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In the coming years, you are likely to hear more and more about genes because they are important players in children with autism spectrum disorders (ASDs). You will also hear a lot about “epigenetics,” which is how the environment inside and outside of your child’s body impacts the way his or her genes function. How well a child’s genes are functioning is an important determinant of how well their nervous and immune systems perform. Those two systems, in turn, play a role in where your child sits on the autism spectrum. Differences in genetics and epigenetics may be keys to understanding part of the diverse range of severity in ASD.

This article breaks genes down into their component parts so that when someone tosses out the term “nucleotide,” for example, you won’t get confused and lose track of what they are saying. After reading this article, you will not only know what a nucleotide is, you will also be able to understand the health implications of epigenetic changes in genes. It is not critical that you remember all of the parts of a gene. However, by sharing these terms with you, we invite you to become more familiar with the molecules that came together to make a gene. Gaining this familiarity is like having been exposed to the unique punctuation used in a foreign language. While you may not need to recall all of the details when having a conversation in that language, it helps to have that knowledge as a reference base.

At the outset, it is helpful to understand that there are two critical concepts related to genes. First, there are inherited changes in genes that predispose you and your offspring to particular health conditions. Your family history of genetic changes is recorded in your own genes. You pass these changes on to your children in your own version of your family history book. Second, once you have inherited these genes you have them for your entire lifetime. You cannot change the structural genes you have inherited. However, how they are turned on or off can change; this is called epigenetics. This genetic on/off switch is affected by nutrition. Moreover, whether the switch is on or off can itself be passed down from generation to generation. In short, an understanding of what a gene is and how it can be turned on or off can provide insights into the effects of genes on your future as well as your child’s future. It can also help to explain the health conditions of your parents, grandparents, and great-grandparents as well as the health of potential grandchildren.

**WHAT IS A GENE?**

One of the hallmarks of life is its ability to reproduce. A gene is a molecular unit of heredity in your body. It is a length of DNA or RNA that holds the information to build and maintain your cells and pass on your genetic traits.

The information that makes each of us unique as individuals is preserved in genes. When your genes are passed on to your children, the uniqueness of you is also passed on. Your kids look, sound, and act something like you and something like your mate. That doesn’t happen by accident.

The information that makes one species different from another but like the members of its own species is also passed on through genes.

You will also hear a lot about “epigenetics,” which is how the environment inside and outside of your child’s body impacts the way his or her genes function.
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DNA

All life on earth uses nucleic acids for storage of genetic information, primarily in the form of deoxyribonucleic acid or DNA and in some cases in a related form called RNA. DNA is remarkably well suited for this task. Because it is very chemically stable, it does not alter its form readily, so the vast amount of information that it contains is preserved.

DNA is able to encode vast amounts of information using four chemical bases (or building blocks) that are designated by the letters A, T, C, and G (see The bases). The bases are called nitrogenous bases because they contain nitrogen. In DNA, the four bases are strung together like the pearls on a necklace, with each base added one at a time like another pearl on the strand. Unlike a pearl necklace, though, DNA is double-stranded and helical (that is, twisted). It is like a ladder that has been twisted into a spiral (see Figure 1).

Because of its role as the repository of genetic information, DNA can arguably be considered the most important biomolecule in living systems. However, DNA is only a part of the core architecture of life. Another type of molecule that is also important is RNA, which is also a nucleic acid.

RNA

Ribonucleic acid, or RNA, is the second important category of molecule in the architecture of life. As Figure 2 shows, RNA is single-stranded and helical. RNA is made up of four bases, three out of four of which are the same as those used to make DNA. As with DNA, the bases in RNA are in a specific order. Figure 2 shows the bases of both DNA and RNA.

The constituent elements of RNA include carbon, hydrogen, oxygen, and nitrogen, which come together in very specific conformations or structural arrangements. Carbon, hydrogen, and oxygen are the chemical elements present in all molecules that make up living organisms, including human beings. These elements can combine in an incredible number of conformations. Carbon, hydrogen, and oxygen form molecules that react with each other in all the sophisticated ways that make up life forms on this planet. Organic chemistry is the name of the discipline that studies the chemistry of living organisms.

