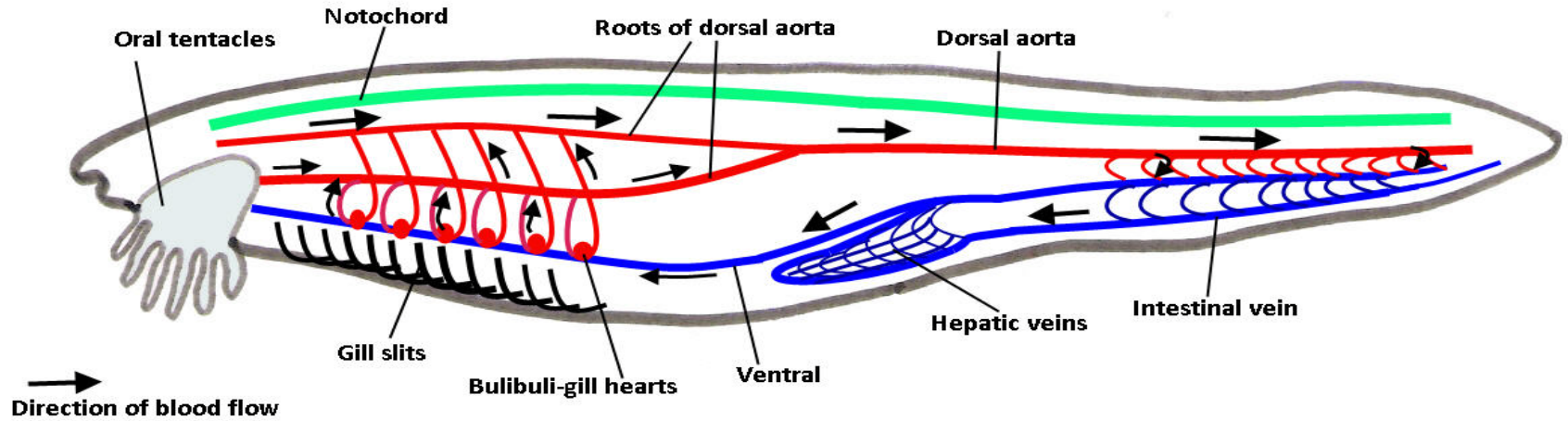


Is there a circulation without a heart?

Branko Furst, MD, FFARCSI
Associate Professor of Anesthesiology
Albany Medical College, Albany NY

