*Neoceratodus* sp.). **F.** Reedfish (*Erpetoichthys* sp.) and bichirs (*Polypterus* spp.). **G.** African and South American lungfish (*Protopterus* spp. and *Lepidosiren* sp., respectively). Adapted from Dean (1895) and Graham (1997).

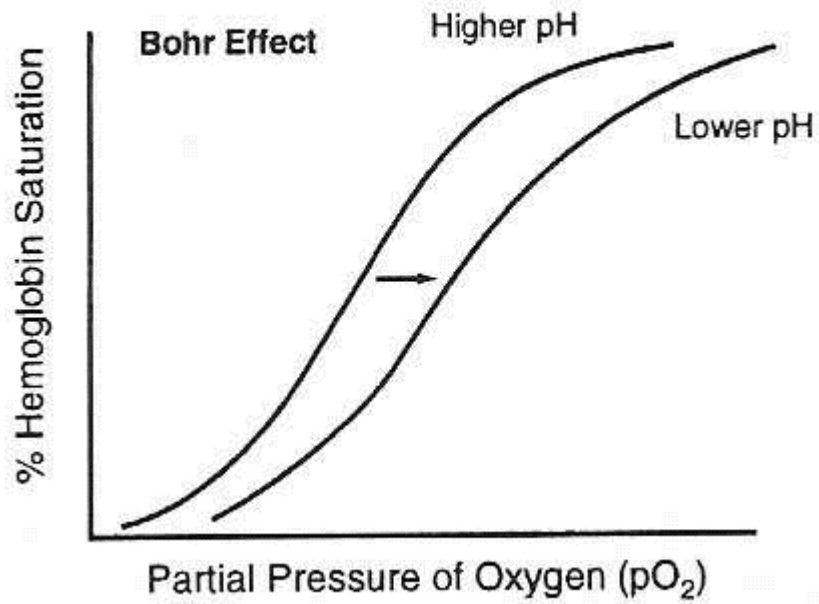


(A)

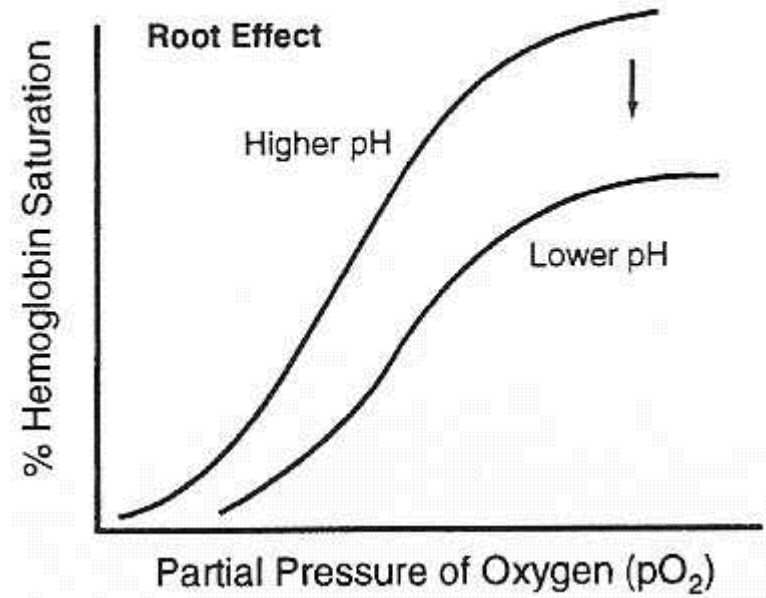


(A) Adapted from Munshi 1976. (B) Adapted from Peters 1976.

