Common principles across physiological systems

W.F. Boron, Department of Physiology and Biophysics, Case Western Reserve University, School of Medicine, Cleveland, OH 44116-4970, USA.

Although the necessity for knowing facts is a fact of life, the discipline of physiology - more than most other biomedical disciplines - is based on understanding fundamental principles, many of which apply to multiple organ systems. One example is that things flow down energy gradients. The first such quantitative description applied to heat (Fourier's law), quickly followed by electricity (Ohm), fluids (Poiseuille), solutes (Fick), water (osmosis), and charged particles (Nernst-Planck, Goldman-Hodgkin-Katz). In each case, a simple physical principle applies to multiple organ systems. The Fick principle or principle of continuity (what goes in = what comes out + consumption/accumulation) is a key for measuring blood flow and renal plasma flow, as well as understanding O_2 delivery or why flow slows in ever smaller vessels or airways. Besides these physical principles, physiological principles also span organ systems. The necessity to remove metabolically generated wastes via one dominant pathway allows us to use arterial P_{CO2} to estimate alveolar ventilation, or blood [creatinine] to estimate GFR. Both the lungs and the kidneys have substantial capillary reserves that can come into play with increased blood flow. The cardiovascular and pulmonary systems share multiple similarities (pulsatile flow, calculation of cardiac output/total ventilation, branching-tree structures). Proximal and distal nephron segments share similarities, respectively, with the small and large intestines. The color of urine and feces comes from breakdown products of hemoglobin. Starling forces produce lymph and glomerular filtrate. The blood-brain barrier is similar to blood-gonad barriers. The clearance of solutes by the kidney finds parallels in the clearance of many other substances (e.g., bile acids, cortisol, testosterone, lactic acid). Although one can learn each of these principles separately in each organ system, one might ease the task - and enhance the insight—by emphasizing broad parallelisms throughout the body.