THE BASES

Nucleotides, also known as bases, are the core chemical structures making up DNA (see Nucleotide units). Two categories of bases are present in nucleic acids, purines and pyrimidines. The major purines are adenine (A) and guanine (G), found in both DNA and RNA. The first major pyrimidine is cytosine (C), which is also present in both DNA and RNA. Thymine (T) is generally only in DNA, and uracil (U) is found only in RNA.

The bases A, T, C, G, and U are essentially building blocks that line up in a certain order in a strand of DNA or RNA. The sequence of the five bases determines what information a DNA or RNA molecule conveys. When a single base in that order changes (for example, if the body places a T where a G would normally be found), that is what is called a SNP or single nucleotide...
polymorphism (also called a single base change). Tests can be run that look at these single changes in nucleotides for a large number of different genes. Sometimes a SNP has no impact on the function of a particular gene. Other times a SNP can impair the gene’s function.

PENTOSE SUGARS
Besides the bases, another important part of DNA and RNA is a sugar molecule to which the base is attached. The carbon atoms in a sugar molecule form a ring, and the number of carbon atoms in that ring categorizes the molecule. Each carbon is numbered. A pentose sugar is a sugar molecule with five carbons. As shown in Figure 3, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are named for the two five-carbon pentose sugars, deoxyribose and ribose, respectively, that attach to the base portion of the molecule. The sole difference between deoxyribose and ribose is that, in the former, the number 2 carbon atom has been divested of its oxygen. This is apparent in the official name of deoxyribose, which is more precisely called 2-deoxyribose.

Although these chemical terms may appear to have no practical relevance, you have likely heard of ribose before. It is often included in supplements to help with energy, just as nucleotides are often used in supplements for nutritional support. By now you can start to understand why it can make sense to supplement some of these nutrients, which are components of your DNA and RNA.

NUCLEOTIDE UNITS
The capacity of DNA and RNA to maintain and transmit archived information efficiently arises directly from their chemical structure. As noted, nucleotides are the molecules that form the basic structural units of DNA and RNA. A nucleotide unit has three components:

- a base (A, C, G, T, or U)
- a pentose sugar (5-carbon sugar)
- a phosphate ester (a connecting group that contains phosphate).

As shown in Figure 4, which illustrates the structure of a DNA molecule, the molecule’s bases are oriented so that the pentose sugars are on the outside of the structure. In addition, a phosphate bond forms between the 3-carbon of one nucleotide and the 5-carbon of the adjacent one. The pentose sugar with its phosphate bond is the component that gives DNA and RNA their stability as chemical structures.

As a result of the shape each nucleotide takes and the orientation of the nucleotide units to each other, the structure of DNA is stacked. Both DNA and RNA consist of repeating nucleotide units that layer one on top of another. This produces linear molecules with a torque that makes both nucleic acids helical.

TRANSCRIPTION
As we have now seen, DNA stores all of the information that determines and controls the cellular processes in your body. However, it does not express this information directly. Instead, the DNA molecule provides a template from which RNA is formed. The RNA formed from the DNA contains the same sequence of
information in the DNA in a slightly different format. The RNA then transmits the information encoded in DNA to the rest of your body. This process is called transcription (see Figure 5).

DNA contains all of the genetic information that is identical in each cell, whereas RNA contains only that portion of the DNA that is actually used within different cells to meet their specific needs. There are several types of RNA. Messenger RNA is the form of RNA that is copied from the DNA sequence and used to make protein from the information encoded in the DNA. Ribosomal RNA makes up structures called ribosomes where the messenger RNA is turned into protein. The ribosomes can be envisioned as miniature production factories that take the information in the messenger RNA sequence and turn it into protein molecules. Finally, transfer RNA works with the ribosomes to add amino acids (recall that amino acids are what make up proteins) based on the messenger RNA sequence. In a sense, transfer RNA is the convergence point where nucleic acids (DNA and RNA) and amino acids (proteins) meet.