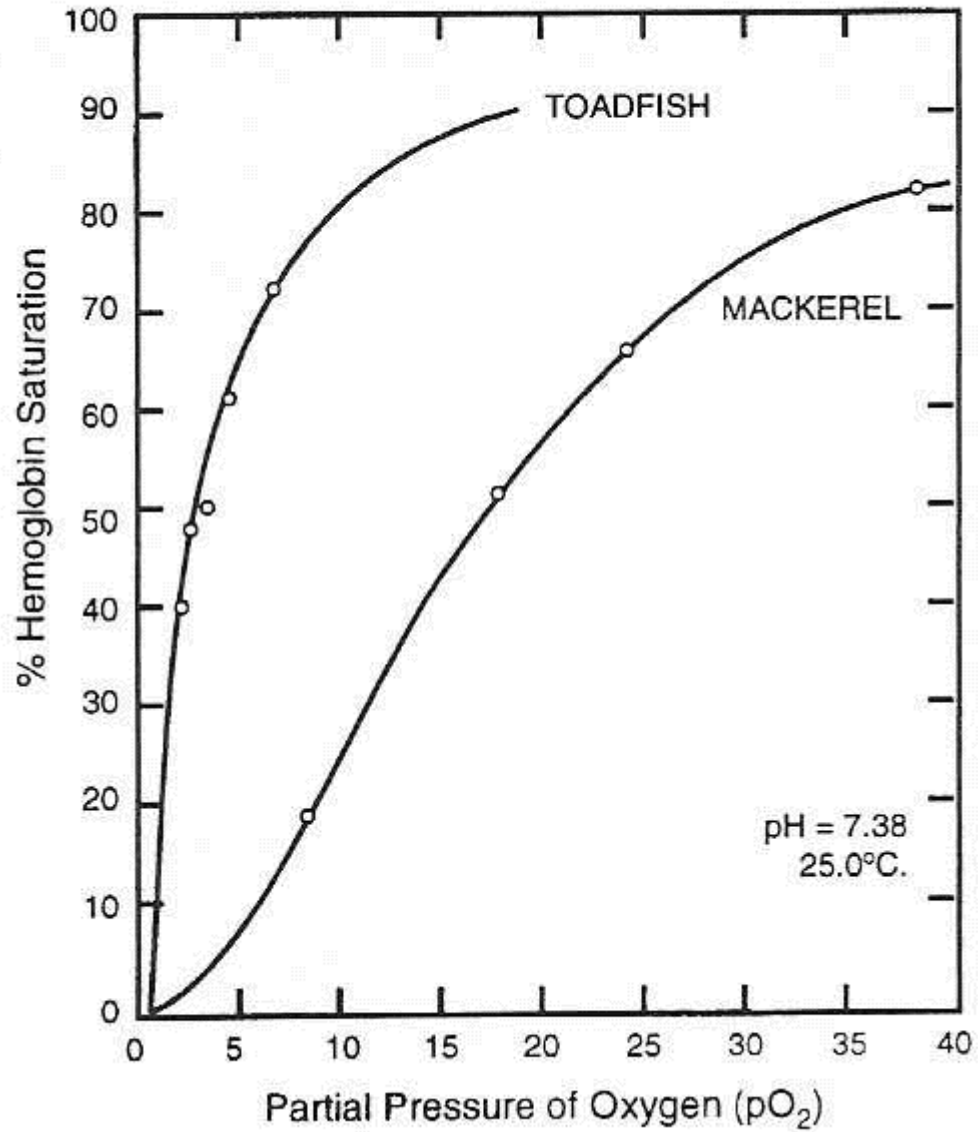
(A)



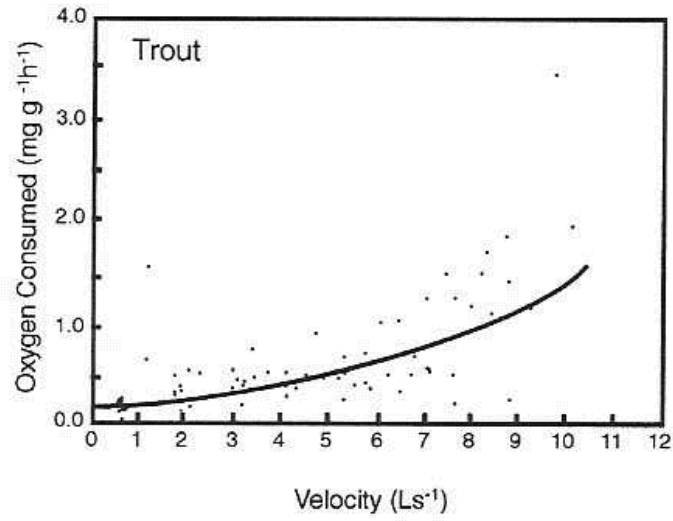
(B)