The lancelet fish



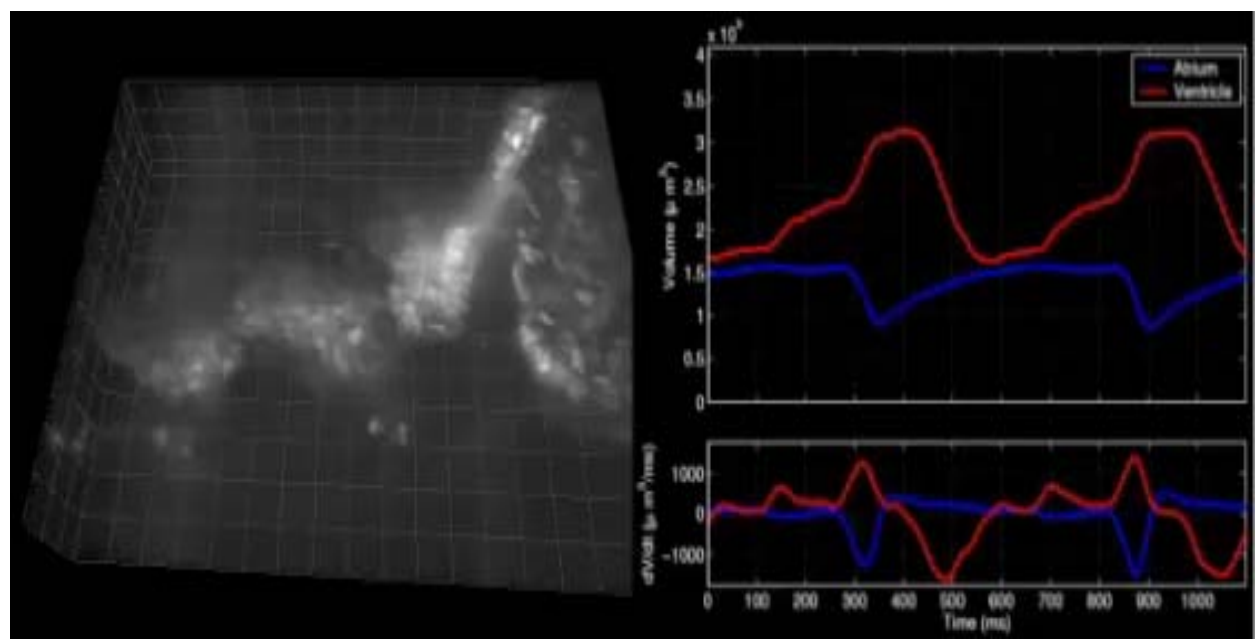
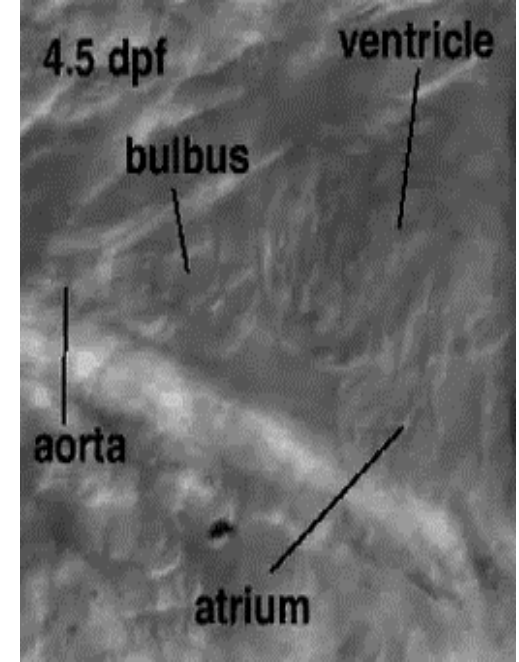
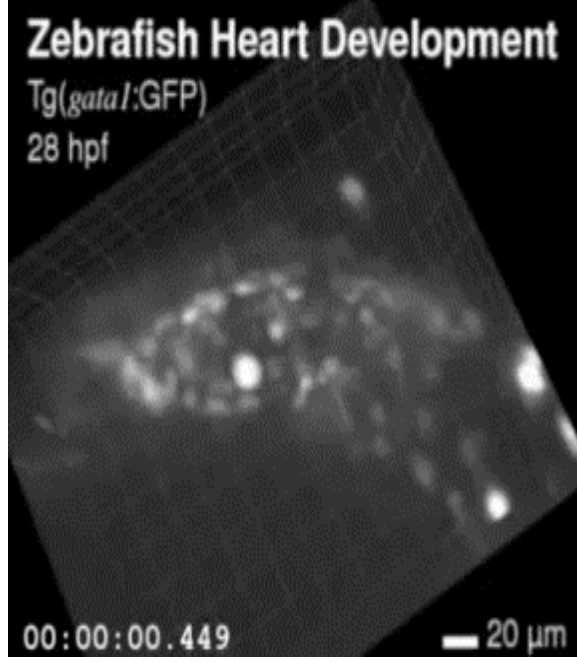
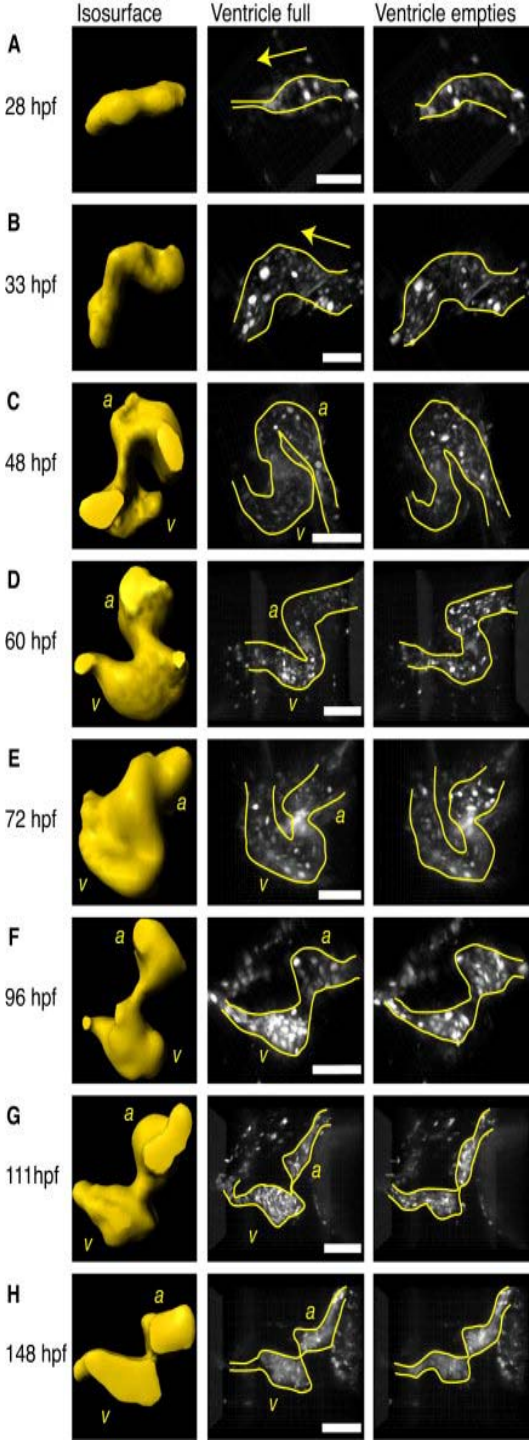
“Open” circulation
No endothelial cells



Amphioxus
(cephalocordates)