THE HUMAN CELL

Figure 6 depicts a human cell. The cell membrane is the outer layer that separates a cell from all the other cells and fluid in your body. The mitochondria (the energy-producing sites in your cells) are the place where the nutrients in the food you eat are converted into the energy that you use to do everything you do, including run the automatic processes of your body. The nucleus of the cell is in its central location, and the nucleolus is central in the nucleus.

Figure 7 depicts a cell nucleus in greater detail. The nucleus is the place where your DNA is located. When your cell is not dividing, chromatin containing DNA is shapeless and dispersed throughout the nucleus. Just prior to cell division, your chromatin becomes organized into structures called chromosomes. Put another way, the nucleus and the nucleolus contain all the building materials for your chromosomes, on which the genes containing your DNA are located.
The DNA on your chromosomes has enormous information-storing capacity. For example, a human cell contains information for the synthesis of 50,000 - 100,000 proteins. This information is stored in the cell nucleus, a structure roughly 0.00001 meter in diameter.

**RIBOSOMES AND PROTEIN SYNTHESIS**

Figure 8 provides another view of the cell nucleus that includes the ribosomes, which are an important structure inside the cells. Ribosomes are the cell's protein-synthesizing machinery. Proteins make up all of the enzymes in your body and are essential to your ability to function. Along with DNA and RNA, proteins are considered the third important class of molecule in the architecture of life.

As already mentioned, ribosomes are comprised of a special type of RNA. Ribosomes cover a structure called the endoplasmic reticulum (ER), which is located in the fluid portion of cells (otherwise known as the cytoplasm). The function of the endoplasmic reticulum is to store and have ready the necessary materials for protein building.

Histones are spherical proteins around which DNA can coil (Figure 9). The DNA is wound around the histone in much the same way that you would wind yarn in a ball for knitting. When DNA wraps around histones, it results in a tenfold reduction in the DNA's apparent length. Thus, histones are an efficient way for the cell to conserve space in order to store DNA.

Histones have an unusually high content of the amino acids lysine and arginine, which makes them slightly charged and causes them to interact with the slightly charged phosphate backbone of DNA. This interaction produces uncharged structures that are very stable.

**METHYLATION AND EPIGENETIC MODIFICATION**

As we have now seen, DNA is a very stable structure that coils around other structures (histones) that make it even more stable. However, modification of the activity of DNA can happen. This occurs when a source external to the DNA makes no changes to the actual nucleotide bases of the DNA strand but alters the DNA's function. This is called epigenetic modification. The predominant form of epigenetic modification is methylation (see Figure 10).

Methylation is the attachment of a methyl group to a strand of DNA. A methyl group is a small chemical structure that consists of three hydrogen atoms and one carbon atom (see Figure 11). (A methyl group is not that different from a water molecule, another small but mighty molecule.) Methyl groups are the global regulatory agents of the body's molecular machinery.

Modification of the activity of DNA can happen. This occurs when a source external to the DNA makes no changes to the actual nucleotide bases of the DNA strand but alters the DNA's function. This is called epigenetic modification. The predominant form of epigenetic modification is methylation.
Methylation is central to a number of important processes in the body. For example, methylation plays a key role in your immune system’s ability to recognize agents to which it needs to respond.

**Table 1. Importance of methylation**

- Cancer prevention
- Digestive issues
- DNA silencing
- Energy production
- Inflammation
- Membrane fluidity
- Metal detoxification
- Myelination
- Neurotransmitter balance
- Protein activity
- Repairing and building DNA and RNA
- Responding to and fighting infection

Methylation is central to a number of important processes in the body. For example, methylation plays a key role in your immune system’s ability to recognize agents to which it needs to respond. Whenever there is an assault on your immune system, your body must synthesize new T cells (white blood cells). If you lack methyl groups, you will not be able to make T cells. In this situation, your body may instead produce more B cells, which can result in autoimmune disorders, hyperimmunity, and poor immune function.

