

CAMPBELL BIOLOGY BIOMOLECULES CHAPTER 6 SUMMARY US

CAMPBELL BIOLOGY CHAPTER 6: BIOMOLECULES - A COMPREHENSIVE SUMMARY

CAMPBELL BIOLOGY BIOMOLECULES CHAPTER 6 SUMMARY US PROVIDES A DEEP DIVE INTO THE ESSENTIAL ORGANIC MOLECULES THAT FORM THE BASIS OF LIFE. THIS CHAPTER EXPLORES THE FOUR MAJOR CLASSES OF BIOMOLECULES: CARBOHYDRATES, LIPIDS, PROTEINS, AND NUCLEIC ACIDS, DETAILING THEIR STRUCTURE, FUNCTION, AND SIGNIFICANCE IN BIOLOGICAL SYSTEMS. UNDERSTANDING THESE MACROMOLECULES IS FUNDAMENTAL TO GRASPING CELLULAR PROCESSES, METABOLISM, AND THE VERY ARCHITECTURE OF LIVING ORGANISMS. WE WILL EXAMINE HOW MONOMERS LINK TO FORM POLYMERS, THE DIVERSE ROLES THESE MOLECULES PLAY FROM ENERGY STORAGE TO GENETIC INFORMATION TRANSFER, AND THE IMPORTANCE OF THEIR SPECIFIC THREE-DIMENSIONAL SHAPES FOR THEIR BIOLOGICAL ACTIVITY.

TABLE OF CONTENTS

INTRODUCTION TO BIOMOLECULES

CARBOHYDRATES: SUGARS AND POLYSACCHARIDES

LIPIDS: THE DIVERSE GROUP OF HYDROPHOBIC MOLECULES

PROTEINS: THE WORKERS OF THE CELL

NUCLEIC ACIDS: DNA AND RNA

INTRODUCTION TO BIOMOLECULES

LIFE AS WE KNOW IT IS BUILT UPON A FOUNDATION OF COMPLEX ORGANIC MOLECULES, OFTEN REFERRED TO AS BIOMOLECULES OR MACROMOLECULES. THESE ARE LARGE, INTRICATE STRUCTURES SYNTHESIZED BY LIVING ORGANISMS, AND THEY PERFORM A VAST ARRAY OF ESSENTIAL FUNCTIONS. THE STUDY OF THESE MOLECULES IS CENTRAL TO BIOLOGY, OFFERING INSIGHTS INTO EVERYTHING FROM ENERGY PRODUCTION AND STORAGE TO THE TRANSMISSION OF GENETIC INFORMATION AND CELLULAR COMMUNICATION. IN ESSENCE, UNDERSTANDING THE BUILDING BLOCKS OF LIFE IS KEY TO UNDERSTANDING LIFE ITSELF.

THE CHAPTER ON BIOMOLECULES IN CAMPBELL BIOLOGY DELVES INTO THE FOUR PRINCIPAL CLASSES OF ORGANIC MOLECULES THAT ARE UNIVERSALLY FOUND IN LIVING THINGS: CARBOHYDRATES, LIPIDS, PROTEINS, AND NUCLEIC ACIDS. EACH CLASS HAS A UNIQUE STRUCTURE THAT DICTATES ITS SPECIFIC FUNCTION WITHIN THE CELL AND THE ORGANISM. WHILE DIVERSE IN FORM AND FUNCTION, THESE MOLECULES OFTEN SHARE COMMON THEMES IN THEIR ASSEMBLY, TYPICALLY INVOLVING THE LINKING OF SMALLER SUBUNITS (MONOMERS) INTO LARGER CHAINS (POLYMERS). THIS POLYMERIZATION PROCESS IS A CORNERSTONE OF CELLULAR BIOSYNTHESIS AND IS CRUCIAL FOR CREATING THE COMPLEX MOLECULAR MACHINERY THAT DRIVES BIOLOGICAL PROCESSES.

THIS SUMMARY AIMS TO PROVIDE A THOROUGH OVERVIEW OF THE KEY CONCEPTS PRESENTED IN CHAPTER 6 OF CAMPBELL BIOLOGY, FOCUSING ON THE US EDITION. WE WILL EXPLORE THE CHEMICAL PROPERTIES AND BIOLOGICAL SIGNIFICANCE OF EACH OF THE FOUR MAJOR BIOMOLECULE CLASSES. BY EXAMINING THEIR MONOMERIC UNITS, POLYMERIC STRUCTURES, AND CRITICAL ROLES, WE CAN GAIN A DEEPER APPRECIATION FOR THE MOLECULAR BASIS OF LIFE AND THE ELEGANT DESIGN OF BIOLOGICAL SYSTEMS. WHETHER YOU ARE STUDYING CELLULAR RESPIRATION, ENZYME KINETICS, OR GENETICS, A SOLID UNDERSTANDING OF BIOMOLECULES IS INDISPENSABLE.

CARBOHYDRATES: SUGARS AND POLYSACCHARIDES

CARBOHYDRATES ARE A MAJOR CLASS OF ORGANIC COMPOUNDS FOUND IN LIVING ORGANISMS, SERVING PRIMARILY AS SOURCES OF ENERGY AND AS STRUCTURAL COMPONENTS. THEY ARE CHARACTERIZED BY THE PRESENCE OF CARBON, HYDROGEN, AND OXYGEN, OFTEN IN A RATIO OF 1:2:1 (CH_2O)_N, THOUGH THIS IS A GENERALIZED FORMULA. CARBOHYDRATES RANGE IN SIZE FROM SIMPLE SUGARS (MONOSACCHARIDES) TO COMPLEX CHAINS OF SUGAR UNITS (POLYSACCHARIDES).

