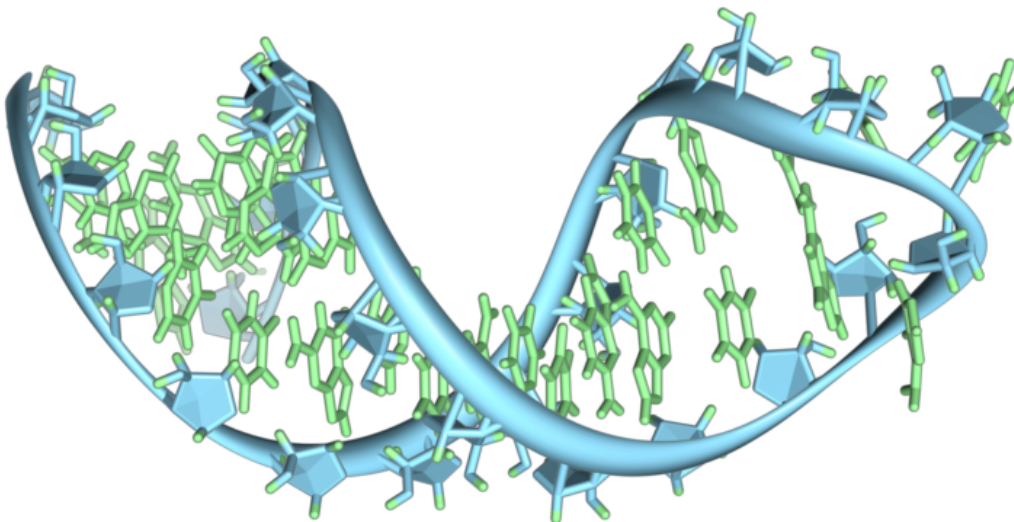


## RNA: Basic Knowledge

[See online here](#)

**Ribonucleic acid (RNA) is a polymeric molecule, which is implicated in different biological roles such as coding, decoding, expression of genes and regulation. Biological reactions within cells are catalyzed by some RNA molecules, which control gene expression and communicate responses to cellular signals. The structure of RNA is similar to that of DNA, but there are some differences between them.**



## Definition and Background

The three major molecules that are essential for all known forms of life are **RNA**, **DNA** and **proteins**. DNA and RNA have a similar chemical structure with two main differences:

- The sugar **ribose** is found in RNA; however, DNA contains the sugar **deoxyribose**, which is slightly different than ribose, in that it **lacks an oxygen atom**.
- DNA has the nucleobase **thymine**; whereas, RNA contains **uracil**. Thymine and uracil have similar base-pairing properties.

