The Body Code Sep 2

DNA mole. Deoxyribonucleic acid, or DNA, carries the inheritance of every living thing. This long-strand molecule stores a unique code in the arrangement of four chemical bases, forming the rungs of this spiral ladder. Human DNA contains about 3 billion of these bases. More than 99 percent are arranged in the same order on each rung in every cell in every person on Earth. The order of these bases programs the body's trillions of cells with unique instructions for each kind of cell. Almost infinite in complexity, this is The Body Code.

CREDITS Opening Credits:

The BBP presents, The Body Code, Narration: Jim Bratton, Score: Shai Fishman

DONE Imagine we could explore a human cell programmed by the DNA in its nucleus. The cell is like a small factory. Elongated mitochondria are the cell's power plants -- producing energy as they absorb oxygen and digest sugar molecules. The nucleus lies in the cell's center and contains its DNA instructions. The human body has over 10 trillion cells, differing in size, shape and function.

Skeleton Bone cells, which are very rigid, form the skeleton that gives the body its shape and provides a structure for our journey. Adult humans have over 200 bones. Bones contain different types of cells: cells that form new bones, cells that maintain healthy bones by controlling the mineral content, cells that break down bone tissue, and cells that cover the bone and regulate the movement of calcium and phosphate.

system Bones protect vital organs like the brain and heart and store calcium, needed in nerves and muscle cells. Also a few large bones have a living soft core called the bone marrow. Bone marrow is a spongy, fatty tissue that contains immature stem cells and extra iron. These stem cells can transform themselves into red blood cells, white cells, and blood platelets. They wait until unhealthy, weakened, or

damaged cells need to be replaced. The circulatory system requires marrow to sustain this river of blood, bringing life to all the body's cells.

Add muscles

Turn body

Muscles and connective tissue hold the bones together. Muscle cells create all body motions -- from breathing to running. The body has over 600 muscles, most occurring in matched pairs on the left and right sides.

Moving Hand

Since each muscle can perform only one motion, the body has opposing muscles to create a behavior like the wave of a hand. The biceps muscle pulls the arm inward while the triceps muscle causes the arm to extend. Most skeletal muscles are under voluntary control, reacting to commands from the nervous system.

Organs

Inside the body's skeleton are other muscles that must operate all the time. In the heart and lungs, liver, stomach and intestines, smooth muscles control breathing, adjust heart rate, and digest food.

Bones+Circ.

Buried within the rib cage is the most critical of all muscles, the human heart. The heart pumps blood through arteries, capillaries and veins to provide every cell with oxygen and nutrients. To carry oxygen to cells, blood must flow from the heart, to the lungs, and back to the heart again. Oxygen-rich blood returns to the heart, which contracts to force it into the main artery, the aorta, and out into the body through a maze of one-way rivers shown in red. Veins carry oxygen-depleted blood, shown in blue, back to the heart from the body's cells. In this manner, the heart circulates all of the body's blood every 30 seconds.

Sea of cells

The body's 5 liters of blood contain red blood cells to carry oxygen from the lungs; white blood cells to help fight infection; and platelets to cause the blood to clot. Red blood cells have a strange shape – a curved disk that is round and flat and can squeeze through capillaries to individual cells. These are the only cells without a nucleus, allowing them to carry more oxygen. The disk shape increases the cell's surface area for oxygen transfer.

White blood cells are much larger and much rarer with almost a thousand red blood cells for each white blood cell. White blood cells circulate in the blood so they can reach any infection quickly. They help produce antibodies that kill invading bacteria.

Skeleton w/ nerves

Master control for this complex super highway is the nervous system with nerves spread throughout the body, connected to the spinal cord and the brain. The brain contains about 100 billion nerve cells or neurons and trillions of support cells. The spinal cord lies within the backbone and connects the brain to the rest of the body. Beyond the spinal cord are two additional nervous systems: the autonomic nervous system and the peripheral nervous system. The autonomic nervous system monitors and controls the body's automatic life-support functions. The peripheral nervous system has motor nerve fibers and sensory nerves sending information to the spinal cord and brain.

