COLD CALLING

***Jane Hall** looks at the science behind what happens to your body in cold water…*

Photo © Chill Swim

In April 2012, Gill Ralphs, a member of the Chiltern Tri Polar Bears, stood on the swimmers' beach in Dover, wrapped up as though for an Arctic winter. As she tried to pour coffee from a flask, her hands shook so much that most of the coffee ended up on the stones at her feet. "I felt OK in the water – why can't I stop shivering?" she wailed.

What happened in Gill's body (and those of the other shivering prospective Channel swimmers around her) during and after her swim is a fascinating story…

April last year in the UK was unusually cold, and the sea temperature in Dover was still only around 10°C at the end of the month when aspiring Channel swimmers started training in the harbour. When the swimmers entered the water, cold receptors in the skin were triggered on a massive scale, releasing the hormones adrenalin*, noradrenalin* and cortisol (the 'stress hormone') into the sympathetic nervous system.

This hormone release is known as 'cold shock'. It causes an initial gasp reflex, followed by hyperventilation and an immediate increase in heart rate and blood pressure. Cold shock is the main cause of panic in novice open water swimmers, and the impact is stronger when coupled with anxiety. Those who may be already nervous about deep water or a rough race will hyperventilate more, triggering a vicious circle that can ruin a swim before it starts. Wetsuit wearers aren't

YOU CAN ALWAYS SPOT THE ADRENALIN JUNKIES IN ANY GROUP OF COLD WATER SWIMMERS immune either as the process is controlled centrally – hands, feet and face exposed to the cold water will trigger the same response, although muted, as will the cold water when it first enters the wetsuit.

Some people seek it out. You can always spot the adrenalin junkies in any group of cold-water swimmers. They're the ones who dive in immediately to get the biggest hit, as opposed to those who shuffle in slowly to reduce the impact.

The sensations associated with the cold shock response only last a few minutes, but a cascade of other physiological reactions is started within the body that is essential for protection against the cold. Water has 20x the heat-removing properties of air, so immersion in 10°C water creates very real risks. The human body wants to protect the vital organs at all costs as a drop of just 2°C in the core is enough to interfere with normal bodily functions: this is the onset of hypothermia.

The human body is amazingly effective at preventing hypothermia. In a 1999 study, Professor Mike Tipton and colleagues at University of Portsmouth had 10 swimmers in 10°C water, and all were able to swim for over an hour before core temperature dropped to 35°C, with some able to maintain their core temperature for much longer than this. Keeping the core warm involves a clever system of insulation, as well as an increase in heat production.

The hormones released by the cold shock response interact with surface receptors on tissue cells, triggering an increase in intracellular calcium. This, in turn, starts a process called vasoconstriction, where smaller blood vessels to the skin and extremities are closed off. Blood is now diverted to deep veins that run alongside the arteries. Warm arterial blood leaving the body's core then passes close to venal blood travelling the other way and warms it before it returns to the heart. This brilliantly simple process of 'heat exchange' conserves heat by recirculating it to ▶▶

the body core where it is most needed. Since the arteries give up much of their heat in the exchange, there is less heat lost through convection at the surface.

Closing off the smaller blood vessels gives the body a 'shell' around the more important body organs. The shell acts as an additional layer of insulation between the core and the cold water. After only a few minutes swimming, the Channel swimmers are now feeling 'used to the water' and much more comfortable, although shell temperature may be as much as 20°C less than the core. Adrenalin levels are steady, allowing swimmers to take better control of their breathing. However, cortisol, adrenalin and noradrenalin levels will remain high throughout the swim, as will heart rate.

UNDER PRESSURE

Vasoconstriction brings its own challenges. The same amount of blood is now travelling around a much smaller volume of blood vessels, causing a large increase in blood pressure, which is a risk for those with existing hypertension. As a way of dealing with this, the body reduces the volume of blood by removing fluid and salts as urine. Our Channel swimmers now find their bladders filling up, which shouldn't cause any problems in the sea. The thirst instinct is suppressed for the same reason and the swimmers will find themselves needing to drink large amounts later in the day to counteract dehydration.