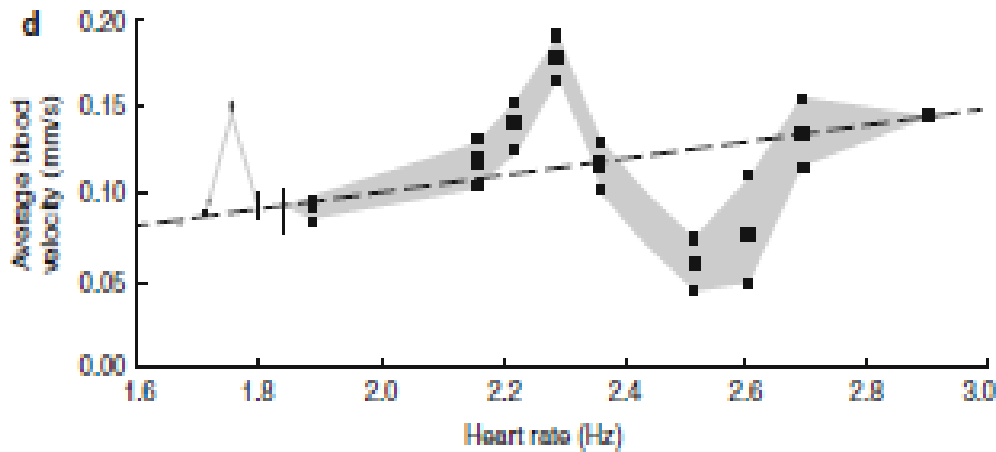
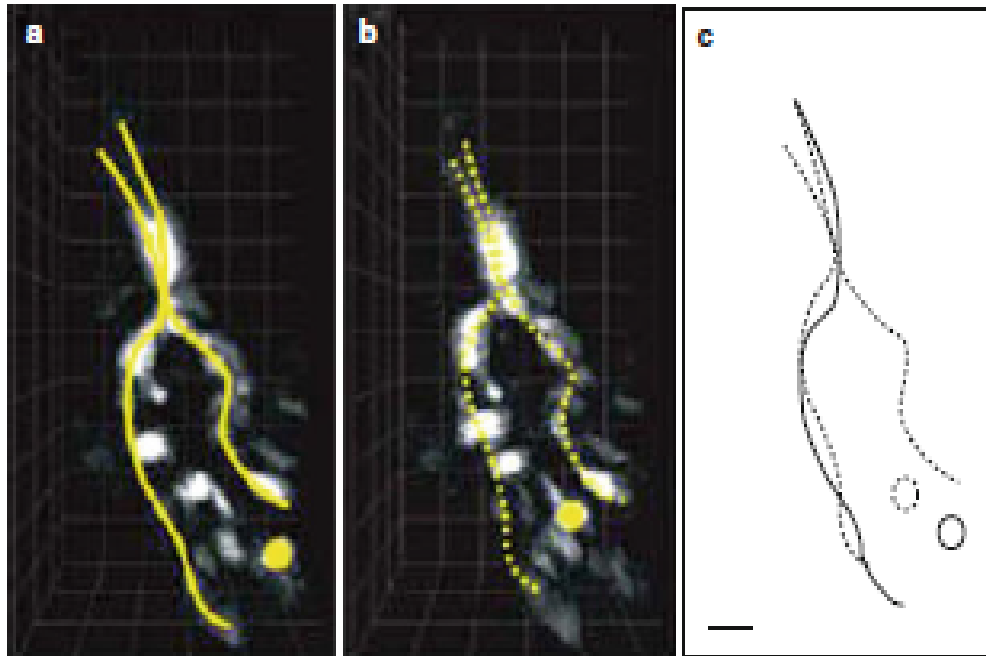


ZEBRAFISH



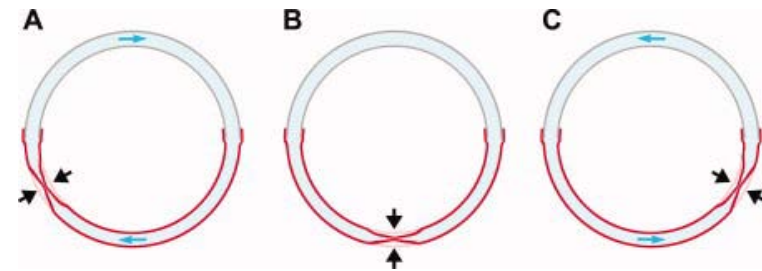
Liebling M et al, Develop. Dyn, 2006

Is the embryo heart a peristaltic pump?



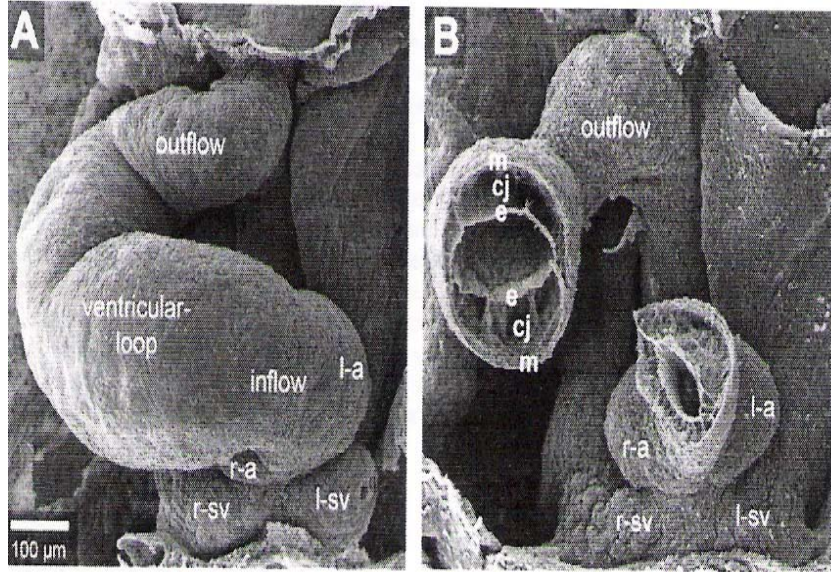
Impedance-suction pump

Valveless pumping principle (Liebau)



Forouhar AS, et al,
Science, 2006

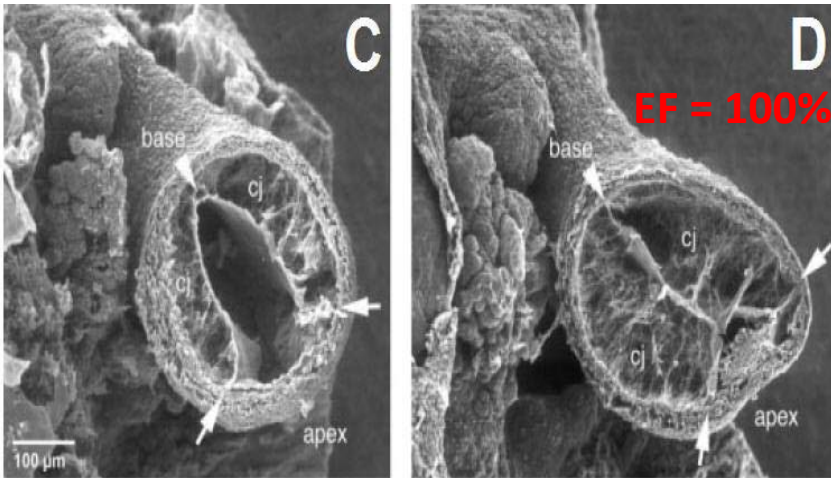
Valveless embryo heart; mode of action



How Does the Tubular Embryonic Heart Work? Looking for the Physical Mechanism Generating Unidirectional Blood Flow in the Valveless Embryonic Heart Tube

