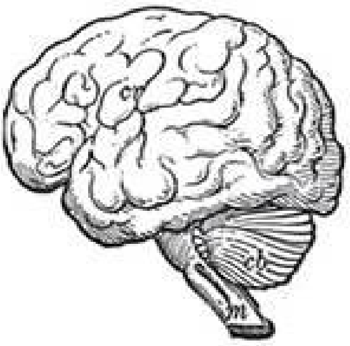
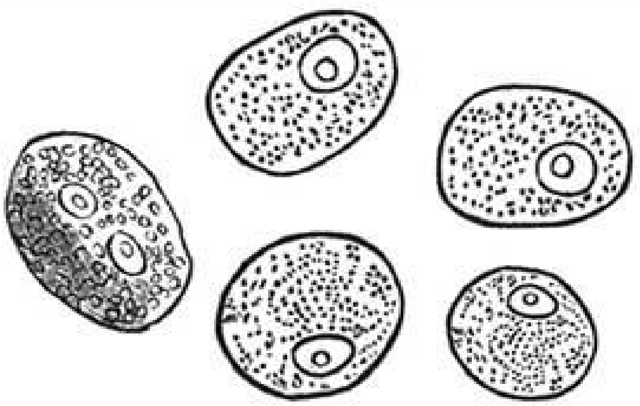


ADULTS PRODUCE
300 BILLION NEW
CELLS EVERY DAY.

NERVE IMPULSES TRAVEL TO AND FROM THE
BRAIN AT MORE THAN 150 MILES PER HOUR.

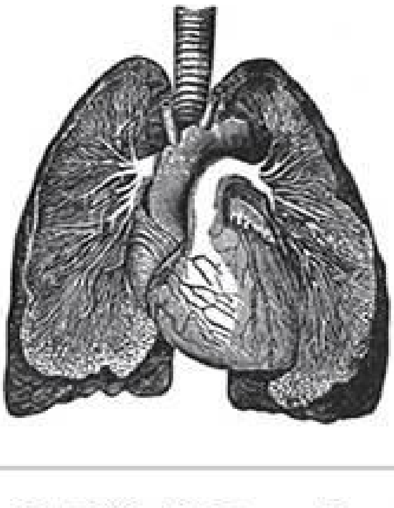


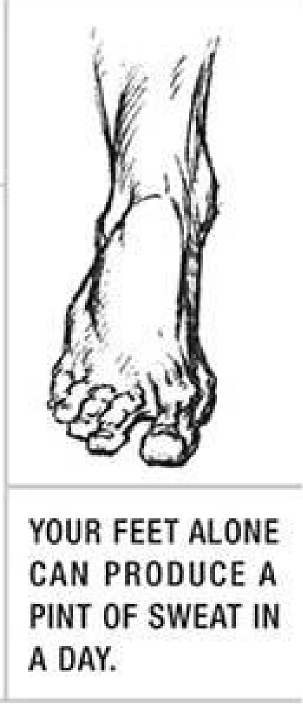
ANATOMY 101

FROM MUSCLES AND BONES TO ORGANS AND SYSTEMS, YOUR GUIDE TO HOW THE HUMAN BODY WORKS

A
CRASH COURSE
IN
ANATOMY AND
PHYSIOLOGY

THE SURFACE AREA OF
A LUNG IS THE SAME AS
THAT OF A TENNIS COURT.





YOUR FEET ALONE
CAN PRODUCE A
PINT OF SWEAT IN
A DAY.

KEVIN LANGFORD, PhD

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FROM **MUSCLES AND BONES** TO **ORGANS AND SYSTEMS,** YOUR GUIDE TO **HOW THE HUMAN BODY WORKS**

KEVIN LANGFORD, PhD

adamsmedia
Avon, Massachusetts

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INTRODUCTION

THE BUILDING BLOCKS OF ANATOMY AND PHYSIOLOGY

The human body has always amazed mankind. Early scientific drawings and diagrams demonstrate the long-standing fascination with the body. Even cave drawings and later hieroglyphs illustrate that people were aware of the complex machinery of the human body. Our fascination continues to the present day, as we dig ever deeper into learning everything we can about the human body. Our understanding has advanced dramatically in just the last 20 years alone.