As another example, DNA methylation is necessary to prevent the expression of viral genes that have been inserted into your body’s DNA. Loss of methylation function can therefore...
From the standpoint of DNA and RNA, it is critical to have proper methylation cycle function. As discussed, this pathway helps to generate the building blocks (the purines and pyrimidines) for both DNA and RNA synthesis. In addition, the methyl groups generated by this pathway function to turn DNA on and off, serving as the traffic lights in epigenetics. Therefore, restoring a child’s methylation processes can bring about dramatic improvements. It is important to get your child’s methyl group-producing pathways functioning efficiently.

result in increased susceptibility to viral illness. Methylation is also needed for such vital areas as supporting new cell growth, keeping cancer cells from proliferating, myelinating nerves, waking up from anesthesia, preventing neural tube defects, and controlling levels of the important neurotransmitters dopamine, norepinephrine, and serotonin.

Finally, methylation turns DNA off or on. Without adequate methylation, you cannot override the errors that happen in your DNA. In addition, at any given time 80% of the DNA in your body should not be expressing. It is a major problem if your DNA cannot be silenced.

**CONSEQUENCES OF POOR METHYLATION**

For an organism to live, it must create new cells as fast as other cells die. This requires that the body make millions of cells every minute. Your body relies on DNA and RNA synthesis to make these new cells. The building blocks for DNA and RNA synthesis are produced as a result of the proper function of methyl group-producing biochemical pathways. When these pathways do not function properly, a reduced capacity for DNA and RNA synthesis results, meaning that your body cannot make all the new cells it may need. Just as the DNA sequence itself is inherited, the ability of the biochemical pathways that produce methyl groups is also inherited. Genetic differences from normal may impact the way the enzymes in your methyl group-producing biochemical pathways function. This can result in reduced methyl group production and reduced capacity for synthesizing DNA and RNA.

A wide range of conditions can result from insufficient methyl group production (Table 2). Reduced capacity for DNA and RNA synthesis is a particularly critical issue for cells that already have difficulty meeting their needs for these important nucleic acids. Fast-growing cells such as bone marrow cells, white blood cells, red blood cells, and some brain cells all need to be supplied with DNA and RNA. They may be compromised without an adequate source of supply. With poor methyl group production, the intestinal mucosal cells also cannot make some of the DNA and RNA bases that they need. In addition, stress and cell repair after injury increase the body’s need for DNA and RNA. If your methyl group-producing capacities are not optimal, your body will not function optimally, especially under stress.

Factors other than genetics can decrease methyl group production in your body. These include increases in certain inflammatory mediators from your immune system, such as IL-6 or TNF-alpha, which can lead to decreases in methylation. Chronic inflammation, therefore, can exacerbate an existing genetic condition that in itself leads to poor methyl group production. Intermediates of the methylation pathways also decrease with age, bringing a decline in methyl group production.

**Table 2. Consequences of insufficient methylation**

<table>
<thead>
<tr>
<th>Aging</th>
<th>Huntington’s disease</th>
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<tbody>
<tr>
<td>Allergic reactions</td>
<td>Language and cognition impairment</td>
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<tr>
<td>Alzheimer’s disease</td>
<td>Leaky gut syndrome</td>
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<tr>
<td>Anxiety</td>
<td>Metal toxicity</td>
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<tr>
<td>Arthritis</td>
<td>Miscarriage</td>
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<tr>
<td>Autism</td>
<td>Mitochondrial disease</td>
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<tr>
<td>Bipolar disorder</td>
<td>Neural tube defects</td>
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<tr>
<td>Bowel dysfunction</td>
<td>Pneumonia</td>
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<tr>
<td>Cancer</td>
<td>Psoriasis</td>
</tr>
<tr>
<td>Chronic bacterial infections</td>
<td>Renal failure</td>
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<td>Chronic fatigue syndrome</td>
<td>Rett syndrome</td>
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<tr>
<td>Cytoskeletal breakdown</td>
<td>Schizophrenia</td>
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<tr>
<td>Diabetes</td>
<td>Seizures</td>
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<tr>
<td>Down syndrome</td>
<td>Sleep disorders</td>
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<tr>
<td>Fibromyalgia</td>
<td>Systemic lupus erythematosus (SLE)</td>
</tr>
<tr>
<td>Heart disease</td>
<td>Thyroid dysfunction</td>
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<tr>
<td>Herpes</td>
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**IMPROVING METHYLATION**

