**The Genetic Code is Carried by a Messenger**

As we have learned, DNA contains the instructions for making all of the proteins needed by an organism. The sections coding for individual proteins are referred to as genes. But how does the cell actually use the instructions in genes to build proteins? As a class, we have already figured out the three-letter code, but there’s more to it. It took scientists years to understand this process.

**I**

It had long been suspected that another molecule called RNA was associated with protein synthesis in the cell because cells making large amounts of protein always contained large amounts of RNA as well. Some RNA is found in the cell nucleus with DNA but most RNA is found in the cytoplasm of the cell where the proteins are actually assembled from the amino acids the DNA codes for. By using techniques that split cells into their parts, biochemists found that the RNA in the cytoplasm was concentrated mainly in tiny granules called ribosomes. Later studies using amino acids tagged with radioactive isotopes showed that new strands of protein were in fact formed on the ribosomes. If proteins were formed on the ribosomes, then somehow the ribosomes must have been given the instructions for assembling the amino acids in the correct order. Scientists believed even then that these instructions were contained in the DNA in the nucleus. So how did they get to the ribosomes? One thing was certain – they could not come from the DNA directly, since it was known that DNA never left the nucleus.

**II**

When biochemists further investigated protein synthesis they learned that DNA does not form proteins directly. Instead, DNA works **through** RNA according to the scheme:

DNA 🡪 RNA 🡪 protein

*(This means: DNA makes RNA and RNA makes protein.)*

**III**

They found that DNA acts as the master blueprint and is always kept securely locked in a safe place, the nucleus. From this master blueprint copies are made of individual protein recipes and carried to the ribosomes. These copies are in the form of special RNA molecules called **messenger RNA (mRNA)**. The genetic message contained in the DNA molecule is transcribed on the mRNA molecule and the mRNA in turn carries it out of the nucleus and to the ribosomes.

Messenger RNA strands are synthesized alongside a DNA strand in much the same way that a new strand of DNA is made in DNA replication. . This copying must be done very exactly. All messenger RNA molecules copied from one gene on a DNA strand must be alike. This ensures that all of the protein molecules made from that gene will be identical. In code language, this means that the nucleotides in the new strand of messenger

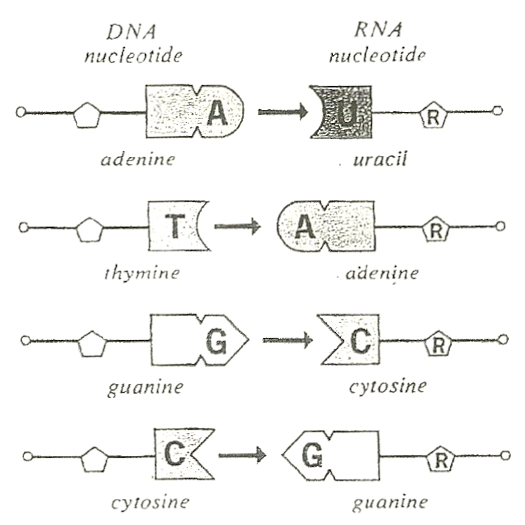
RNA must match the nucleotides of the DNA perfectly. We have since learned that the RNA alphabet of 4 nucleotides is very similar to that of DNA, the only differences being that they contain a slightly different sugar, ribose, instead of the sugar found in the DNA backbone, deoxyribose. These sugars give RNA and DNA their respective names (**r**ibonucleic acid = **R**NA, **d**eoxyribonucleic acid = **D**NA).