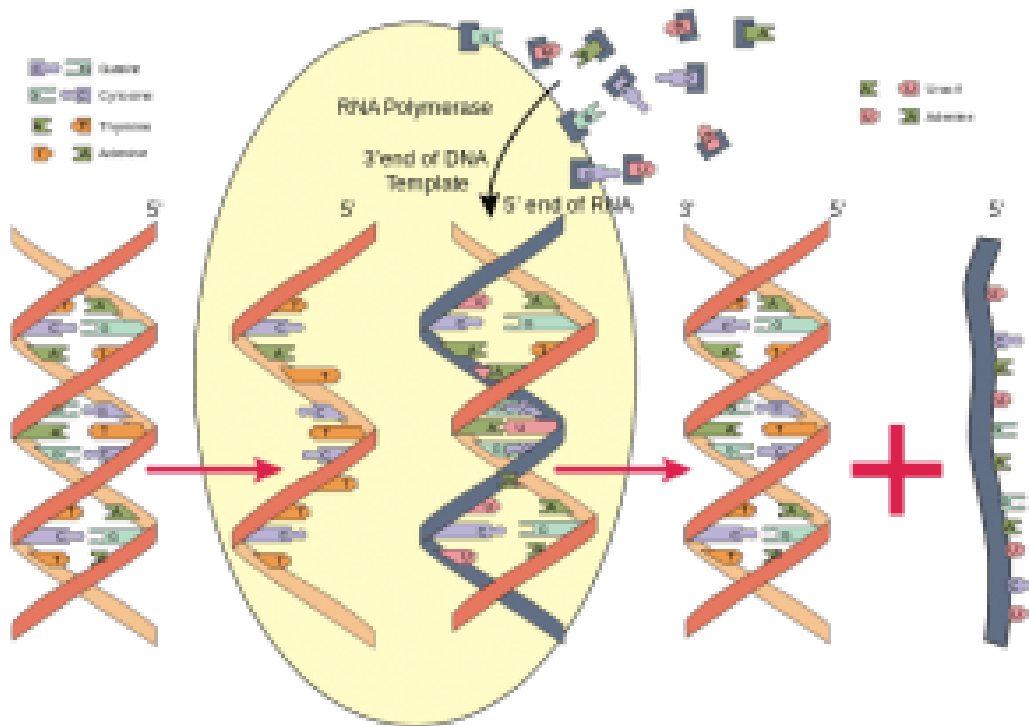
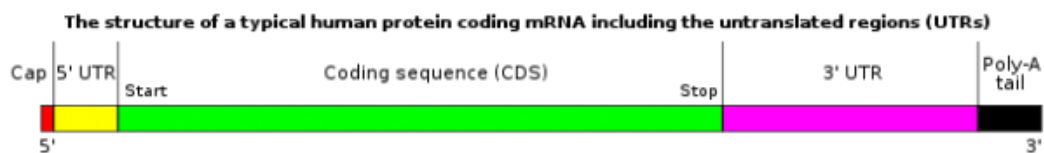


Image: "Formation of an RNA strand from a DNA template" by Fred the Oyster. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

## Types of RNA

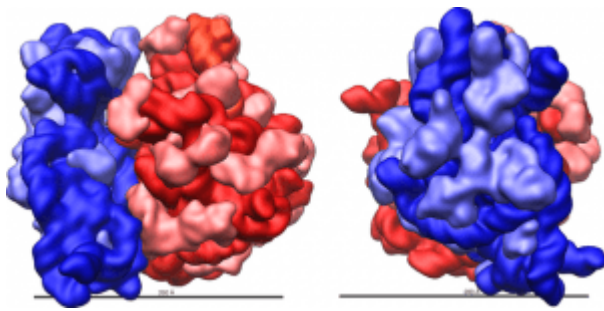
### Messenger RNA (mRNA)

**Messenger RNA (mRNA)** is transcribed from a **DNA template**. Coding information to the sites of the ribosomes is carried through mRNA. In mRNA, the genetic information is encoded in the sequence of nucleotides, which is arranged into **codons** that consist of three bases each. A specific amino acid is encoded by each one of the codons, except the stop codons, which are responsible for terminating the process of protein synthesis. Two other types of RNA are required in this process, which are **ribosomal RNA (rRNA)** and **transfer RNA (tRNA)**.



The structure of a mature eukaryotic mRNA. A fully processed mRNA includes a 5' cap, 5' UTR, coding region, 3' UTR and poly(A) tail.

