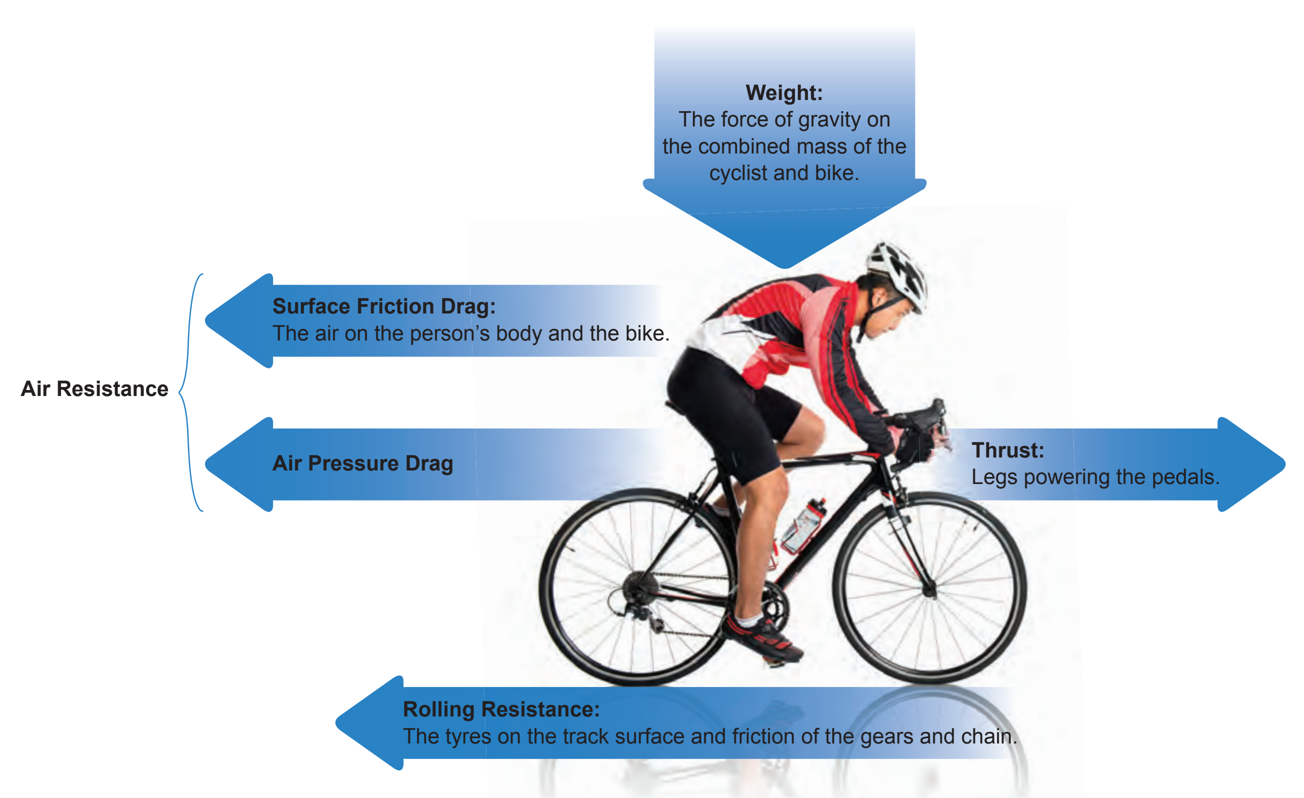
Why do Cyclists Shave Their Legs?

The main forces acting on a cyclist as they travel along a surface are shown in the diagram below.

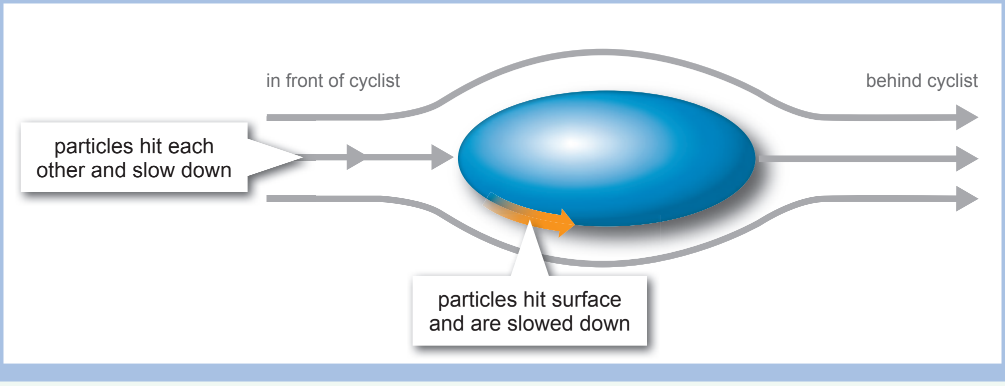


The amount of **rolling resistance** and the **friction** of the gears and chain don't really change much with the speed of the cyclist, they are fairly constant. However, the air resistance and surface friction drag do change, so it is important these forces that are opposing the movement of the cyclist, don't exceed the thrust force that the cyclist has to apply to the pedals to make the bike go forward. Competitive cyclists look to reduce resistance so that they can minimise the energy expended in struggling against the opposing forces. They look to science to help them reduce air resistance by modifying their bikes and altering their body surface.

