Vascular Hemodynamics

***What is/are the function/s of the cardiovascular system?**

Transport nutrients to the tissues.

Transport waste products away.

Transport hormones from one part of the body to another.

Thermoregulation.

Maintain an appropriate environment in all the tissue fluids for survival and optimal function of the cells.

Hemodynamics:
The governing principles of blood flow and its behavior in the blood vessels.

Blood flow:

- Blood flow rate means the quantity of blood that passes a given point in the circulation in a given period of time.
- The overall blood flow in the total circulation of an adult person at rest is about 5000 ml/min. This is called the **cardiac output** because it is the amount of blood pumped into the aorta by the heart each minute.

- **Blood flow through a blood vessel is determined by two factors:**
- **(**1) pressure difference of the blood between the two ends of the vessel, also sometimes called the **pressure gradien**t along the vessel, which pushes the blood through the vessel. (Pressure gradient from high to low).

- the impediment to blood flow through the vessel, which is called vascular resistance. (Opposing force—> Resistance).

Q (or F) = ΔP/R

- Physiologically, this means that blood flow is equal to the **change** in **pressure** divided by **systemic resistance**. In other words, to increase blood flow, one could either increase the pressure difference (e.g., increased cardiac force) or decrease the systemic vascular resistance (e.g., dilate blood vessels).
- It is the difference in pressure between the **two ends of the vessel,** not the absolute pressure in the vessel, that determines flow rate.
- The direction of blood flow is determined by the direction of the pressure gradient and always is from **high to low pressure**.

- **The major mechanism** for changing blood flow in the cardiovascular system is by changing the **resistance** of blood vessels, particularly the **arterioles**.

- The resistance of the **entire systemic vasculature** is called the **total peripheral resistance (TPR)** or **the systemic vascular resistance (SVR).**
- Blood vessel **resistance** can be thought of as how difficult it is **to pass blood through a given set of**

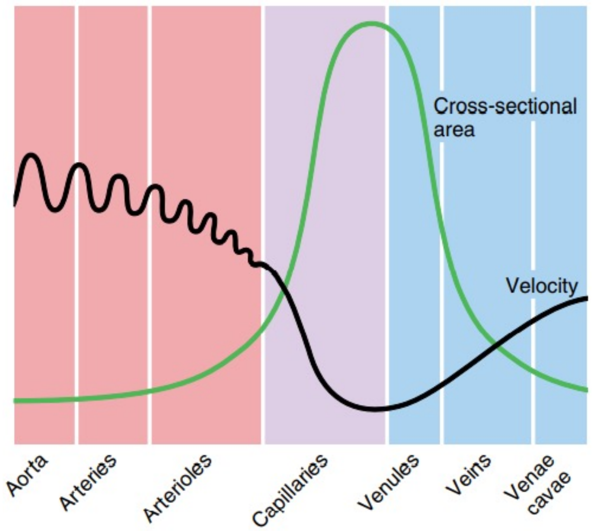
vessels. Intuitively, the **size** and **shape** of the blood vessel can alter the **ease** of blood flow

Velocity of blood flow

- The rate of displacement of blood per unit time.
- **V=Q/A**
- v =Velocity of blood flow (cm/s)
- Q =Flow (mL/s)
- A =Cross-sectional area (cm2)

Vessels Cross-Sectional Area (cm2)

- Aorta 2.5 - the highest velocity
- Small arteries 20
- Arterioles 40
- Capillaries 2500 – the lowest velocity
- Venules 250
- Small veins 80
- Venae cavae 8



Laminar flow

- Ideally, blood flow in the cardiovascular system is laminar or streamlined.
- In laminar flow, there is a smooth **parabolic profile of velocity** within a blood vessel, with the velocity of blood flow highest in the center of the vessel and lowest toward the vessel walls.
- The reason for these differences in blood flow velocity is wall stress (a type of shear stress). When blood flows through a vessel, friction exists between the fluid and the wall of the vessel. This friction decreases the velocity of the blood closest to the wall.

Turbulent flow

- In turbulent flow, the fluid streams do not remain in the parabolic profile; instead, the streams mix radially and axially.

- Because kinetic energy is wasted in propelling blood radially and axially, more energy (pressure) is required to drive turbulent blood flow than laminar blood flow.
- Laminar flow is silent, while turbulent flow is audible (noisy).
- For example, the Korotkoff sounds used in the auscultatory measurement of blood pressure are caused by turbulent flow.
- Blood vessel stenosis (narrowing) and cardiac valve disease can cause turbulent flow and often are accompanied by audible vibrations called murmurs.

Reynolds' number

- The **Reynolds number** is a dimensionless number that is used to predict whether blood flow will be laminar or turbulent. (The measure of the tendency for turbulence to occur.)
- It considers a number of factors:

$$Re = \rho VD/\mu$$

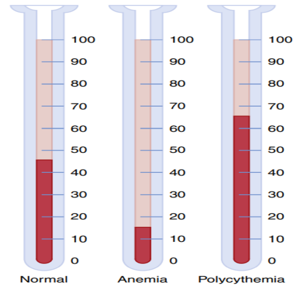
- Re is the Reynolds number, ρ is the **density**, V is **velocity**, D is the **diameter** of the cylinder, and μ is the **viscosity**.
- Turbulence is more likely to develop at a high Re number.

- when Reynolds' number rises above approximately 2000, turbulence will usually occur, even in a straight, smooth vessel.
- Reynolds' number for flow in the vascular system normally rises to 200 to 400, even in large arteries. As a result, there is almost always some flow turbulence at the branches of these vessels. In the proximal portions of the aorta and pulmonary artery, Reynolds' number can rise to several thousand during the rapid phase of ejection by the ventricles, which causes considerable turbulence.

Anemia

- Two common clinical situations, anemia and thrombi, illustrate the application of Reynolds number in predicting turbulence.
- Anemia is associated with a **decreased hematocrit** and, because of turbulent blood flow, causes functional murmurs. Reynolds number, the predictor of turbulence, is increased in anemia due to **decreased blood viscosity**. A second cause of increased Reynolds number in patients with anemia is a high cardiac output, which causes an **increase in the velocity of blood flow** (v = Q/A).

Hematocrit



Hematocrit—the Proportion of Blood That Is Red Blood Cells.

If a person has a hematocrit of 40, this means that 40% of the blood volume is cells, and the remainder is plasma.

Thrombi

Thrombi are blood clots in the lumen of a vessel.

• Thrombi narrow the **diameter** of the blood vessel, which causes an increase in blood **velocity** at the site of the thrombus, thereby increasing Reynolds number and producing turbulence.