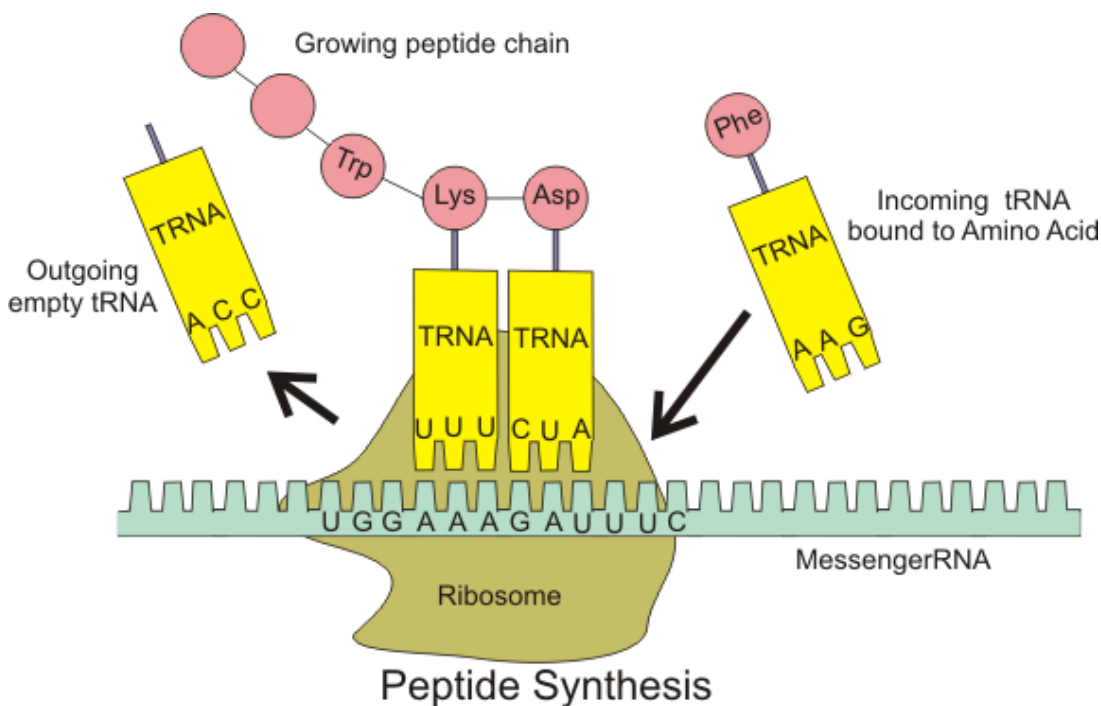
### Ribosomal RNA (rRNA)



**Image:** "Structure and shape of the *E. coli* 70S ribosome. The large 50S ribosomal subunit (red) and small 30S ribosomal subunit (blue) are shown with a 200 Ångstrom (20 nm) scale bar. For the 50S subunit, the 23S (dark red) and 5S (orange red) rRNAs and the ribosomal proteins (pink) are shown. For the 30S subunit, the 16S rRNA (dark blue) and the ribosomal proteins (light blue) are shown." by Vossman. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

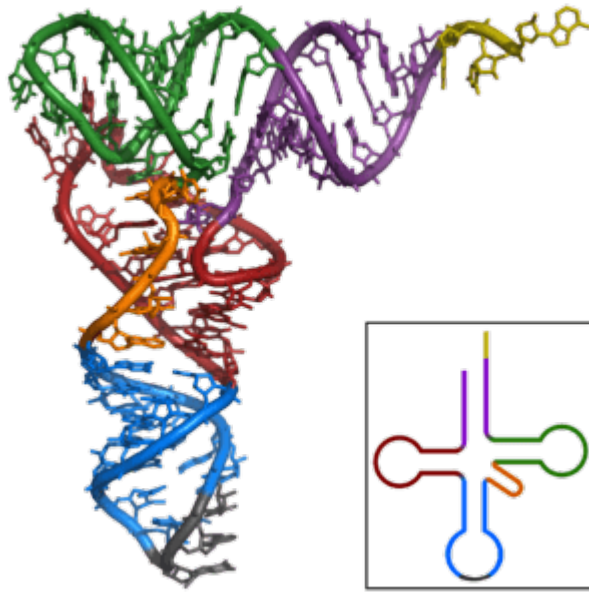
**Ribosomal RNA (rRNA)** is the RNA component of the ribosome. The mechanism for decoding mRNA into [amino acids](#) is provided by ribosomal RNA, it also **interacts with tRNAs** during translation and provides peptidyl transferase activity. The necessary amino acids that correspond to the appropriate mRNA codon are brought by the tRNAs.

## Transfer RNA (tRNA)



**Image:** "The Interaction of tRNA and mRNA in Protein Synthesis." by Boumphreyfr. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

**Transfer RNA (tRNA)** functions in the **transfer of specific active amino acids**, during translation, to a growing polypeptide chain at the ribosomal site of protein synthesis. Transfer RNA contains the **anticodon**, which is a three base region and can base pair to the corresponding three base codon regions on mRNA. Only one type of amino acid can be attached to each type of tRNA molecule; however, the same amino acid may be carried by tRNA molecules bearing different anticodons because multiple codons that specify the same amino acid are found in the genetic code.