The study of the human body is divided into two different but closely related disciplines. Human anatomy is the study of the structure of the human body while physiology is the study of its function. Together, they help us understand how the human body works. In this book, you won't just learn the structure of the human body and the functions of its various parts, you'll also discover *why* it does what it does.

Cells, tissues, and organs are often intricately arranged to facilitate many functions simultaneously; complex biochemical processes take place that enable your body to perform those functions. In *Anatomy 101*, all of these processes and structures of the human body are explained. After reading this book you'll know the human body inside and out.

The amount of complexity can seem overwhelming when you're studying anatomy and physiology, especially at first, and particularly if you don't have a strong background in biology. Don't be intimidated! This book is designed for the reader who doesn't already have a PhD in biochemistry. Even if it's been a few decades since high-school biology, with careful reading, you'll be able to grasp the principles described in this book. By starting with a solid foundation, you will eventually master the intricacies of the human body. Don't forget that you already have a head start: you own a human body.

While it may seem obvious that the human body is made of organs and the structures that connect them to each other, this book doesn't start there, at the macro, big-picture level. It starts at the micro level, inside your very cells, with a description of the processes at work that help your body's cells know what to do, when, and how. We'll look at the biochemical basis of human life—the organic and inorganic elements, compounds, and molecules that are necessary for the functioning of your body. We'll look at how cells communicate and replicate. That will help create the solid foundation you'll need to understand the rest of the material.

Once those building blocks are in place, we'll move on to a discussion of tissue, the foundation of all the organs in your body. Once this material is covered, we'll move on to the major systems in your body, including the skeletal, nervous, cardiovascular, and respiratory systems (among others).

For each system, common diseases and disorders are also described. Related material, such as how the senses integrate into the sensory system and the importance of nutrition to human health, are also covered.

Consider this book your one-stop information source for understanding the human body from cranium (head) to phalange (toe).

THE CHEMISTRY OF CELLS

Nuclear Reactions and Why We Love Them

Everything in the universe—from the largest of stars in the sky to the smallest grain of sand on the beach—is made up of matter. To be more precise, everything that takes up space and has mass is made up of matter. That small grain of sand may not seem like it takes up any space or has any real mass, but wait until it gets in your shoe. Then you'll know it as a physical object.

We might call matter "physical substance" (as opposed to that random thought you just had about what's for lunch; random thoughts have no physical essence).

The study of the structure of matter, its properties, and how different kinds of matter interact is called chemistry, and an understanding of basic chemistry is crucial to learning the principles of anatomy and physiology.

The interaction of atoms—which you probably know as the building blocks of matter—has created the human body and the world it inhabits. Atoms together form elements, a type of matter that cannot be broken down by chemical means (that's where the nuclear reaction comes in—elements can only be changed by nuclear means). Various elements combine together to create cells, which are the smallest structural units in the human body that perform a function. For example, your blood cells carry oxygen throughout your body. They have a distinct structure from cells that perform other functions, such as nerve cells or muscle cells.

Chemistry rules not only how these cells are structured but also how they perform their functions.

The Most Important Elements

Just as the human body doesn’t have a single “most important” organ, several elements are essential for the creation of life. These are among the most important elements of all living things on earth:

- hydrogen (which is denoted by its chemical symbol, H)
- carbon (C)
- nitrogen (N)
- oxygen (O)

Whether in the air we breathe, the food we eat, or the materials that make up the physical structures of the human body, without these elements humanity would not exist. What makes these elements so essential to the formation of life is their ability to interact with other elements and then organize them into important molecules (matter that is composed of more than one atom) or compounds (molecules composed of two or more different elements). They can do this because of their subatomic structure and particles.

Anatomy of a Word

molecule

A molecule is a piece of matter consisting of more than one atom. A molecule can be made up of atoms that are all the same element (such as a molecule of oxygen) or it can be made up of different atoms, meaning that a molecule can be a compound (such as a molecule of water, which is a combination of hydrogen atoms and oxygen atoms).