From the standpoint of DNA and RNA, it is critical to have proper methylation cycle function. As discussed, this pathway helps to generate the building blocks (the purines and pyrimidines) for both DNA and RNA synthesis. In addition, the methyl groups generated by this pathway function to turn DNA on and off, serving as the traffic lights in epigenetics. Therefore, restoring a child’s methylation processes can bring about dramatic improvements. It is important to get your child’s methyl group-producing pathways functioning efficiently. To do so, you may first need to assess the genetic interferences with methyl group production in your child’s body (by running SNP tests) so that you can bypass them with specific nutritional supplementation. It is both possible and important to look at SNPs that occur in the particular genes that are involved in methylation because methylation plays such a critical role in turning genes on and off and because methyl groups are the
traffic lights of biochemical pathways. Again, this is also the pathway that generates A, C, G, T, and U for DNA and RNA synthesis. As you nutritionally support methyl group production, you may need to address other systemic conditions. Addressing complex conditions such as ASDs can be like trying to follow Ariadne’s thread out of the labyrinth. It is important to remember that each intervention lays the foundation for the next. If you try to jump ahead and intervene on a given symptom prematurely or attempt an intervention that is inappropriate for a child’s nutritional status or genetics, you may waste time and money. Worse, you may end up discouraged or you may give up and never see your child’s function become all that it was meant to be.

Consider the fact that methyl groups also play a role in detoxification in the body. Arsenic, for instance, requires methyl groups for its detoxification. Although we all realize that the excretion of toxins is desirable, their excretion can cause non-ideal detoxification symptoms. Therefore, making sure that basic nutrients are in place before restoring methylation cycle function makes sense. For example, if your child has been eating a nutrient-depleted diet or has a disturbed gastrointestinal tract function, then it is certain that he or she does not have all the nutrients needed to restore and maintain balanced body function. Under these conditions, any attempt to nutritionally induce methyl group production could provoke symptoms if excretion of toxins begins in a nutritionally depleted body.

Ideally, the best approach is to work with a trained healthcare provider to restore and support basic organ function through nutrition. It is important to support the gastrointestinal tract, look at the use of probiotics, and implement a proper diet that avoids gluten, casein, and glutamate. Your provider may also recommend a general multivitamin that provides basic minerals while being low in iron and copper. At the point where these measures are in place, you can look at specific methylation cycle support based on having run SNP panels. If you do not have knowledge of your child’s specific mutations in this pathway, then at the very least it may be possible to consider more generic support for the methylation cycle to help its function.

CONCLUSION
The ability of the body to synthesize DNA is critical for new cell growth and to repair damaged cells in the body. The need to synthesize RNA is paramount to making proteins in the body. Methyl groups are needed to turn your DNA on and off, to regulate histones, to silence viruses, and to alter protein function. Methyl groups help to regulate your immune system. Perhaps most significant in terms of this article’s focus on demystifying genes is that methyl groups, through their role in epigenetics, are the only tool you have to modify the DNA that you have inherited. Epigenetic modification is your key to changing your inherited destiny. The epigenetic changes that you make to your DNA can then be passed on to your children and your children’s children.

Ultimately, knowing which genes have polymorphisms that can affect your child’s production of methyl groups gives you the opportunity to use nutrition to restore optimal methyl group production. Having a basic understanding of the language and function of DNA is an important tool. Remember, moreover, that working to restore function is not just about today. DNA is inherited, generation to generation, as is optimal methyl group production. Changing nutrition today can help restore proper biochemical pathway regulation by methyl groups both now and for the future generations.