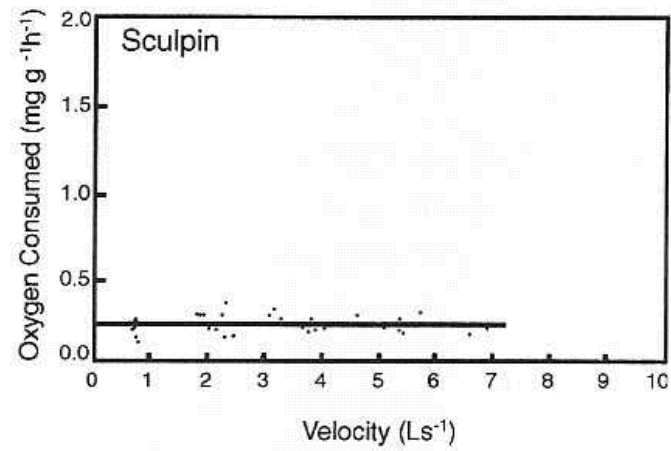
(C)



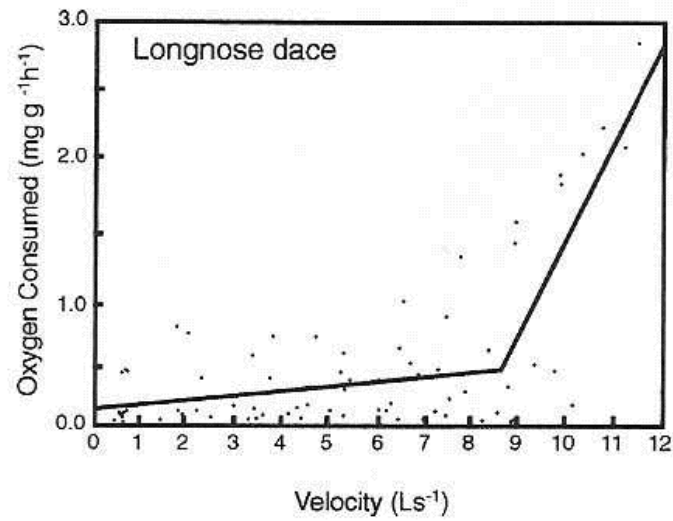
(A)



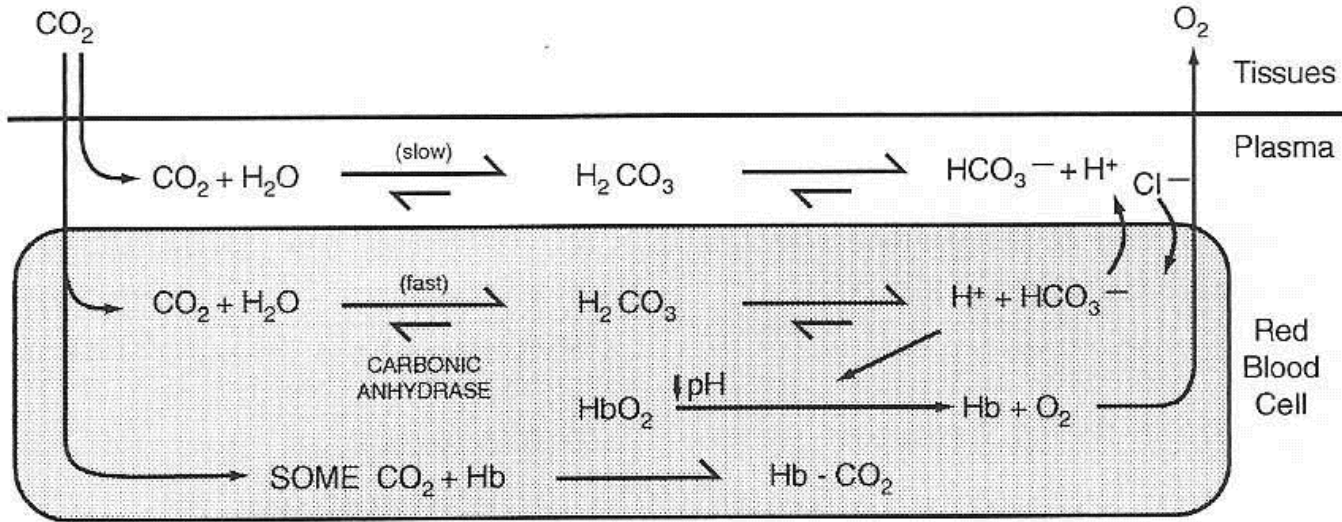
(B)



