**Viscosity and Turbulence**

Viscosity is a measure of how much force it takes to move a fluid across a given space.

When a fluid is moving through a tube (or blood vessel), its viscosity or “stickiness” causes it to drag on everything around it. This includes the walls of the vessel and even itself. Flow ends up looking like this:

- **a) High viscosity fluid**
- **b) Low viscosity fluid**

The fluid touching the vessel walls slows down due to friction, which in turn slows down the fluid further toward the centre. The flow rate is greatest in the centre of the tube, away from the walls.

A highly viscous fluid (like syrup) will stick to itself and slow down more than a less viscous fluid (like water).

This kind of flow where the fluid is all moving at the same angle in smooth layers is called **laminar flow**. Ideally when embalming we want laminar flow because it allows even distribution through the vessels.

Right is an image made from flow data inside the arch of the aorta during cannulation. The top image is an injection from the carotid artery, and the bottom image is injection from the femoral artery. Red indicates high velocity flow and blue is low velocity flow.

Mixed red and blue indicates turbulent flow, and you can see branching vessels experiencing turbulence receive uneven flow.

**Turbulence happens close to the injection site. Nearby vessels receive inconsistent flow and this is why swelling and discolouration are common around the initial injection site.**

Turbulence is when the flow is complex and mixing between layers occurs. This can be predicted by the following equation:

$$Re = \frac{pvL}{\eta}$$

- $Re$ = Reynold’s Number
- $p$ = density of the fluid
- $v$ = velocity of the fluid
- $L$ = the length of the tube
- $\eta$ = viscosity of the fluid

Generally within a closed tube (blood vessel) a Re of less than 2000 predicts laminar flow, and above 3000 indicates turbulence. However, embalmers only need to be aware of the relationship between values and not the values themselves.

From this equation we know that the likelihood of turbulence will increase if:
- the fluid is more dense
- the fluid is moving faster
- the tube is longer
- the fluid is less viscous

...And the flow is likely to be laminar if:
- the fluid is more viscous
- the fluid is moving slower
- the tube is shorter
- the fluid is less dense

**Blood Viscosity**

While the viscosity of our embalming fluid is relatively low (close to water), blood is not only much more viscous but also more complicated.

Blood is a **heterogenous mixture**, meaning it is made up of a mixture of different parts. One factor which greatly affects blood viscosity is **hematocrit**, which is the amount of red blood cells in it. Higher hematocrit makes the blood more viscous.

Because of its heterogenous nature, blood viscosity changes with how fast it’s moving.

- At **high velocity**, the blood cells don’t stick together as much and it behaves like a **low-viscosity liquid**.
- At **low velocity** the blood cells start to group together and the blood begins to separate into its parts, so it behaves like a **very viscous mixture** of suspended solids.

So during embalming, we really want to ensure that our flow rate is enough to keep the effective viscosity of blood low. This is one reason that less is not always more when it comes to flow rate.