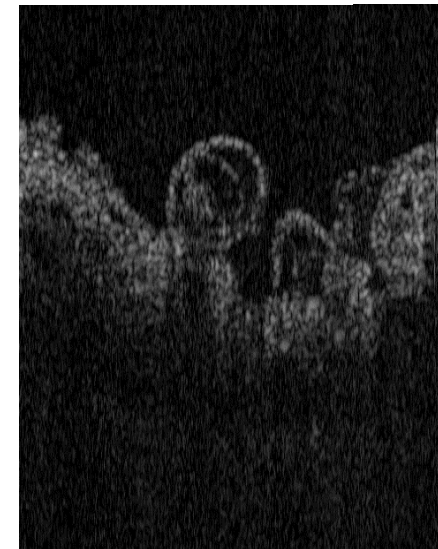
Jörg Männer,^{1,2*} Armin Wessel,³ and T. Mesud Yelbuz³

DEVELOPMENTAL DYNAMICS 239:1035–1046, 2010



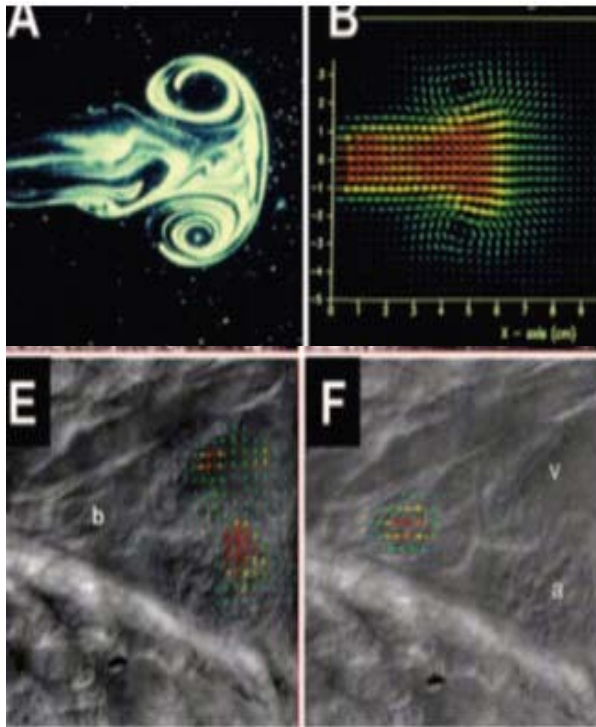
DIASTOLE

SYSTOLE



HH 14 Chick embryo
Manner et al, 2009,
2010

Vortex flow, a damming-up phenomenon

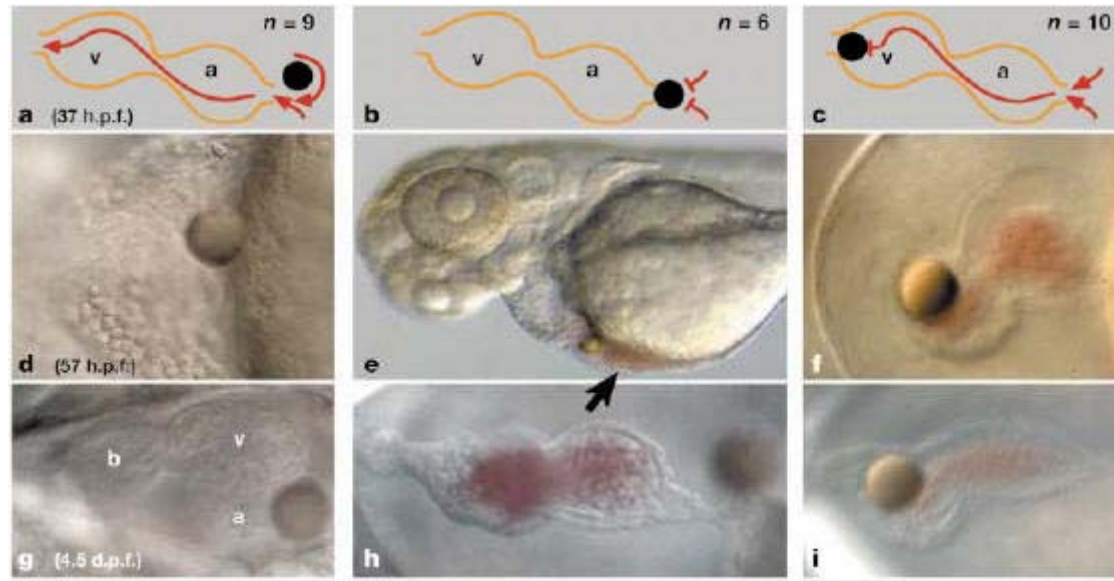


Digital particle imaging
velocimetry