Sea of cells

Cells of the nervous system, called neurons, carry electrochemical "messages" from cell to cell. Neurons have three parts – the cell body with all the basic cell functions, the axon, a long thin cable-like projection of the cell that carries electrochemical messages along the length of the cell, and dendrites or nerve endings that make connections with other cells, allowing cells to communicate with each other or sense the environment.

Sensory neurons carry signals toward the central nervous system. Motor neurons carry signals from the central nervous system to other parts of the body. Receptors sense the environment and encode this information into electrochemical messages that are transmitted by sensory neurons.

Full body

Nerve receptors sense change, including pressure, taste, sound, and light. These changes are converted to a signal carried by neurons to the sensory centers of the

brain or spinal cord. Here neurons interpret the input and generate a response by sending commands to cause muscles to move or the heart to beat faster.

With all of its operating systems, the body is a complex machine, a miniature universe to explore. Our journey starts in the optic nerve connecting the eye and brain.

For this animated journey, we'll travel though the body inside a tiny imaginary submarine, with a virtual reality console showing our path.

First we explore the eye's structure with beams of light streaming in when the person opens her eye. These light beams have passed through the cornea and the dark iris of the eye. Just like the lens of a camera, the lens of the eye focuses light waves. The lens changes shape to focus light from near or distant objects.

The focused light now beams through the center of the eye toward its final destination: the retina, located at the back of the eye. In a way, the retina is like a movie screen. The focused light is projected onto its flat, smooth surface. Signals sent from the photoreceptors travel along nerve fibers to a nerve bundle at the back of the eye, called the optic nerve. It carries all information collected from the eye to the brain. Vision occurs when the brain receives and interprets the eye's signals – all in a fraction of a second.

We've now entered the brain's cerebral cortex. This is the command center as well as the center of all creativity and intelligence -- a super computer without equal. The brain is running the equivalent of 10 billion to one hundred billion micro processes simultaneously. These processes use about 20% of the body's energy and generate about 25 watts of power.

From the brain, we travel to our second sensory destination: the inner ear, a labyrinth of fluid-filled canals. Some are used for balance while others convert vibrations to electrical signals carried to the brain.

We're preparing to cross the barrier between the inner and middle ear. The eardrum lies directly ahead. Once a sound wave travels into the ear canal, it vibrates the tympanic membrane, which we call the eardrum. This eardrum is a thin, cone-shaped piece of skin, about a centimeter wide, located between the ear canal and the middle ear. The eardrum is rigid and very. Higher-pitch sound waves move the drum more rapidly, and louder sound waves move the drum a greater distance.

Moving bones amplify the force of the sound wave creating a pressure on the inner ear that is over 20 times the pressure felt at the eardrum. This pressure is required to move the hair like fibers of the inner ear which then send electrical impulses describing the pitch and loudness of the sound to the hearing center of the brain.

As the ear drum vibrates, it shakes the three smallest bones in the body -- the hammer, anvil, and stirrup. When the eardrum vibrates, it moves the hammer from side to side like a lever. The other end of the hammer is connected to the anvil, which is connected to the stirrup. The other end of the stirrup rests against the inner ear. The stirrup acts like a piston, creating waves in the inner-ear fluid to represent the air-pressure changes of the sound wave.

We're preparing to leave the ear now -- passing the ear drum and the hammer, anvil, and stirrup once again -- moving into the circulatory system.

We have now entered the superior vena cava. This vein carries oxygen-depleted blood to the heart from the head, neck and arms. The turbulence here is incredible, especially as we flow into the heart's right atrium.

