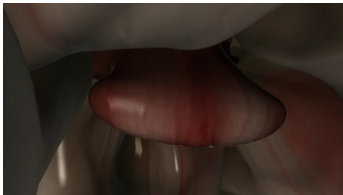


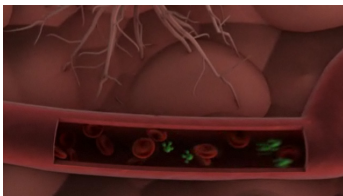
# Fight or Flight Response: Play-by-Play

One of the most remarkable examples of cell communication is the fight or flight response. When a threat occurs, cells communicate rapidly to elicit physiological responses that help the body handle extraordinary situations. The movie depicts just some of the communication and responses involved in the fight or flight response. Below is a detailed guide to events taking place in the movie.

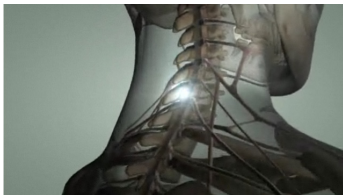
## Time Event



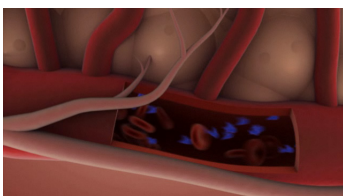
0:16 An environmental signal travels **into the brain**. In response, the amygdala, a primitive structure in the brain, fires off a nerve impulse to the hypothalamus (not shown). The hypothalamus sends a chemical signal to another part of the brain called the pituitary gland.



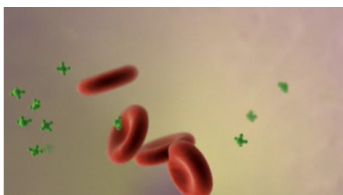
0:25 **In the pituitary gland**, corticotrope cells release adrenocorticotrophic hormone (ACTH, green molecules) into the blood stream.



0:38 Simultaneously, nerve impulses travel from the hypothalamus along the spinal cord to the adrenal gland (atop the kidneys). Both the chemical signal (ACTH) and the nerve impulse initiated in the hypothalamus travel to the adrenal gland.

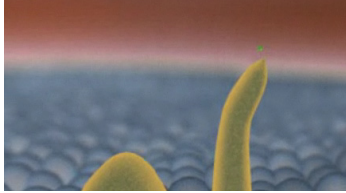


0:49 **In the adrenal gland**, the nerve impulse signals chromaffin cells to release epinephrine (blue molecules, also known as adrenaline) into the bloodstream. Epinephrine will travel to many different cell types throughout the body.



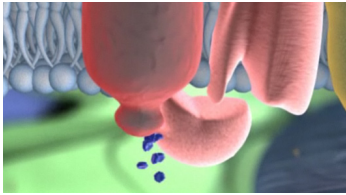
0:54 The ACTH (green) previously secreted by the pituitary gland travels through the blood stream to cells in another area of the adrenal gland.

## Fight or Flight Response: Play-by-Play

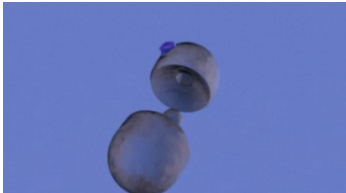


1:01 - 1:35 *The Cortisol Production Signaling Cascade:*

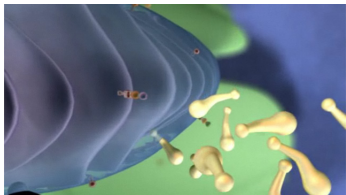
1:01 **On the surface of an adrenal cell**, the signaling molecule ACTH (green, not drawn to scale) docks on a MC2-R receptor (yellow), causing it to change shape.



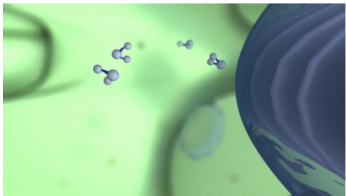
1:03 **Inside the adrenal cell**, the conformational change of the receptor causes the G protein complex (pink, right) to become activated and uncoupled. The G protein stimulates adenylate cyclase (red, left) to convert ATP (the cell's energy molecule) into cAMP (a signaling molecule, blue).



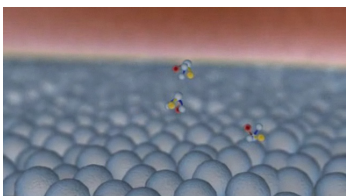
1:08 cAMP activates Protein Kinase A (PKA) causing it to release its catalytic subunits (only one is shown here for simplicity). The catalytic PKA subunit travels to the mitochondrial membrane and switches on a protein called steroidogenic acute regulatory protein (StAR, not shown).



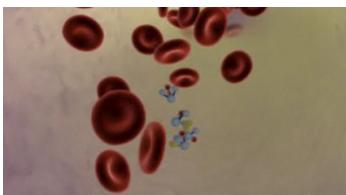
1:11 StAR is responsible for mediating the complicated task of importing cholesterol (yellow) into the mitochondrion.



1:13 Inside the mitochondrion, enzymes convert the cholesterol into 17-OH-pregnenolone. 17-OH-pregnenolone is released from the mitochondrion and sent to the endoplasmic reticulum, where it is converted into 11-deoxycortisol.

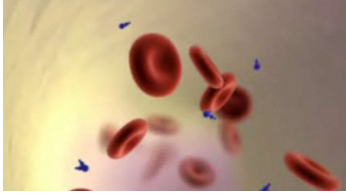


1:25 This compound is then sent back to the mitochondrion where it is finally transformed into the final product, cortisol. Cortisol **leaves the adrenal cell** by freely crossing the cell membrane, and it enters the bloodstream.