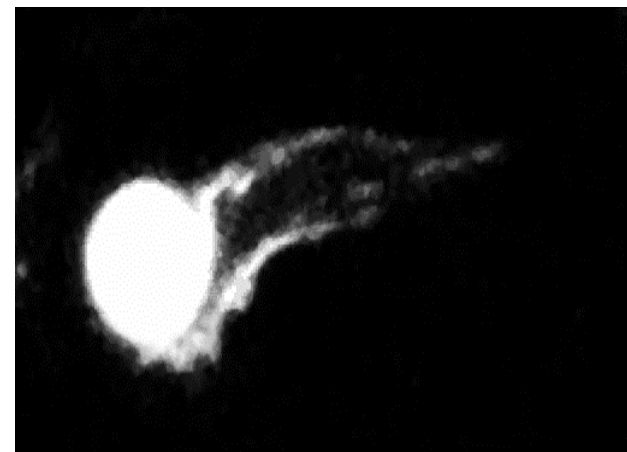
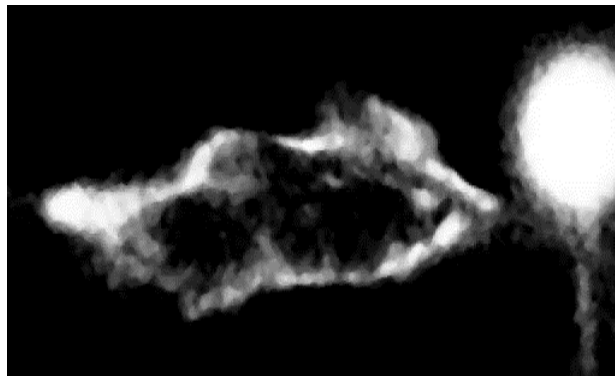
E ventricle
F aortic bulb

Hove, 2006

Blood flow - essential factor for embryonic cardiogenesis

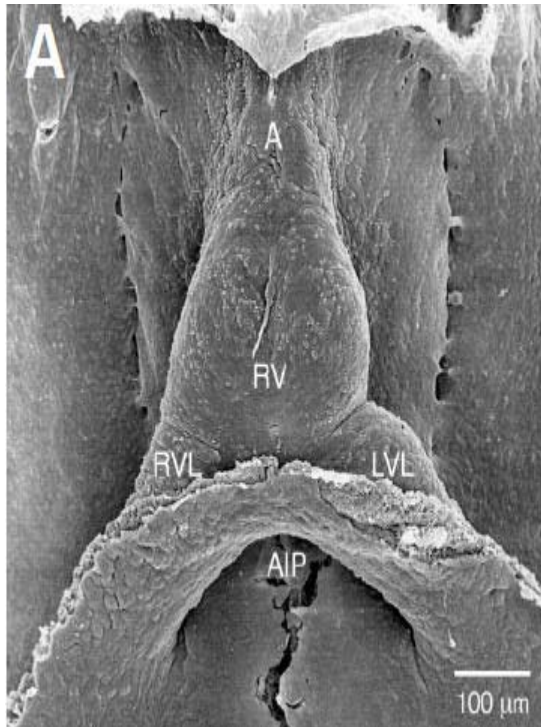


37hpf zebrafish embryo heart

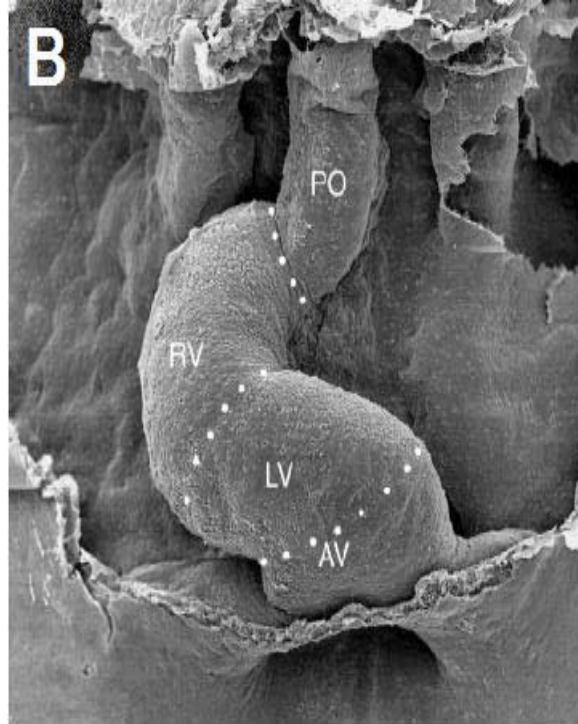


Hove J et al, Nature, 2003

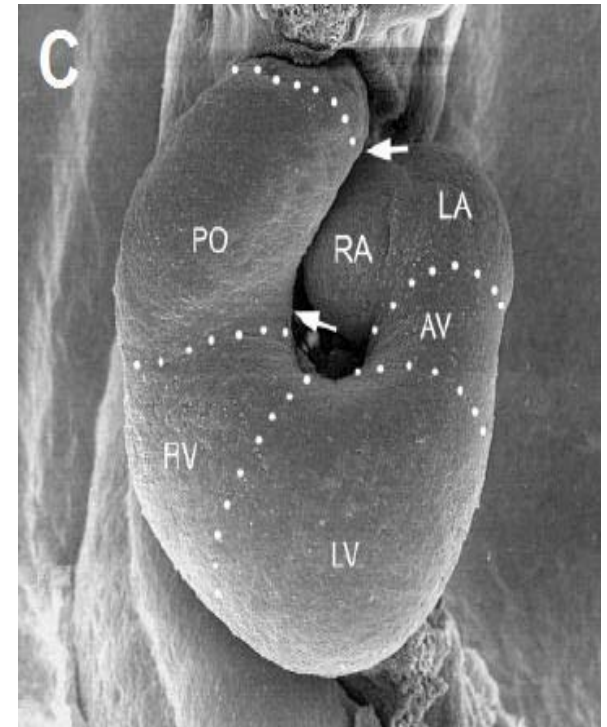
Early embryo heart - functional morphology