Aerodynamics is the study of how gases, such as air, interact with moving objects. It is concerned with drag, which is also called **air resistance**. This resistance works against the object's forward motion and can slow it down. This occurs in two main ways:

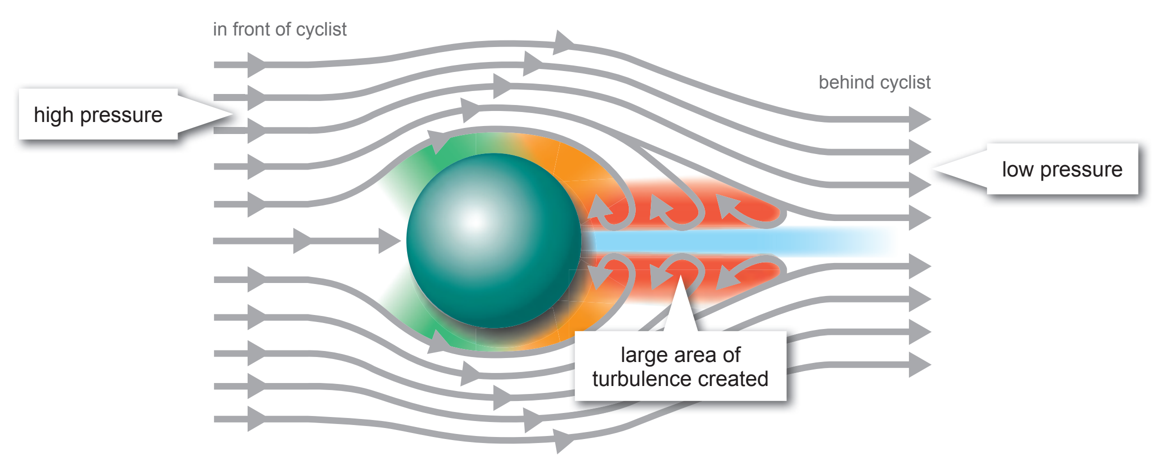
Surface Friction Drag

Surface friction drag is where particles of air hit the rough surface of the object (e.g. skin and hairs) and slow its motion. As a cyclist rides forwards, they hit a wall of air and the faster they go, the bigger and stronger the wall is. The air particles bump into the cyclists' skin and are slowed down. They also slow the particles behind them, thus creating resistance to the rider. This is shown in the diagram below.



Air Pressure Drag

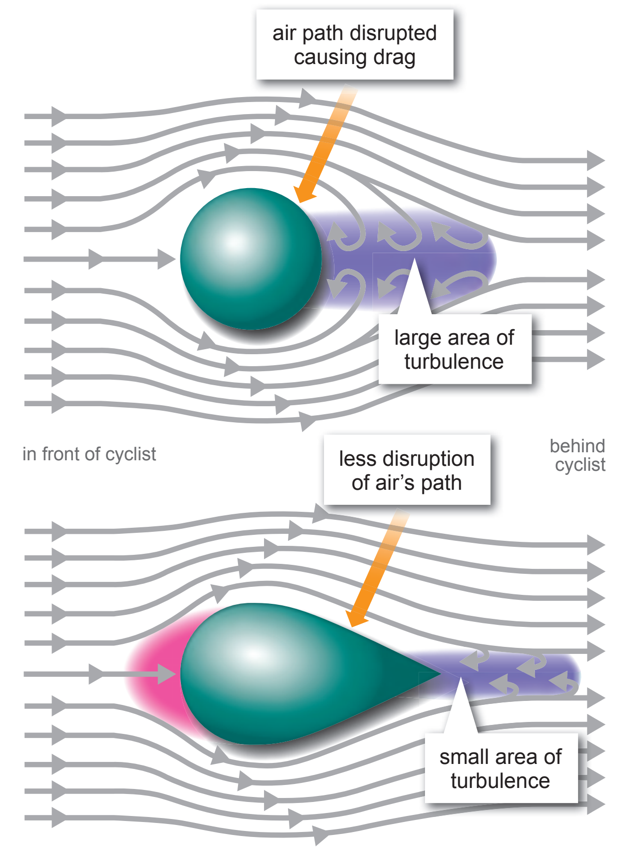
Air pressure drag has a much greater effect on the motion of the cyclist than surface friction drag. The air particles in front of the cyclist are under greater pressure than the particles behind the cyclist. This means that the particles are denser and closer together in front. This difference in pressure essentially pulls the cyclist backwards as it pushes more on the front than the back. The faster the cyclist rides, the greater this resistance becomes. At high speeds, the cyclist can use 90% of their energy just trying to fight the drag. This is shown in the diagram below.