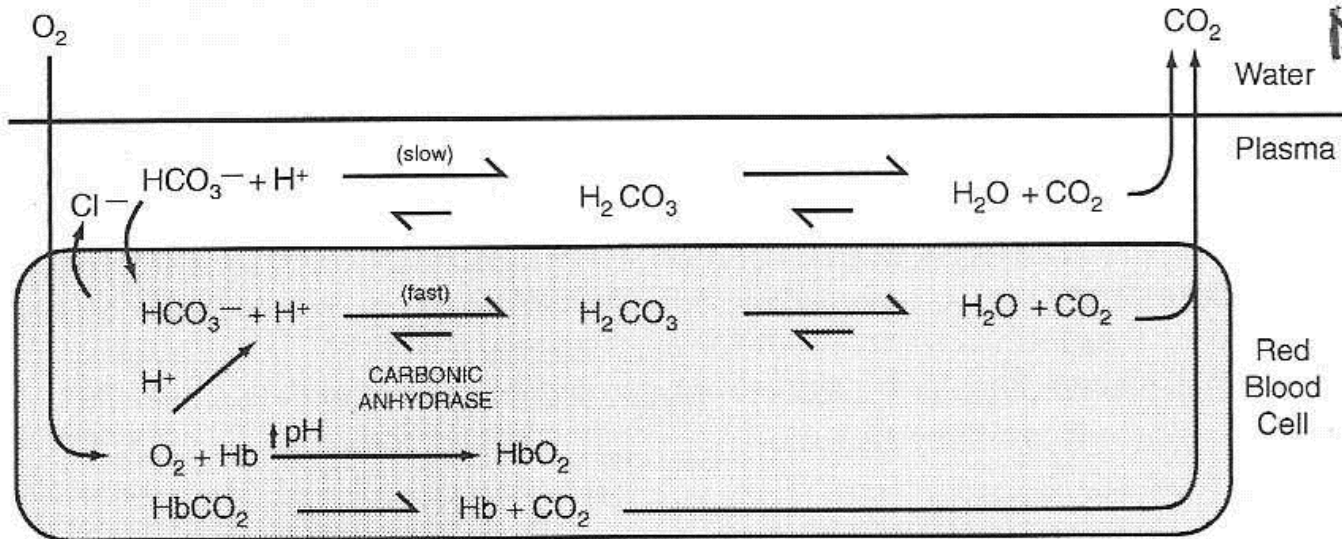
(C)



