Is the Water-Tower Analogy Justified?

To the Editor:

I read, with great interest, the article by D. P. Swain in the December 2000 issue of *Advances in Physiology Education* (2). The paper was very well written and stimulating.

As I looked into the operation of the water-tower system more carefully, it became clear that the differences between the two systems are striking and fundamental. The following is an outline of the major differences.

**WATER-TOWER SYSTEM**

1. “Open” system: air inside the tower that is exposed to the atmosphere, confirmed by two engineers dealing with water towers. Likewise, the drainage system and the riverbed are open.

2. Flow to consumers is downhill due to gravitational “potential” of water at the tower.

3. Motor pump drives the water from the river (or another source) *uphill* against essentially the gravitational “pressure” of the water to the tower.

4. Flow cannot occur from the tower to houses or businesses that are *above* the level of the tower because the flow is due to gravity.

**CARDIOVASCULAR SYSTEM**

1. “Closed” system: heart and blood vessels form a continuous circuit without a break.

2. Flow is caused by the pumping of the heart against the viscous resistance of the vessels, chiefly that of arterioles and capillaries (depending on length, diameter, number of parallel vessels, and viscosity of blood).

3. Gravity *does not* drive blood and *does not* hinder flow uphill because gravitational pressure in arteries is counterbalanced by the gravitational pressure in veins (known as the counterbalancing principle).

4. Blood flow occurs above the aorta to the head in an erect position (unlike the water tower) because gravity is not the driving force. However, gravity affects the circulation because the blood vessels are compliant (especially the veins) and alter their capacitance and resistance. Reflex mechanisms operate to counteract the gravitational effects of postural changes.

From this summary, it is clear that the dynamics of flow in the water-tower system are very dissimilar to that of the cardiovascular system. I find that the initial presentation of the water-tower system to students would introduce misconceptions that might be difficult to eradicate, particularly the role of gravity in the circulation of blood. In my opinion, students would do better by studying the cardiovascular system as such without the water-tower analogy. My experience in teaching medical and dental students has shown that presenting the dynamics of circulation without analogies entails no difficulties in conveying the basics. A more thorough presentation of the role of gravity in open and closed systems has been discussed by Hicks and Badeer (1).

HENRY S. BADEER
Department of Biomedical Sciences
Creighton University
School of Medicine
Omaha, NE 68178

REFERENCES


REPLY

To the Editor:

H. S. Badeer has raised interesting points regarding the analogy of a municipal water-tower system and the cardiovascular system. He is correct in stating in point no. 1 that the former is an open system while the latter is a closed system, and this point was addressed in my article. In regard to Dr. Badeer’s remaining three points, the two systems are much more similar than they are dissimilar. Dr. Badeer states in point no. 2 that flow in the water-tower system is due to the gravitational potential of the water in the tower. However, it must be noted that the ultimate cause of this flow is not the tower but the energy imparted by the pump. Analogously, the aorta is the pressure head for blood flow, but the heart is the source of energy. As Dr. Badeer states in point no. 3, the gravitational pressure of the water in the tower is a force that must be overcome by the pump. This is analogous to the afterload placed on the heart by aortic blood pressure. Regarding Dr. Badeer’s fourth point, the analogy remains that, for both systems, flow can only occur when the pump provides sufficient energy to overcome opposing forces.

DAVID P. SWAIN
Wellness Institute and Research Center
Old Dominion University
Norfolk, VA 23529-0196
dswain@odu.edu