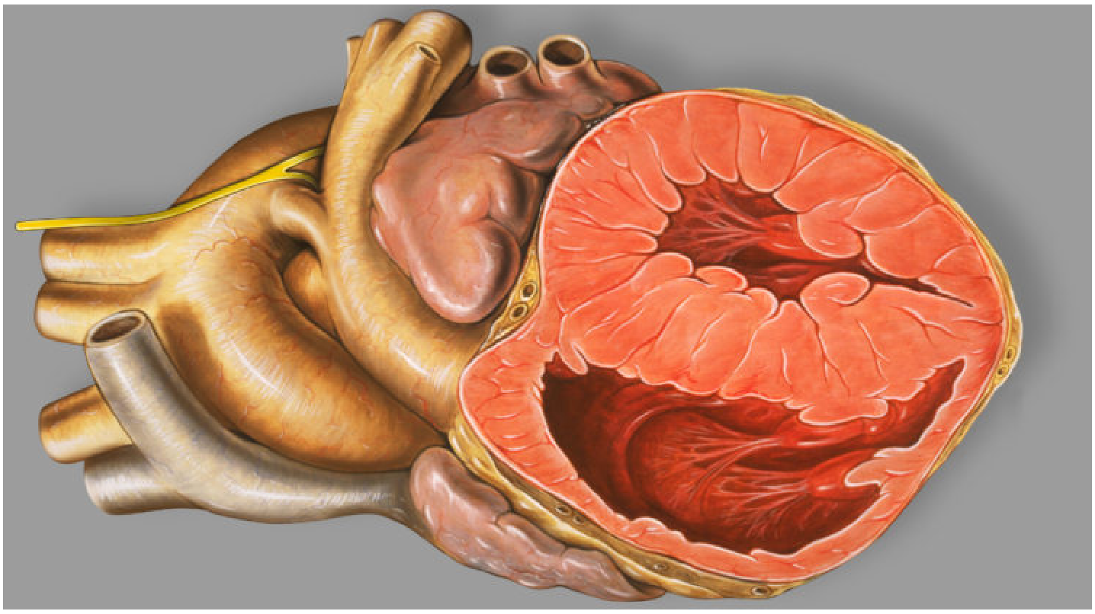
Frank-Starling Law — Preload and Afterload

See online here

The heart – a muscle that works continuously without exhaustion or breaks. It ensures the blood transport through the circulatory system. However, the conditions under which the heart is working do not always stay the same. Aortic stenosis, or increased blood reflow via the veins, strain the heart. In machines, the settings and scaling would have to be changed. Our body, however, has its own ways of dealing with that. One of them is the so-called Frank-Starling mechanism.



What is the Frank-Starling Mechanism?

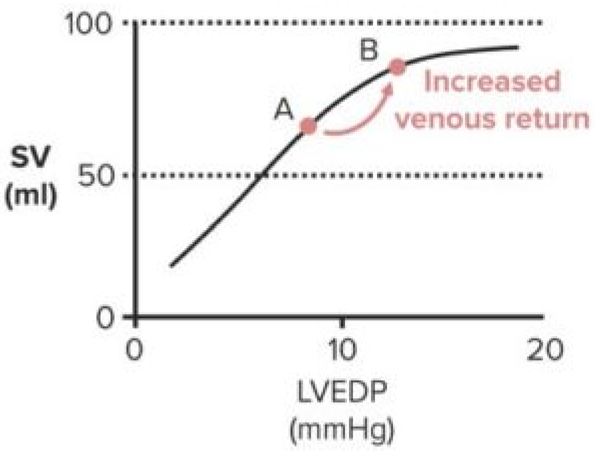


Image: Frank-Starling law. By Lecturio

The Frank-Starling mechanism is a **regulatory mechanism** of the heart. It gets activated when the heart needs to pump an increased blood volume following increased venous return. That way, the **law of continuity is maintained**.

If the right ventricle is pumping more blood than the left ventricle, **congestion** in the pulmonary circulation would be the consequence. The lungs' vessels would have to take up more blood, causing pulmonary edema. Similarly, if the right ventricle pumped less blood than is required to sustain left ventricular function then, edema in the extremities would appear. Hence, a **balance** is important to maintain circulation.

