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Evolutionary model of circulation confirms the autonomous movement of blood

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Heart, blood vessels and blood comprise the first functional organ system in the developing embryo. They emerge from common mesoderm-derived progenitors with the potential to become cardiomyocytes, endothelial cells and vascular smooth muscle cells. Recent *in vivo* observations have shown that the valve-less early embryo heart does not propel, but only rhythmically interrupts the flow of blood. The blood's movement originates at the level of the microcirculation and exists before the functional integrity of the heart. The validity of the proposed circulation model is confirmed by comparing key developmental stages of the invertebrate, mammalian and avian species. Unlike the early vertebrates (e.g., the lancetfish) which have an open circulation and lack the heart as the central organ of circulation, fishes have a primitive, two-chambered heart a single atrium and ventricle and a closed circulatory system. This predominantly venous type of circulation is found in organisms with low metabolic rates subsisting on small amounts of oxygen dissolved in water. The components of the fish circulation are arranged in a single loop with the heart in-series with the gills. The crucial step in the evolution of the circulatory system occurs with the transition to land where along with the adaptation to primitive lung respiration, a new heart chamber, the left atrium is formed. The unique feature of the three-chamber amphibian heart is that the single ventricle is placed in-parallel with the systemic and pulmonary circulations, which are thus subjected to equal pressures. In spite of apparent mixing of the venous and arterial blood in the (single) ventricle, the separation nevertheless occurs, suggesting that morphogenetic flow factors play a dominant role over pressure. Only in higher vertebrates, such as mammals and birds, there is a complete separation of arterial and venous circulations. With significantly increased metabolic rates needed to maintain a homeothermic inner environment, the developmental demands now call for a high-pressure, arterial limb in the systemic circuit and for a new heart chamber, the left ventricle. An overview of the salient developmental stages across the vertebrate species shows a stepwise transformation of a single-circuit, predominantly venous circulation in fishes, to a double-circuit (systemic and pulmonary) circulation in mammals, arranged, once again, in-series. The importance of the developmental circulation model for understanding of hemodynamics of congenital heart malformations will be discussed.

Biography

Branko Furst is a graduate of University at Ljubljana Medical School, Slovenia and completed Residency in Anesthesiology at Queen Alexandra Hospital in Portsmouth and at the Middlesex Hospitals in London, UK. His academic career began in El Paso, Texas where he joined the Faculty at the Department of Anesthesiology at Texas Tech University Medical School. His research interests include cardiovascular physiology and mechanisms of general anesthesia. He is the author of the book "*The Heart and Circulation: An Integrative Model*" (Springer, 2014) and has lectured on various aspects of the circulation nationally and internationally. Currently he is an Associate Professor of Anesthesiology at Albany Medical College, Albany, NY where he divides his time between clinical work, resident education and research.

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