Subatomic Particles

All atoms are made up of three basic subatomic (i.e., anything smaller than an atom) particles:

- protons (which have a positive electrical charge)
- neutrons (which have no charge)
- electrons (which carry a negative electrical charge)

The number and organization of these particles dictates whether an atom will readily interact with any other atom—and also defines what type of atom it is. If an atom has only 1 proton, it must be a hydrogen atom.

Positively charged protons are found in the nucleus of the atom.

Where do atomic numbers come from?

The number of protons present in an atom is the atomic number for that element. For example, carbon has an atomic number of 6 and oxygen has an atomic number of 8, which means carbon has 6 protons and oxygen has 8 protons in the nucleus.

Another particle found in the nucleus of an atom is the neutron. While neutrons don’t contribute any charge to the atom, they do contribute to the mass of the atom. Therefore, the atomic mass of an atom is the number of protons *and* neutrons present in the atom. So while carbon has an atomic number of 6 (6 protons), it has an atomic mass of 12 (which means there are also 6 neutrons in the nucleus).

However, while the nucleus is populated, there is an unequal charge for the atom. As with most things in the universe, atoms seek balance. To obtain this balance, atoms have negatively charged particles that orbit around the nucleus. These are called electrons. It is the electrostatic attraction between the electrons and the protons that keeps the electrons spinning in orbit around the nucleus, much like the moon is held close to the earth by gravity. In fact, to find a natural balance, atoms will have the same number of protons as electrons, leaving the atom with an overall net neutral charge.

Electrons, however, are not restricted to a single location, such as the nucleus. They are found in orbitals (shells) around the nucleus. An atom can have many orbitals. In illustrations, these will often be drawn as concentric circles with the first being closest to the nucleus. The first orbital of any atom (that is, the orbital closest to the nucleus) can contain up to 2 electrons. After this orbital is filled, if the atom has more electrons, they will be packed into the next orbital, which can contain up to 8 electrons. Once the next orbital is filled (if there are more electrons), then they are packed into the next and so on. All orbitals after the first can contain up to 8 electrons.

Orbitals by the numbers

For carbon, with an atomic number of 6 (meaning 6 protons and thus 6 electrons), 2 of the electrons will be in the first orbital and the remaining 4 will be in the second (and outermost) orbital.

With this basic understanding of atoms and subatomic particles, you can better understand how atoms will combine together to form molecules and compounds.

The *real* building blocks of matter

The fact that subatomic particles exist is why scientists cry out in despair when people say atoms are the building blocks of matter. Particles such as protons are smaller than atoms, and for many years scientists thought *they* were the building blocks of matter … until someone discovered quarks, which have itty bitty charges and combine to form protons and neutrons. No one has actually seen a quark, but experiments show they must exist. Thus it is quarks that are actually the building blocks of matter (and will continue to be until someone finds something smaller).

Periodic Table of Elements

In order to show the relationship of the various elements, scientists have arranged them into the periodic table of elements, which you probably remember from high-school chemistry class. The table of the elements begins with the element that has an atomic weight of 1 (hydrogen) and goes to—well, that depends on the table you're looking at. There are 114 confirmed elements and several others are suspected to exist, such as 118 (ununoctium, a synthetic element no one knows much about, sort of like that weird neighbor down the street). Ninety-eight elements occur in nature; the others are only found in labs (where they are synthesized).

Each entry in the table includes the element's atomic number and its chemical symbol. Some tables may also show the atomic mass. Color coding is often used to indicate groups of elements that share similar qualities.

CHEMICAL BONDS

How Atoms Stick Together

Atoms sometimes create connections (bonds) with other atoms, allowing them to form relationships we call molecules or compounds. Sometimes these bonds are long-lasting, and other times they are shorter-lived than that thing you had with that drummer back in high school. Bonds between atoms are generally created by the attraction of opposite charges. For that reason, if an atom has an outer shell (orbital) that is already filled with electrons, it is unlikely to form molecules or compounds with other atoms/elements.

However, if the atom has room in its life (outermost orbital), it is more receptive to a bond. A bond can be accomplished by the atom either giving or receiving electrons from other atoms, or by sharing electrons with other atoms.