Work Diagram of the Heart

Before clarifying how the mechanism works, 1st the normal functioning of the heart without any load is shown in a volume-pressure-diagram (see work diagram of the heart):

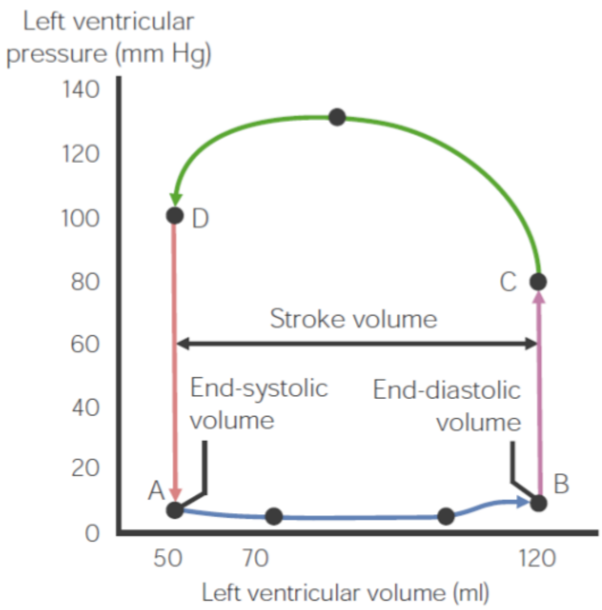


Image: Volume-pressure diagram. By Lecturio

Point A marks the volume and the pressure at the **end-diastolic volume load**. In the isovolumetric contraction phase, the myocardium contracts and the pressure rises, while the volume remains constant. At the end of this phase, **point C** is reached.

During **systole**, the blood is ejected. The volume decreases while the pressure keeps rising to later decreased at **point D,** marking the end of systole.

The myocardium relaxes and the pressure decreases. The volume, however, remains constant until blood flows from the atrium into the ventricle through the atrioventricular valve.

Diastolic filling begins at **point A**. See that end ventricular volume is never 0, since the ventricle never empties completely but always ends up with a residual volume.

After connecting points A-D, the resulting **area A1** approximately indicates the work provided by the heart. Area A2 shows the **diastolic work**. The change in volume from point C to D is equivalent to the **stroke volume**.

The following curves, acquired through experimental studies, can be inserted into the work diagram:

Resting tension curve: This curve is obtained after filling the heart with a certain amount of liquid and measuring the resulting volume. With the increased volume, myocardial extensibility decreases, and the pressure rises rapidly.

Isovolumic peak curve: While the volume does not change, the pressure rises to a maximum due to the contraction of the heart.

Isotonic peak curve: At a certain constant pressure, the stroke volume is determined by using a point on the resting tension curve.

Afterload peak curve U: For every point on the resting tension curve, there is an afterload peak curve. It is obtained by drawing a vertical line until it crosses the isovolumic peak curve and a horizontal line until it crosses the isotonic peak curve. The resulting intersection points are connected to show the afterload peak curve. Point C is always on that curve.

Adaptation of heart activity is necessary for a change of preload and afterload.

The **preload** is the volume load at the **end-diastolic phase** (point A). Increased preload is equivalent to a higher volume strain. In diastole, the ventricle is filled with more blood.

The **afterload** is the resistance that the heart must overcome to pump blood out of the heart chambers during systole. It is equivalent to the **pressure inside the aorta**. Increased afterload results in a **higher pressure burden** for the heart – it has to pump against a higher resistance.

The Frank-Starling Mechanism in Charge of Preload

No matter what, the heart has to do **more work** during increased volume or pressure strain, to maintain a balance between blood inflow and blood ejection. The easiest way to learn that is to draw a work diagram by yourself by following these instructions:

The **end-diastolic volume** is **increased**:

- Point A is pushed further to the right on the resting tension curve (A’).
- Pressure remains constant: point B changes its position only on a horizontal line (by the same amount as A; B’).
- According to a different starting point on the resting tension curve, a different **afterload peak curve U2,** point C and D are also shifted (C’, D’).
- The resulting work area **A3 is bigger** than under normal circumstances and the increased stroke volume is also measurable (SV1 < SV2).

If more blood flows into the right ventricle in diastole, the myocardium is **pre-stretched** more. This enables a higher tension growth to **raise stroke volumes**.