**Image:** "Tertiary structure of tRNA. CCA tail in yellow, Acceptor stem in purple, Variable loop in orange, D arm in red, Anticodon arm in blue with Anticodon in black and T arm in green." by Yikrazuul. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

## Other Types of RNA

### Small interfering RNA (siRNA)

Small interfering RNA (siRNA) is also known as **short interfering RNA**, which is a class of double-stranded RNA molecule. siRNA is involved in the **RNA interference pathway**. It controls the stability of the mRNA by interfering with the expression of specific genes.

### Small nuclear RNA (snRNA)

snRNA molecules are either **transcribed by RNA polymerase III** along with all nuclear tRNAs and the 5S rRNA, or by **RNA polymerase II** along with mRNA. They are involved in the maintenance of the **telomeres** and **splicing** by removal of introns from pre-mRNA.

### Heterogeneous nuclear RNA (hnRNA)

hnRNA is considered a single immature strand of mRNA. The two terms **pre-mRNA** and **hnRNA** are almost identical, and they are used interchangeably.

## RNA Nucleobases

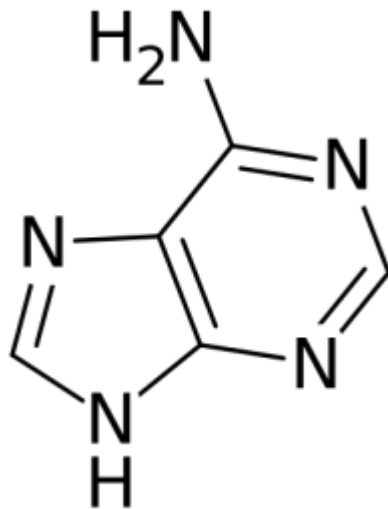


Image: "Chemical Structure of Adenine in Vector Format" by Pepemonbu. License: [CC BY-SA 3.0](#)

## Adenine (A)

Adenine is a **purine derivative** nucleobase with different roles in biochemistry, including **cellular respiration**, in the form of **ATP**, **NAD** and **FAD**. It also plays a role as a chemical component of DNA and RNA in protein synthesis. Adenine has a shape that is complementary to either uracil in RNA or thymine in DNA.

## Cytosine (C)

Cytosine is found in both **DNA** and **RNA**, which is a **pyrimidine derivative**. It has a heterocyclic aromatic ring and two substituents attached which are a **keto group** at position 2, and an **amine group** at position 4). **Cytidine** is the nucleoside of cytosine.

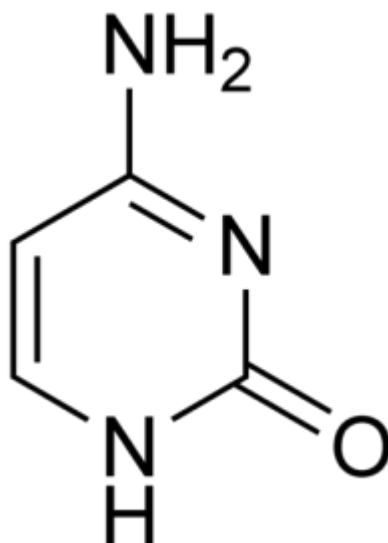
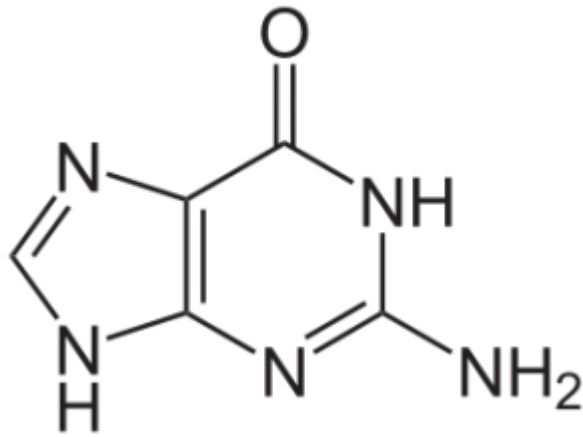