Track cyclists usually race indoors in a special stadium called a **velodrome** where there is no actual wind and the weather conditions are constant. However, there is still air resistance due to the shape of the athlete and the speeds that they go. The individual pursuit is an Olympic event that involves two riders battling each other to see who's fastest over a distance of 3 km around an oval shaped 250 m track. The cyclists reach speeds of up to 50 km/h, which is impressive on a short oval circuit. New Zealander Sarah Ulmer set the women's World Record for this event at the Olympics in Athens in 2004, with a time of 3 minutes 24.5 seconds. Cyclists like Sarah Ulmer use all sorts of adaptations to help them go faster.

The weight of a cyclist and their bicycle can create more resistance, especially the rolling resistance of the tyres on the ground. The greater the weight, the more resistance created. Bicycle design has played a large part in reducing this by altering the materials that the bikes are made from. They can be made from steel, aluminium or carbon fibre, and each material has its advantages as well as disadvantages. Carbon fibre is light weight and very strong, however, it is **irreparable** if damaged as it tends to splinter. Steel is heavy and can be twice the weight of a carbon fibre bike, however, in comparison it is cheap and able to be repaired easily. Aluminium is also light but not as light as carbon fibre. It is strong and while it can't be repaired easily, it is cheaper to replace than carbon fibre. Because the weight of the bike affects how safe and strong it is, the UCI (Union Cycliste Internationale) have made a rule stating that a bike must be at least 6.8 kg. This has prevented the materials being modified too much.

Cyclists are very poorly shaped as a human sitting atop a bicycle isn't very **streamlined**. Their bodies are like a wall that impedes air flow and creates drag, which means they have to cycle harder and **expend** more energy in order to maintain their speed. The area of their bodies facing the air coming at the bike, is referred to as the **frontal area size**. If you sit upright on a bicycle, there is more area for the air to hit, thus increasing drag. Cyclists take a hunched over position close to the handlebars, with their back flat. This shape reduces drag. Professional cyclists have additional or specially designed handle bars called **aerobars** that sit low and allow the rider to grip on in this low, bent over position. The shape of the bike frame can also increase the amount of drag. If the frame uses circular tubing, it creates more resistance than a teardrop shape, as shown in the diagram opposite. The area of **turbulence** is reduced greatly with



tear drop shape reduces resistance

the teardrop shaped frame. Brake and gear cables can create drag if they are hanging of loose so bike manufacturers tend to hide these behind the frame to reduce drag. The human head is a block shape that increases the frontal area of the cyclist. By wearing an **aerohat** (teardrop shaped helmet), drag is reduced as it cuts through the air and reduces the pressure differences which can occur.

Cyclist wearing an aerohat.

Bikes have wheels and friction is needed to get the cyclist moving. The rubber tyres on the wheels grip to the surface, giving the cyclist **traction** so that movement occurs. But the amount of friction created shouldn't be too much that it slows the cyclist. This is why they have smooth tyres instead of chunky tread. For example, mountain bikes need extra friction to ride through soft mud and dirt. The smooth rubber tyres reduce the surface friction drag because the air isn't hitting the tread and slowing the cyclist down. The type of wheel on a professional racing bike is very different to a normal bike. They do not have spokes but instead have solid discs. The spokes break the air passing and each one creates **eddies** (swirling air) which in turn slows the bike down. The flat solid disc is slightly heavier but the increase in rolling resistance is far less than the reduction in drag.

The surface of a human's skin isn't smooth and neither are many fibres such as wool or cotton. When air hits this rough surface, it slows down and creates surface friction which slows the bike. Cyclists wear tight fitting clothes and often shave their leg and arm hair to create smooth surfaces for the air to bounce off easily. The clothing is often made of Lycra as this is a very smooth and shiny material that reduces friction.

The percentage of aerodynamic drag reduction has been calculated for some of these methods:

Method	Percentage of Aerodynamic Drag Reduction
disk wheels	70%
drop down position	27.8%
tight clothing	11%
aerohat	7%
Lycra clothing	11%

As you can see, there is a whole lot of science behind cycling. Cyclists have a range of tricks up their sleeves to try and go that little bit faster than their rivals. In fact, some of these techniques are so effective they have been banned or restricted by the UCI, these include:

- No bikes lighter than 6.8 kg.
- Cyclists must wear a helmet that is protective.
- Lotus Monocoque frame is banned (shown in the photo above).
- Obree Position is banned (arms tucked in, knees together and hunched far forward over the handle bars).
- No modification of factory parts, e.g. by taping parts down or plugging holes.
- Bikes must have equal size front and back wheels.
- Only the equipment that is available to anyone who races bicycles, is allowed to be used.
- A rider has three points of support on the bicycle. These are feet on the pedals, hands on the handlebars and seat on the saddle.

As well as this, the UCI has the right to check each cyclist before racing and permission must be sought before the race for any modifications or unique technologies. So while the bike's design and the human can be modified to provide more speed through decreased resistance, it is heavily controlled. This makes it a fairer and a more level playing field.