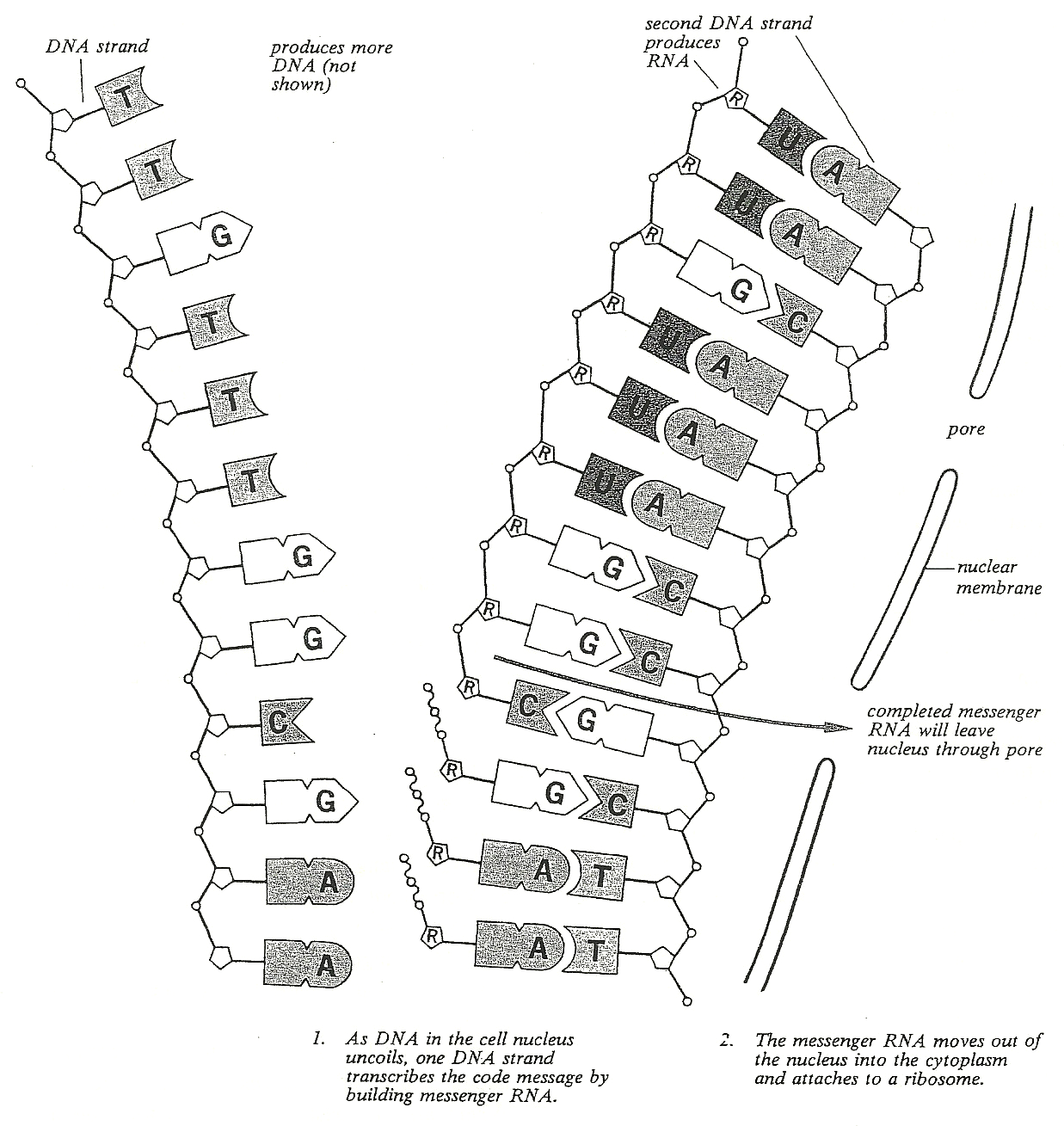
**IV**

The other difference is that the base T (thymine) of DNA is replaced by U (uracil) in RNA. Thymine and uracil differ slightly in their chemical make-up but their shapes are almost identical. Recall that in DNA cytosine always pairs with guanine, and adenine always pairs with thymine. This same pairing must be followed when a DNA strand makes a strand of RNA except that now uracil pairs with adenine instead of thymine (see figure on back of page). Thus, whenever an adenine nucleotide is located on the DNA strand, a uracil nucleotide will be located on the RNA strand.

**IV (cont.)**

**Pairing between DNA bases and RNA bases**

Making the messenger involves a number of steps that we are not going to memorize in this class, but note how the message is transcribed into the mRNA using the same rules about base-pairing that we already figured out. Assembling the messenger RNA also relies on the double-stranded DNA “unzipping”, just as we saw in the process for DNA replication.



1. *The messenger RNA is translated into a protein in the cytoplasm at the ribosome. (Not shown.)*