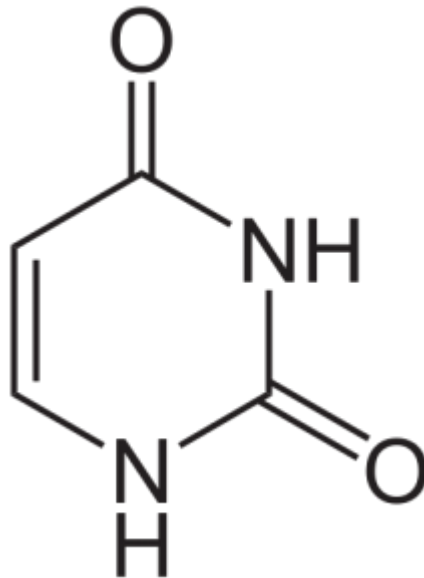
Image: "Chemical Structure of Cytosine." by Cacycle. License: [CC BY-SA 3.0](#)



Guanine

## Guanine (G)

Guanine is found in both RNA and DNA. It is a derivative of **purine** and consists of a **fused pyrimidine-imidazole** ring system, along with conjugated double bonds. Guanine is paired with cytosine in DNA.



Uracil

## Uracil (U)

Uracil is a **demethylated form of thymine**, and it binds to adenine, via **two hydrogen bonds, in RNA**. In DNA, **thymine** nucleobases replace uracil.

## Differences between DNA and RNA

Both DNA and RNA are **very similar** in their structures; however, there are five main differences between them both:

	RNA	DNA

<b>Nucleobases</b>	Adenine, Guanine, Cytosine, <b>Uracil</b>	Adenine, Guanine, Cytosine, <b>Thymine</b>
<b>Structure</b>	Usually exists as <b>single stranded</b>	Always a <b>double helix</b>
<b>Sugar</b>	<b>D-ribose</b> sugar	<b>2'-deoxy-D-ribose pentose</b> sugar
<b>Stability</b>	It contains a <b>2'-OH hydroxyl group</b> , which makes it less stable	More stable
<b>Nucleobases pairs</b>	RNA is usually single stranded, and the portions are not necessarily equal	<b>Equal portions</b> of Adenine-Thymine and Guanine-Cytosine nucleobases