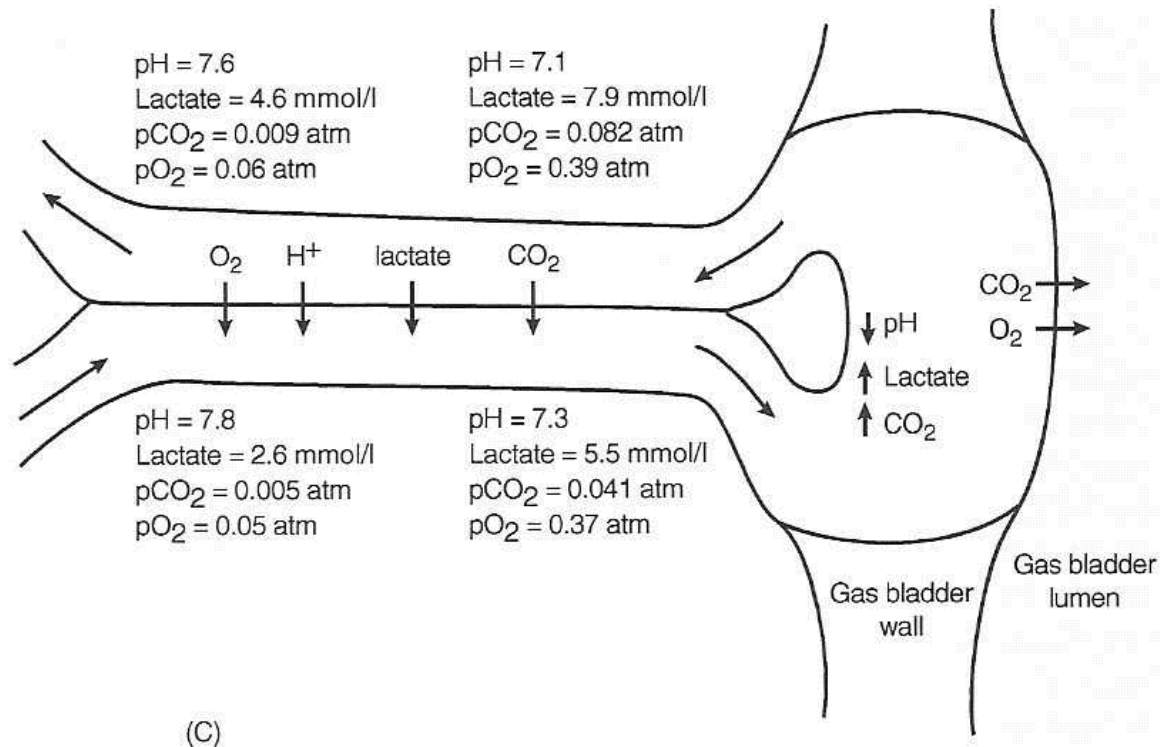
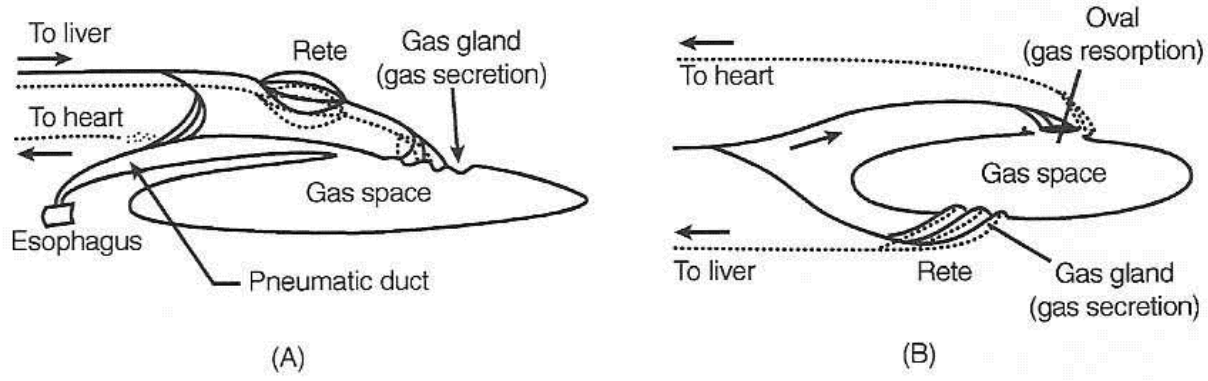
At the Tissues