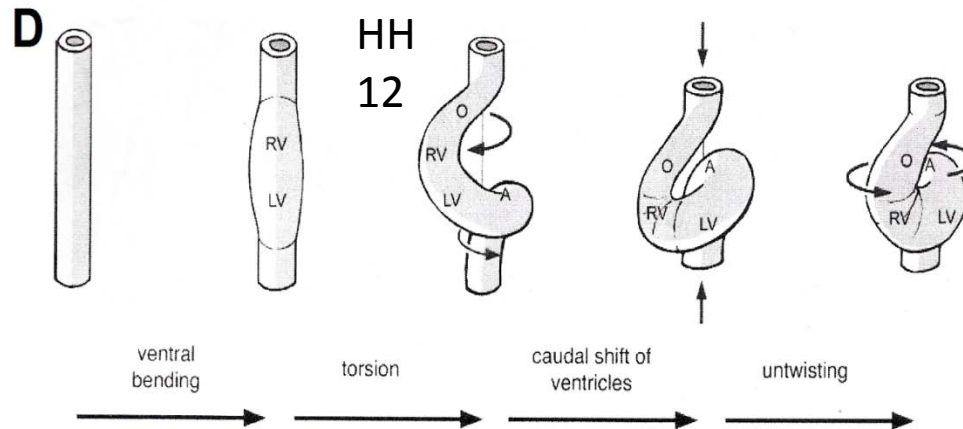
HH9



HH
12



HH17



Manner J, 2009

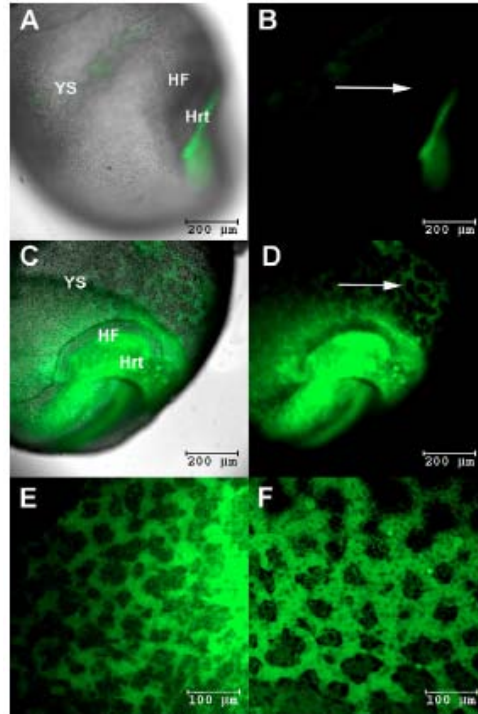
“Primary” circulation: mouse embryo

Plasma circulation, 10 min

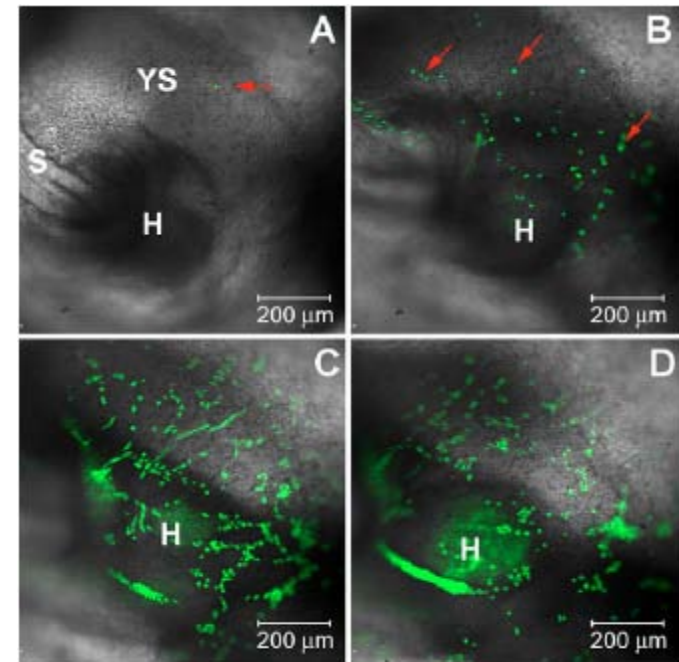
A,B,C,D: 2 Somite stage

E 3 somite embryo

F 6 somite embryo



Erythroblast migration, 12 hrs 6 SS embryo



Cranial flexure of 5 part brain

Eye

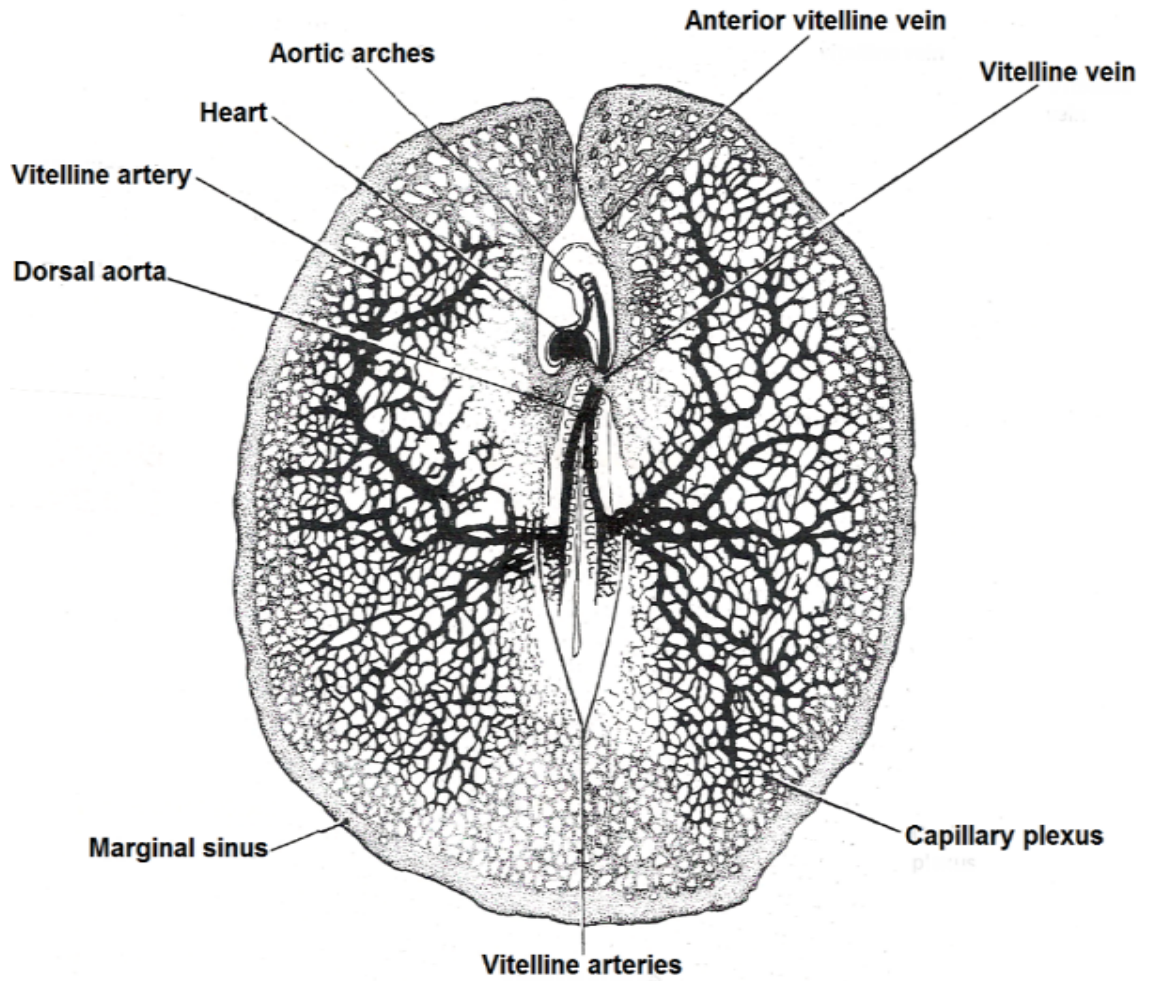
Heart tube
twisted upon itself

Anterior intestinal portal

Lateral body folds

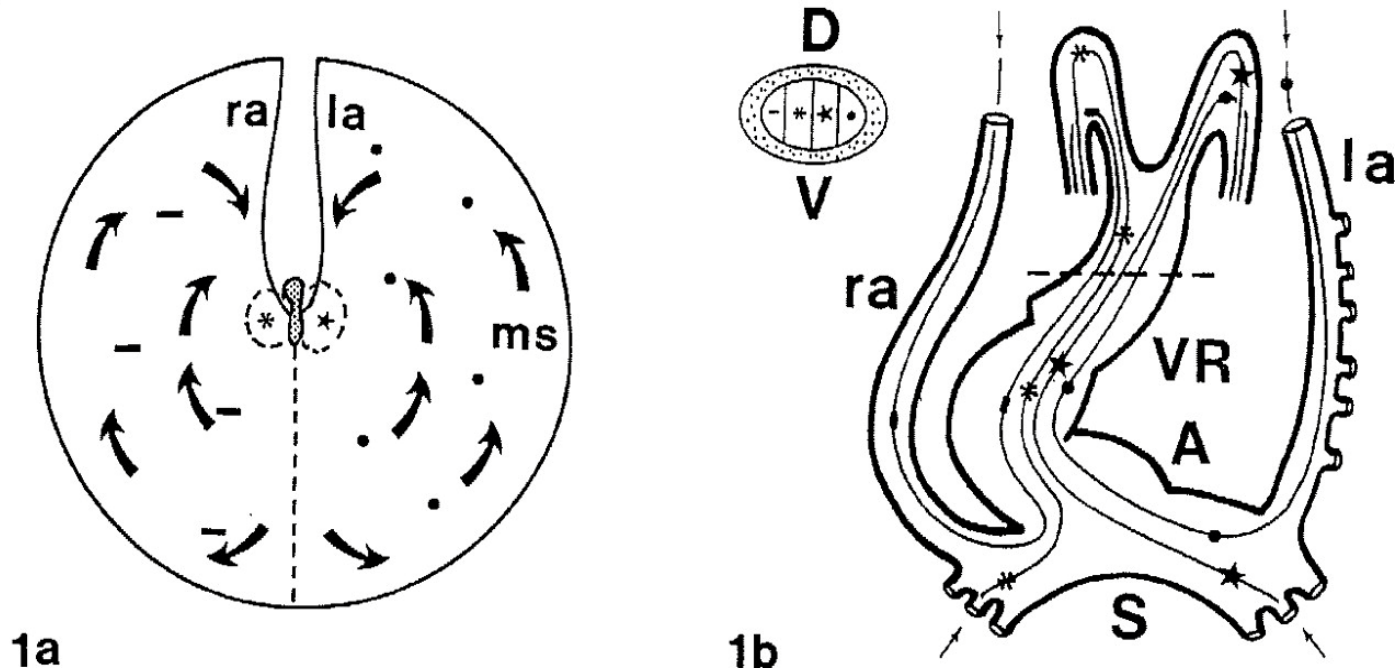
Tail bud

Tail fold



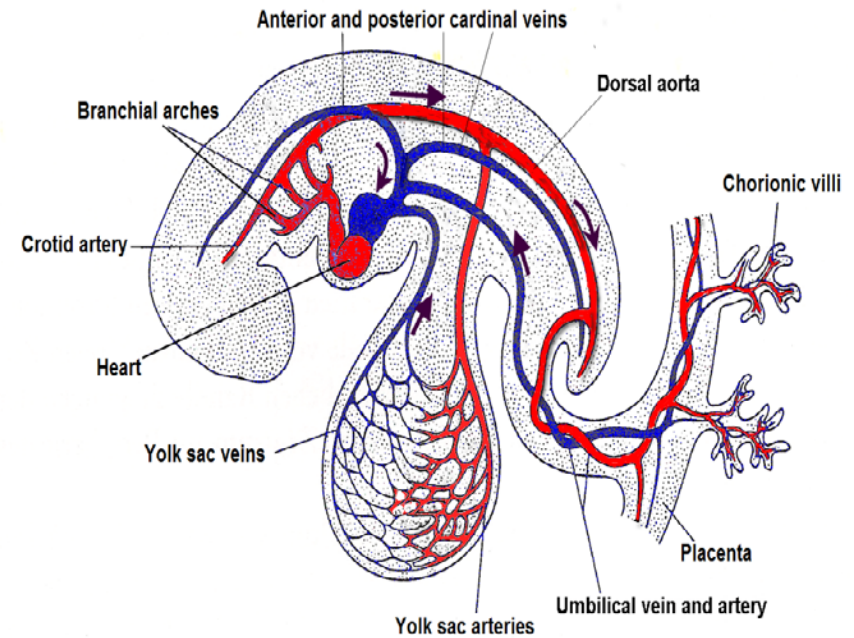
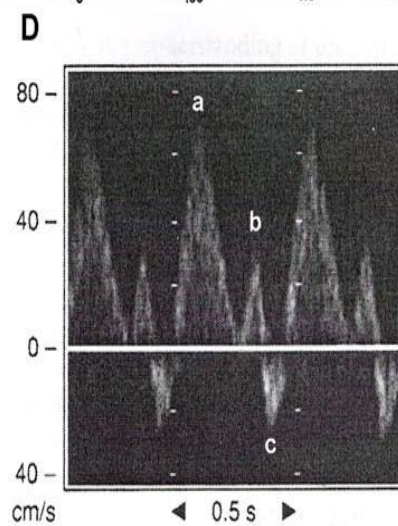