Ionic Bond

An ionic bond is when 2 atoms form molecules by giving up or taking electrons from others to complete their outermost orbitals. The classic example is the compound salt (sodium chloride, NaCl). Na (sodium) has a single electron in the outermost (third) orbital. That is one lonely electron. To fill the outermost orbital, sodium could recruit 7 more electrons from other atoms, but that would be a lot of work and impractical and is totally against the law in several states. Therefore, Na gives up the single electron and leaves the complete second orbital filled with 8 electrons, a very stable arrangement. However, now this atom has 10 electrons and 11 protons. This imbalance between protons and electrons yields an ion. In this case, the sodium ion with 10 electrons has an overall positive charge.

On the other hand, chlorine (Cl) has the dilemma of needing a single electron to complete its outermost shell. With an atomic number of 17, there are 7 electrons in the third orbital of chlorine and there is room for 8, making it a natural partner for sodium (and it didn’t even have to join an online dating service). Sodium gives up its electron to chlorine, which then uses the electron to complete its shell. Since it now has 1 more electron than proton, it has become a chloride ion with an overall negative charge.

This is where the bond happens. The positive charge of the Na^+ ion is attracted to the negative charge of the Cl^- ion, and the two will form a moderately strong chemical bond to create NaCl, or salt.

Anatomy of a Word

ion

An ion is a charged atom that has an unequal number of electrons and protons. An ion can be positively or negatively charged depending on whether it has fewer electrons than protons (positively charged) or more electrons than protons (negatively charged).

Hydrogen Bond

Hydrogen bonds are formed when atoms share electrons unequally in compounds. Water is the classical example of this type of bonding. Hydrogen has an atomic number of 1, so its shell is half full. Oxygen, with an atomic number of 8, lacks 2 electrons from filling its outermost shell. Thus, oxygen will share an electron with 2 hydrogen atoms, which will complete the outer shells of all three members of this compound, creating H_2O, or water. (The subscript 2 on the chemical abbreviation for hydrogen indicates that there are 2 atoms of hydrogen in the compound.)

However, with more protons in the nucleus of oxygen, the shared electrons will spend more time around that nucleus than around either hydrogen nucleus. This imbalance will create a slight negative charge on the oxygen side and slight positive charge on the hydrogen arms. This polarization of charge will cause water molecules to be attracted to each other. In this way, water will adhere to itself. This type of bond is the weakest of the three chemical bonds. It is also the type of bond that holds two strands of DNA (genetic code) together in chromosomes, which are the instruction books that tell an organism how to be what it is supposed to be.

Covalent Bond

The strongest of the chemical bonds, the covalent bond is when a molecule or compound shares electrons equally. Carbon, the foundation atom of organic molecules, is well adept at this type of bond formation since its atomic number of 6 means it needs 4 electrons to fill its outermost shell. Because of this, carbon can form 4 single covalent bonds with other atoms.

What is an example of a compound with a covalent bond?

A great example of a compound with a covalent bond is the basic structure of an amino acid. Amino acids are organic compounds that combine to form proteins (which are necessary to create tissue, organs, hair, skin—you name it, it needs an amino acid to help build it). The carbon is the central atom in an amino acid, onto which four components attach, each using one of the available bonds: a carbon group, a nitrogen group (called an amino group), a single hydrogen atom, and a fourth group, the structure of which changes from amino acid to amino acid. This variable side group (sometimes referred to as a side chain) is called an R group.

pH: Ions, Acids, and Bases

A pH measurement tells you whether a substance is an acid or base. An *acid* has a low pH and will release hydrogen ions (under certain circumstances) and a *base* has a high pH and will release hydroxide ions (under certain circumstances). Vinegar is an example of an acid. Baking soda is an example of a base. Acids and bases react if combined. If you mixed vinegar and baking soda together, you would produce a gas (which creates those bubbles and that hissing noise).

A mixture's pH is essentially a measure of its hydrogen ions. If a substance has molecules or compounds that will yield a large number of H^+, the substance, based on a mathematical logarithm, will result in a lower pH number and be considered an acid or acidic solution ($pH < 7.0$). Conversely, with lower H^+ concentrations, the pH will be above 7 and considered a base (also called a basic solution or alkaline). This standard is set internationally using known materials, such as pure water (pH of 7.0).