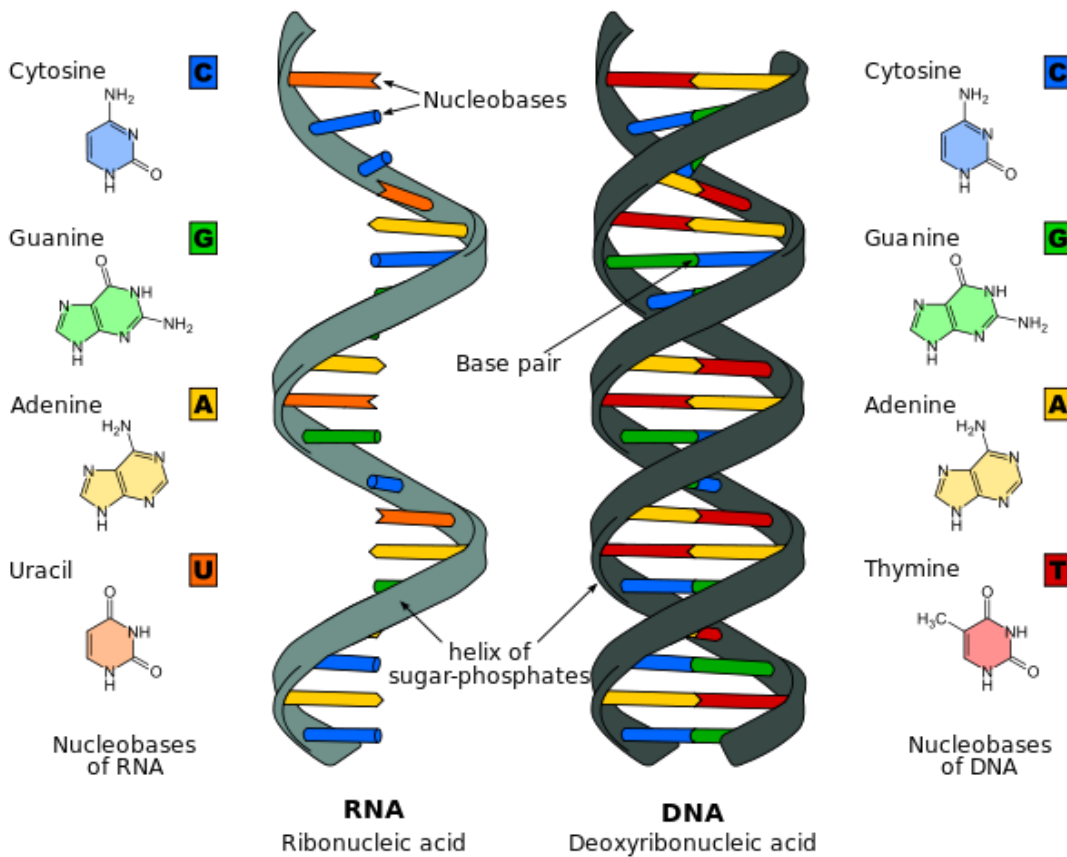


Image: "Comparison of a Single-Stranded RNA and a Double-Stranded DNA with their Corresponding Nucleobases" by Sponk. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

## Collagen

### Background

- From greek "kolla" (glue) "gen" (producing)
- Boiling hooves to make glue
- Gelatin — collagen that has been irreversibly hydrolyzed
- Medical uses in treating bones and skin
- Most abundant protein in body
- 25—30 % of all body protein by weight
- Synthesis decreases with age
- 29 types in the body

- Over 90 % of the collagen in the human body is type I
- Most common types — I, II, III, IV, V
- Type I collagen fibrils are stronger by weight than steel
- Basement membrane of extracellular matrix
- Blood vessel damage exposes collagen — signal to clotting system

<b>Collagen I</b>	Skin, tendon, vascular ligature, organs, bone
<b>Collagen II</b>	Cartilage
<b>Collagen III</b>	Reticular fibers
<b>Collagen IV</b>	Basal lamina, the epithelium-secreted layer of the basement membrane
<b>Collagen V</b>	Cell surfaces, hair, and placenta

## States of collagen

- State of collagen depends on mineralization
- Bone, tendon, cartilage
- Fibrillar and non-fibrillar types
- Most abundant fibrous tissue — ligaments, tendons, skin

## Structure

- Triple helix of helices
- Each polypeptide chain up to about 1,400 amino acids
- Type 1 collagen contains two identical  $\alpha$ -1 chains and one  $\alpha$ -2 chain
- Each chain is a left-handed helix
- Three chains coiled together to make right-handed strand (superhelix)
- Strands combined together to make fibers

## Biochemistry of collagen

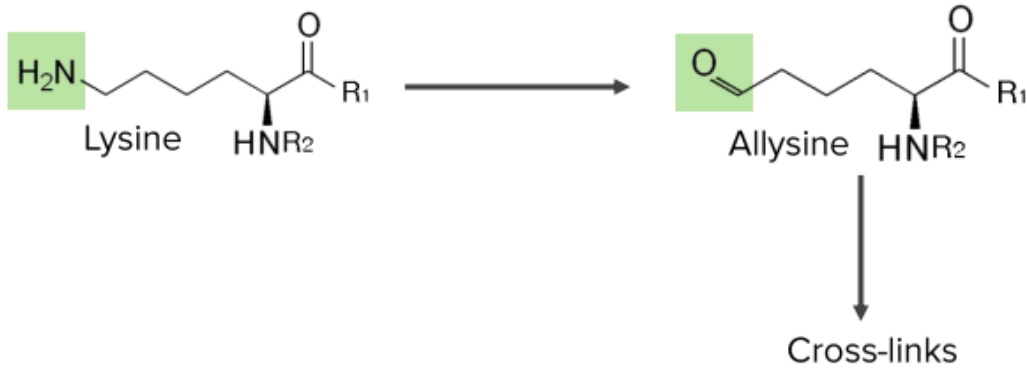
- Strands synthesized into endoplasmic reticulum (ER)
- Hydroxylation of prolines and lysines occurs in ER
- Hydroxylation necessary for collagen secretion
- Secreted collagen strands form helix
- Helices cross-link for strength