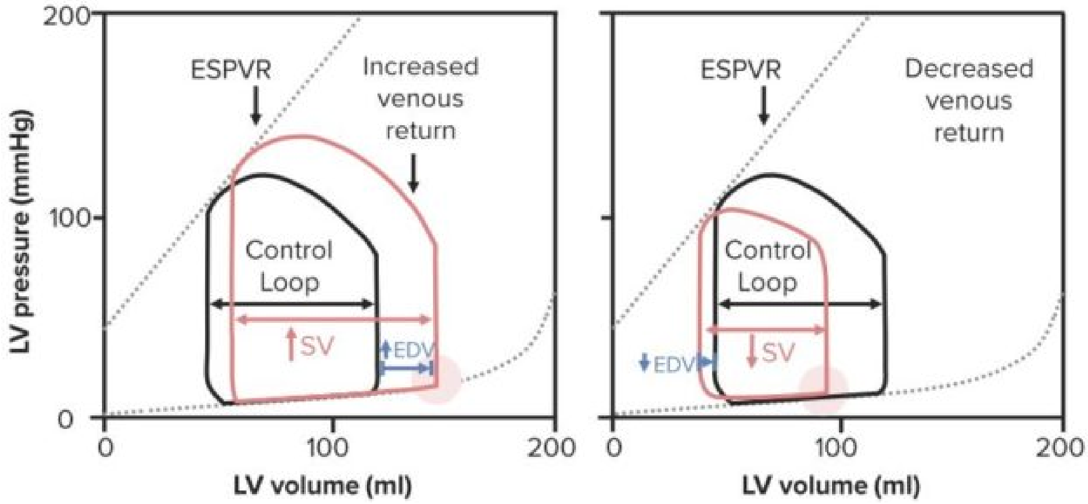


Image: Effects of preload on PV loops. By Lecturio

The Frank-Starling Mechanism in Charge of Afterload

Increased aortic pressure demands more work done by the left ventricle, otherwise, the stroke volume cannot be maintained constant.

- Point A **does not change** its position; the ventricle is filled with the same amount of blood.
- However, point B is now on a higher position on the pressure axis (increased aortic pressure, B”).
- Point C is shifted towards the top part (C’’) of the **same afterload peak curve** (point A remains in the same position on the resting tension curve) and the afterload peak curve is reached earlier. Initially, the **stroke volume is decreased**.
- **Higher end-systolic volume** is obtained: D is shifted towards the right, too (D”).
- During the next stroke, the same amount of blood flows into the ventricle, causing increased **end-diastolic volume**.
- This state corresponds to an increased preload.

The **pressure strain** is transformed into a **volume strain**.

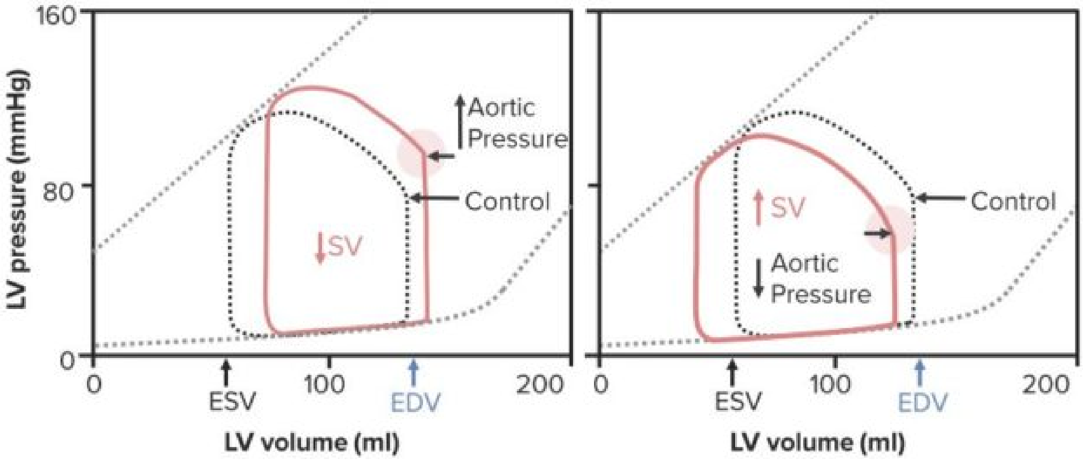


Image: Effects of afterload on PV loops. By Lecturio

References

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Notes