THE HUMAN BODY WANTS TO PROTECT THE VITAL ORGANS AT ALL COSTS

Obviously, wearing a neoprene wetsuit will give a swimmer an additional 'shell' to insulate the body, but, although there were few wetsuits in sight on Dover beach, many Channel swimmers come with their own layer of additional insulation in the form of subcutaneous fat (termed 'bioprene' by cold water swimmers). Fat is an excellent insulator, as is inactive muscle. "When someone lies still in the water, 70% of insulation is provided by muscle," says Tipton, "but swimming at even a very easy pace removes the capacity of the muscle to insulate." Using the muscle requires a good flow of blood, which allows heat to escape.

There is also little insulation around the head. The blood supply to the brain is vital, so vasoconstriction does not happen here and front crawl swimmers, with heads in the water most of the time, lose much of their heat through the scalp.

If the swimmers stay in cold water for long enough, and core temperature falls, vasoconstriction will extend to keep blood closer to the core. The blood supply to the muscles is reduced and muscles will begin to feel tired and heavy until they are unable to maintain activity. 'Swim failure' normally begins before hypothermia.

As well as insulation, the body increases heat production (thermogenesis) to maintain core temperature. Although the muscles may be ineffective as insulators, they produce heat whilst in use – the bigger the muscle and the more it's used, the more heat will be produced. The harder you swim, the more heat your muscles will create, so fitter swimmers, who can maintain a higher work effort for longer, will be able to maintain core temperature better.

In babies and small mammals, the primary means of heat production is non-shivering thermogenesis (NST), sited in pockets of brown fat around major organs. It used to be believed that brown fat in humans was lost during childhood, but over the last decade it has been discovered that adult humans also have active brown fat, mainly in deposits in the top of the chest and lower neck. This fat is activated by noradrenalin to turn stored fats and carbohydrates into heat energy. By siting deposits around the neck, NST could help warm cooler blood returning from the poorly-insulated brain. Although studies have been limited by practical difficulties in observation of the tissue, it is likely that brown fat has a major role to play in heat production.

So why was Gill Ralphs shivering so badly?

As she and the other swimmers came out of the water, the adrenalin levels in their bodies began to drop and blood began to flow back into the cold 'shell'. This is vital to prevent flesh damage (eg frostbite or necrosis) due to the lack of fuel and oxygen from the blood, but it triggers the least pleasant part of cold water swimming. When warm blood flows into cold flesh, it returns to the core cold. The body needs to increase thermogenesis to warm it up, and it does this by shivering. Whilst swimming, shivering is suppressed by muscle activity, but now it becomes the primary method of heat production – synchronous muscle movements are very effective at creating heat and will increase metabolic rate by 2-3 times. For swimmers struggling desperately to pull on warm clothes, it can feel more like violent shaking than shivering.

Swimmers in Dover are warned not to try to rush the warming process after a swim. Freda Streeter, who coaches prospective Channel swimmers training on Dover beach, has strict rules: "Put on warm hats and clothes, then have a hot drink. No hot showers or car heaters until you've warmed up." A hot shower will cause vasodilation – the opposite of vasoconstriction – where small blood vessels to the surface of the body open up. Blood pressure will drop dramatically, with a high risk of fainting. If you want or need to warm up quickly after a cold swim, Mike Tipton recommends a hot bath and to stay sitting down in it for long enough to get the core properly warm. Exercise, such as going for a run, will also improve thermogenesis, and may be more pleasant than shivering.

A process called diet-induced thermogenesis is also sited in brown fat, but is even less well understood than NST. It seems that short-term overeating can also trigger activation of brown fat to increase metabolism and produce heat. This may be the root of the instinct to eat cake as soon as possible after a swim. If nothing else, it's a good excuse… ●

** Adrenalin and noradrenalin are only called this in the UK. The rest of the world calls them epinephrine and norepinephrine.*

REYNAUD'S PHENOMENON

Reynaud's Phenomenon, also known as 'white finger', is suffered by millions of people in the UK alone. It is a hyperactivation of the sympathetic nervous system, which causes extreme vasoconstriction in fingers and toes. The skin turns pale and white and becomes cold and numb. It is painful and debilitating, and can occasionally cause long term damage to flesh. It's generally triggered by cold or stress and worsened by stimulators such as caffeine and nicotine, so sufferers are recommended to avoid these. In extreme cases, drug treatment with calcium channel blockers (vasodilators) is offered.