The tricuspid valve lies ahead with its three leaflets controlled by three muscles. It is opening and we're being pushed into the right ventricle. Going through this valve is a one way trip and there's no going back. This chamber pumps deoxygenated blood into the pulmonary artery that carries it to the lungs. The tricuspid valve keeps blood from flowing back into the right atrium.

We have just detected cells which do not belong. These are the foreign cells of a massive viral infection that is growing rapidly. If these cells are not destroyed, they can cause a heart attack and even death. To fight them, we must go to war at the cellular level – killing these cells without damaging the healthy cells of the heart.

We turn to nanotechnology to build a treatment that can work with individual diseased cells without damaging the cells nearby. At Rice University's Center for Nanoscale Science and Technology, a transmission electron microscope shows us the atoms making up the complex molecules inside human cells.
The new bullets are tiny glass spheres – smaller than the nucleus of a cell and coated with gold. These are called nanoshells. These nanoshells absorb heat at specific wavelengths determined by their color. The energy is delivered by an infrared laser that does not harm normal tissues. As the nanoshells warm up, they cause the cell around them to explode.

This is just what we need to save our patient. A hypodermic needle delivers the nanoshells into the blood stream. We can follow their journey through a vein and into the heart.

This river of blood must sustain every cell or the cell will die – bringing in nutrients and carrying away cellular waste. Eventually it will carry our nanoshells to the heart and to the diseased cells that they have been targeted to find. Within

30 seconds the nanoshells should find the infection and attach themselves to it. We won't be far behind.

To see the circulatory system in more detail, we are adding more search lights to our imaginary submarine. For detailed images we are also creating a smaller imaginary vehicle. Neither of these vehicles is real, but they help us visualize and explore very real parts of the body with images based on real photography of the circulatory system.

A large vein or artery is wide enough to carry our millimeter-wide submarine. But an individual cell is only 10 microns wide. Since it is imaginary, we can make our submarine a hundred times smaller to watch the nanoshells destroy the diseased cells that we found in the heart.

We can see the infection up close. It is very aggressive, attacking everything in its path. These cells must be killed before they attack any more of the body's healthy tissues. The body does not recognize this danger and is not sending white blood cells to fight the infection.

If this is an inflammation of the heart muscle, it is probably a viral infection that has not triggered a response from the body's white blood cells. If this infection damages the heart, it cannot pump blood as forcefully, the organs of the body will not receive enough blood, and fluid will build up in the lungs. This is a condition without many good treatment options… until now.

It's up to the nanoshells. Unlike regular tissue, nanoshells will heat up when exposed to an infrared laser – a beam that passes into the body without damaging any healthy cells. Heat causes the attached cells to die.

When the nanoshells are attached to the infection, we can engage the infrared laser -- heating the nanoshells until the temperature destroys the infection. The

laser beam pumps a lethal amount of energy into the nanoshells attached to the diseased cells. We can observe the battle that would rage at the cellular level as radiation fills the area and the infected cells die.

When the disease is gone, the healthy cells that remain are programmed by their DNA to begin repairs. Inside the nucleus, we can see the coiled DNA. Here almost two meters of DNA are wound into a tight ball that fits into a cell's nucleus only one micron in diameter. Inside this tightly packed ball are 46 individual chromosomes in 23 matching pairs. Specific locations on these chromosomes, called genes, carry instructions for cell reproduction and repair.

If this were a human reproductive cell, it would contain only 23 individual chromosomes. When reproductive cells from mother and father combine, a new set of DNA instructions is produced. Once the new DNA combines into a set of 46 new chromosomes – half from the mother and half from the father – a new life is born.

To see this new life, we increase our submarine's size a million-fold, traveling from inside the nucleus of a cell to inside the womb. Carefully we slip under the umbilical cord and follow it to the baby.

Here a new arrangement of bases on the DNA ladder has made a new human being, unique, but connected by DNA to parents and to common ancestors all over the world – ultimately to all humans through shared bonds of DNA. This is the molecule that makes us all both human and unique. This is the wonder of The Body Code.