## Clinical biochemistry

- Proline hydroxylation
- Requires vitamin C
- Deficiency leads to scurvy
- Crusaders of 13th century suffered from scurvy
- Value of citrus fruits for preventing scurvy known by Vasco de Gama's voyage of 1497
- Nonetheless, over 2 million sailors died of scurvy between 1500 and 1800
- Proline hydroxylation increases collagen's thermal stability
- Stabilizes collagen at body temperature
- Cooking hydrolyzed collagen — tenderizing

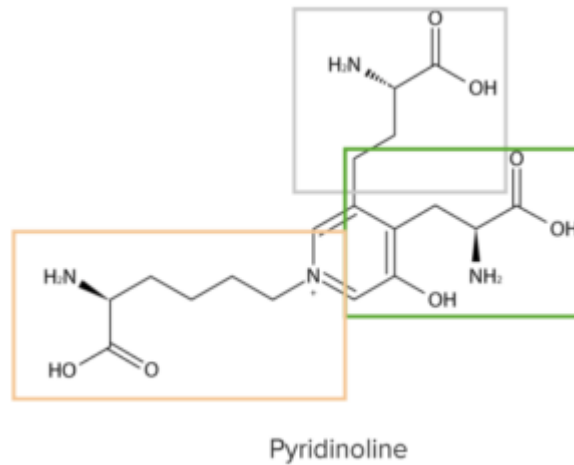


## Lysyl oxidase



- Extracellular enzyme
- Oxidizes lysines/ hydroxylysines to aldehydes in extracellular matrix

## Collagen crosslinking



- Aldehydes of allylysine can react with amines of other lysines to form pyridinoline
- This cross-linking gives collagen its strength

## Disease & Collagen

Scurvy	
Collagen vascular disease	Genetic diseases of collagen synthesis/ processing
<ul style="list-style-type: none"> <li>• Autoimmune—Lupus,</li> <li>• Systemic Lupus Erythematosus,</li> <li>• Scleroderma</li> </ul>	<ul style="list-style-type: none"> <li>• Osteogenesis Imperfecta — Brittle bones — Type I</li> <li>• Chondrodysplasias — Skeletal Disorders — Type II</li> <li>• Ehlers-Danlos-Syndrome — Connective Tissues — Type III</li> <li>• Knobloch Syndrome — Brain, Retina — Type VXII</li> </ul>

## Review Questions

The answers are below the references.

### 1. All of the following are types of RNA except:

- Messenger RNA (mRNA)
- Transfer RNA (tRNA)
- Ribosomal RNA (rRNA)

D. Nuclear RNA (nRNA)

**2. In a protein, each amino acid is specified by:**

- A. A promoter
- B. A codon
- C. Several genes
- D. An mRNA molecule

**3. RNA and DNA have the same nucleobases, except that RNA contains:**

- A. Cytosine instead of guanine
- B. Cysteine instead of cytosine
- C. Uracil instead of adenine
- D. Uracil instead of thymine

## References

Kevin Ahern. [RNA: Basic Knowledge](#). Lecturio. Accessed March 19, 2016.

[An Introduction to Molecular Biology/RNA:The ribonucleic acid](#). WIKIBOOKS. Last modified February 1, 2016. Accessed March 19, 2016.

[RNAs, Structure and Function](#). WikiLectures. Last modified March 14, 2016. Accessed March 19, 2016.

**Correct answers:** 1D, 2B, 3D

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Notes