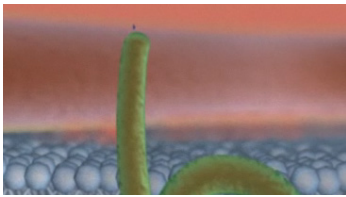


1:35 Cortisol will travel through the bloodstream to several cell types. It will initiate signaling cascades in these cells resulting in an increase in blood pressure, an increase in blood sugar levels, and suppression of the immune system (not shown).

## Fight or Flight Response: Play-by-Play

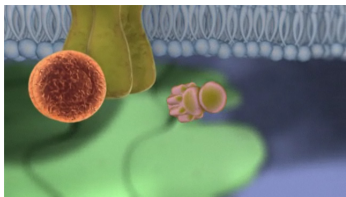


- 1:42 A view of epinephrine (blue) that was released earlier by the adrenal gland. From here, the epinephrine will travel to several cell types, eliciting different responses.

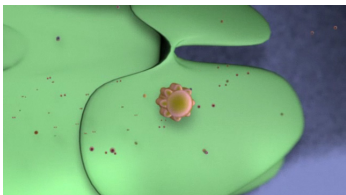


### 1:45 - 2:20 The Glycogenolysis Signaling Cascade:

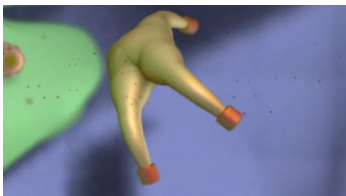
- 1:45 **On the surface of a liver cell**, epinephrine (blue, not drawn to scale) binds to an alpha-1 adrenergic receptor (yellow), causing it to change shape.



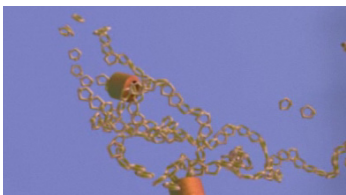
- 1:47 **Inside the liver cell**, the conformational change of the alpha-1 adrenergic receptor causes the G protein complex to become activated and uncoupled. The G protein (red, left) binds to phospholipase-C (center), causing it to produce and release the signaling molecule IP<sub>3</sub> (pink, right).



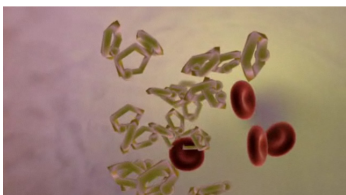
- 1:58 IP<sub>3</sub> binds to receptors on the surface of the endoplasmic reticulum (ER, green), stimulating the release of calcium ions (red spheres).



- 2:04 Calcium interacts with phosphorylase kinase (yellow), stimulating it to release its associated molecules of glycogen phosphorylase (orange).

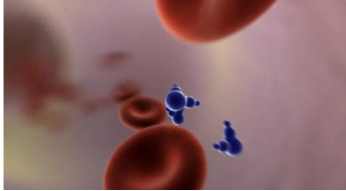


- 2:11 Glycogen phosphorylase breaks a glycogen molecule into individual glucose subunits.



- 2:26 The newly-formed glucose is transported **out of the liver cell** and it enters the bloodstream. This glucose will provide an immediate source of energy for muscle cells (not shown).

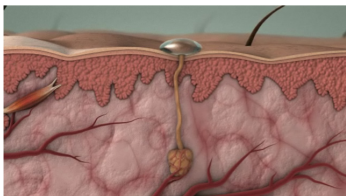
## Fight or Flight Response: Play-by-Play



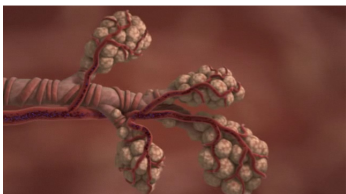
2:28 Simultaneously, epinephrine (blue) travels through the bloodstream to other cell types.



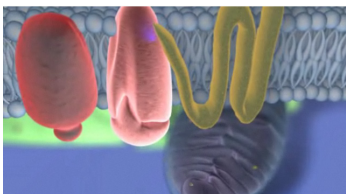
2:42 **In the skin**, epinephrine binds to a receptor on an erector pili smooth muscle cell. This causes a signaling cascade (similar to the glycogenolysis signaling cascade, above) that contracts the muscle, raising the hair on the surface of the skin.



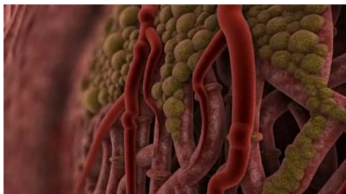
2:56 **On the surface of sweat glands**, epinephrine binds to Alpha-1 adrenergic receptors, triggering a signaling cascade that contracts the gland, squeezing sweat to the skin's surface.



3:15 **In the lungs**, epinephrine sets off a signaling cascade (similar to the cortisol signaling cascade, described above) that relaxes muscle cells surrounding the bronchioles to enable increased respiration.



3:26 Epinephrine can have opposite effects (contraction, or relaxation) depending on the type of signaling machinery present **in the cell**. Docking on alpha-1 adrenergic receptors on the erector pili muscle causes contraction, while docking on beta-2 adrenergic receptors on bronchiole muscle cells cause relaxation.



3:51 **In the heart**, epinephrine acts on the pacemaker cells, stimulating them to beat faster. As a result, energy and messenger molecules are circulated throughout the body at a faster rate.