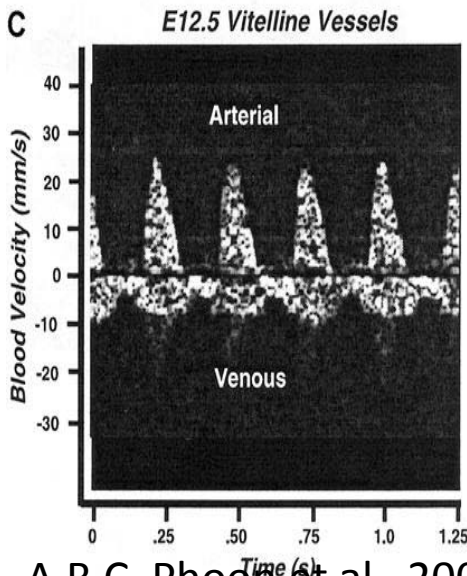
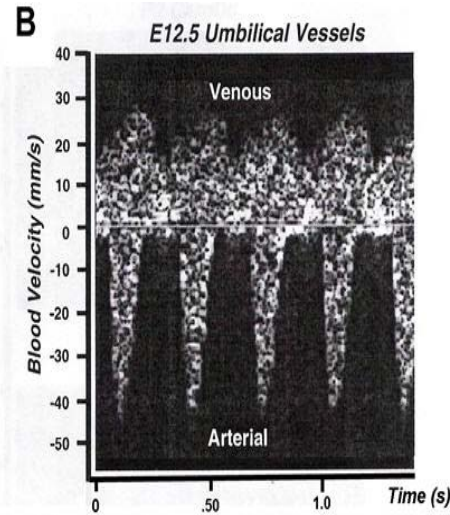
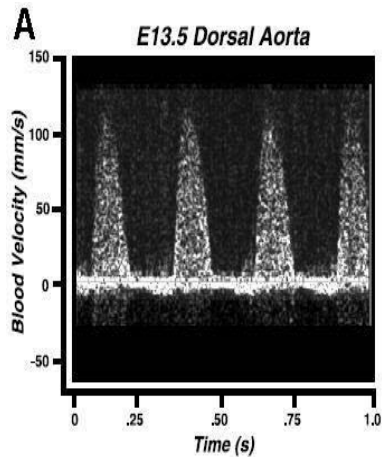
Chick embryo circulation: Invariant blood flow patterns

Schematic representation of the yolk sac circulation in stages 12 to 13



Hogers B et al. *Circulation Research*
1995;76:871-877

Doppler flows in mammalian embryo



Sadler, 2010

A,B,C, Phoon et al, 2003;

D from

Huisman 2001

Is there a circulation without a heart?

- Fish embryos **without hearts** survive 2 weeks (Loeb, 1893)
- **Heartless** larvae of Mexican salamander survive up to 2 weeks
- Mouse embryos (genetic mutants) with **non-contracting hearts** survive up to E10 (1/2 gestation)

Stöhr frog embryo experiments (1925)

- Tube heart explanted, reversed 180°, implanted **against** the flow of blood
- Heart contracts in the **opposite** direction of blood flow
- *“It is possible to reverse the heart, but not the direction of blood flow.”*



Summary

- Circulation **without a heart** in many invertebrates and primitive vertebrates
- Additional proof for **autonomous** blood movement
 - No valves in early embryo heart
 - Vortex blood flow patterns
 - The heart interrupts the flow of blood
 - Flow essential for heart's formation