At the Gills

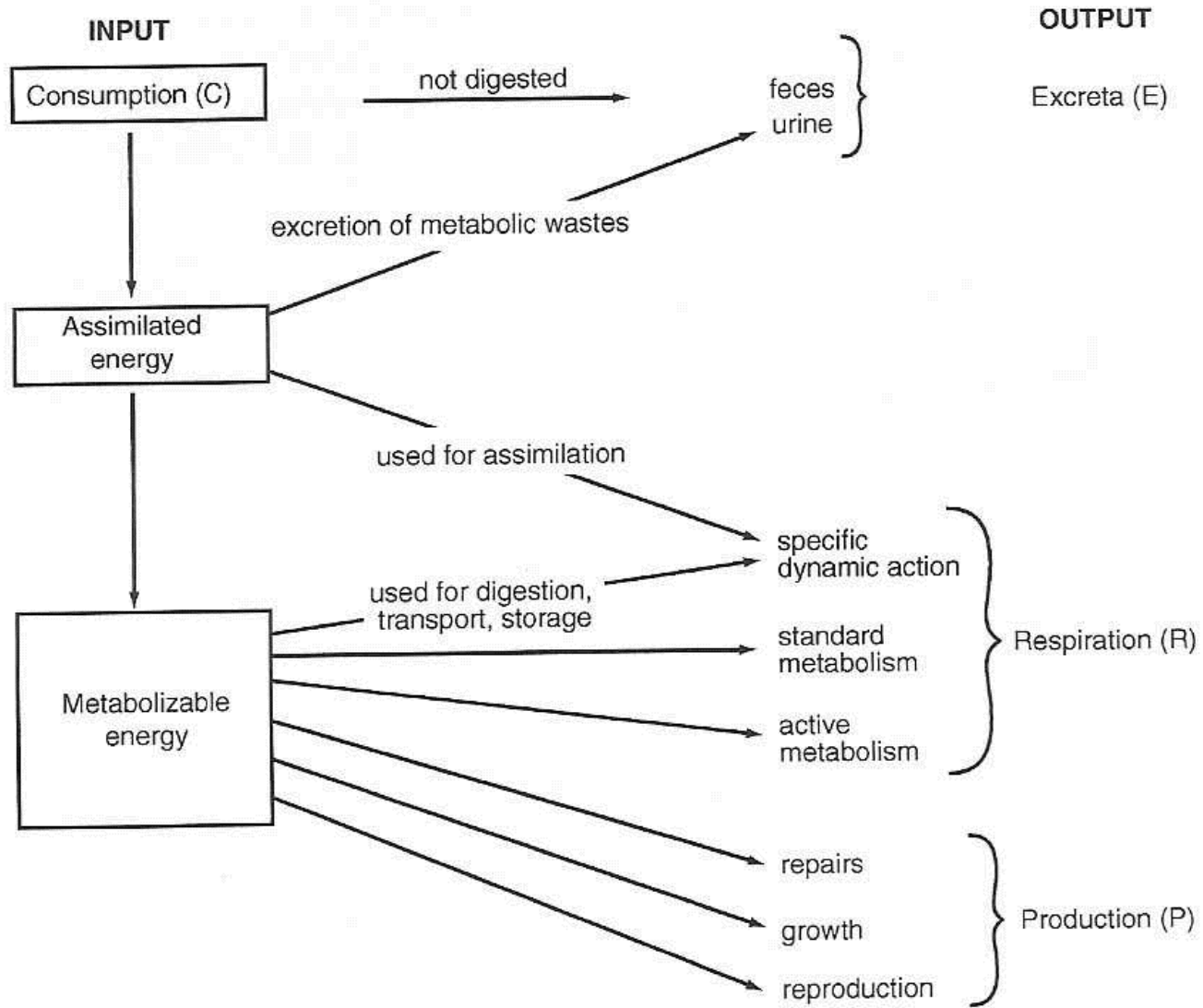


Handwritten note: NH_4^+ and Na^+ ions are shown near the gill membrane.



(A), (B) After Eckert et al. 1988. Data presented in (C) are for eels (*Anguilla*), from Kobayashi et al. 1989, 1990.

$$C = E + R + P$$



Adapted from Videler 1993.