MONOSACCHARIDES: THE SIMPLEST SUGARS

MONOSACCHARIDES, OR SIMPLE SUGARS, ARE THE FUNDAMENTAL BUILDING BLOCKS OF CARBOHYDRATES. THE MOST COMMON MONOSACCHARIDES ARE GLUCOSE, FRUCTOSE, AND GALACTOSE, EACH WITH THE MOLECULAR FORMULA $C_6H_{12}O_6$. GLUCOSE IS PARTICULARLY IMPORTANT AS IT IS THE PRIMARY FUEL SOURCE FOR MOST ORGANISMS AND IS CENTRAL TO CELLULAR RESPIRATION. MONOSACCHARIDES CAN EXIST AS LINEAR CHAINS OR, MORE COMMONLY, AS RING STRUCTURES IN AQUEOUS SOLUTIONS. THEY POSSESS CHIRAL CENTERS, LEADING TO ENANTIOMERS AND STEREOISOMERS, WHICH CAN INFLUENCE THEIR BIOLOGICAL ACTIVITY.

DISACCHARIDES: TWO MONOSACCHARIDES LINKED

WHEN TWO MONOSACCHARIDES ARE JOINED TOGETHER BY A GLYCOSIDIC LINKAGE, A DISACCHARIDE IS FORMED. THIS LINKAGE OCCURS THROUGH A DEHYDRATION REACTION, WHERE A MOLECULE OF WATER IS REMOVED. COMMON DISACCHARIDES INCLUDE SUCROSE (TABLE SUGAR, GLUCOSE + FRUCTOSE), LACTOSE (MILK SUGAR, GLUCOSE + GALACTOSE), AND MALTOS (MALT SUGAR, GLUCOSE + GLUCOSE). DISACCHARIDES SERVE AS TRANSPORTABLE ENERGY SOURCES FOR PLANTS AND ARE IMPORTANT DIETARY COMPONENTS FOR ANIMALS.

POLYSACCHARIDES: COMPLEX CARBOHYDRATES

POLYSACCHARIDES ARE LONG CHAINS OF MONOSACCHARIDE UNITS, OFTEN HUNDREDS OR THOUSANDS OF MONOMERS LONG. THEY CAN BE CLASSIFIED BASED ON THEIR FUNCTION: STORAGE POLYSACCHARIDES AND STRUCTURAL POLYSACCHARIDES. STARCH, THE PRIMARY STORAGE FORM OF GLUCOSE IN PLANTS, AND GLYCOGEN, THE STORAGE FORM IN ANIMALS, ARE BOTH COMPOSED OF GLUCOSE UNITS AND ARE BRANCHED TO VARYING DEGREES. THIS BRANCHING ALLOWS FOR RAPID RELEASE OF GLUCOSE WHEN ENERGY IS NEEDED. CELLULOSE, A MAJOR COMPONENT OF PLANT CELL WALLS, IS ANOTHER GLUCOSE POLYMER BUT HAS A DIFFERENT TYPE OF GLYCOSIDIC LINKAGE (B-LINKAGE) COMPARED TO STARCH AND GLYCOGEN (A-LINKAGE). THIS STRUCTURAL DIFFERENCE MAKES CELLULOSE INDIGESTIBLE FOR MOST ANIMALS, HIGHLIGHTING HOW SUBTLE CHANGES IN LINKAGE CAN DRAMATICALLY ALTER FUNCTION.

OTHER IMPORTANT STRUCTURAL POLYSACCHARIDES INCLUDE CHITIN, FOUND IN THE EXOSKELETONS OF ARTHROPODS AND THE CELL WALLS OF FUNGI, AND PEPTIDOGLYCAN, A KEY COMPONENT OF BACTERIAL CELL WALLS. THESE COMPLEX CARBOHYDRATES PROVIDE RIGIDITY, SUPPORT, AND PROTECTION TO CELLS AND ORGANISMS.

LIPIDS: THE DIVERSE GROUP OF HYDROPHOBIC MOLECULES

LIPIDS REPRESENT A DIVERSE GROUP OF MOLECULES THAT ARE CHARACTERIZED BY THEIR INSOLUBILITY IN WATER, OR HYDROPHOBICITY, DUE TO THEIR LARGE NONPOLAR REGIONS. DESPITE THIS SHARED CHARACTERISTIC, LIPIDS ENCOMPASS A WIDE RANGE OF STRUCTURES AND FUNCTIONS, INCLUDING ENERGY STORAGE, INSULATION, PROTECTION, AND ACTING AS KEY COMPONENTS OF CELL MEMBRANES. THEY ARE NOT TYPICALLY FORMED BY THE REPEATED LINKING OF MONOMERS IN THE SAME WAY AS OTHER MACROMOLECULES.

FATS: ENERGY STORAGE AND MORE

FATS, ALSO KNOWN AS TRIGLYCERIDES, ARE ESTERS FORMED FROM GLYCEROL AND THREE FATTY ACIDS. FATTY ACIDS ARE LONG HYDROCARBON CHAINS WITH A CARBOXYL GROUP AT ONE END. THEY CAN BE SATURATED (NO DOUBLE BONDS BETWEEN CARBON ATOMS IN THE HYDROCARBON CHAIN, TYPICALLY SOLID AT ROOM TEMPERATURE) OR UNSATURATED (ONE OR MORE DOUBLE BONDS, TYPICALLY LIQUID AT ROOM TEMPERATURE, E.G., OLIVE OIL). FATS ARE AN EFFICIENT FORM OF LONG-TERM ENERGY STORAGE BECAUSE THEY YIELD MORE ENERGY PER GRAM THAN CARBOHYDRATES. THEY ALSO PROVIDE INSULATION AGAINST HEAT LOSS AND CUSHION VITAL ORGANS.

PHOSPHOLIPIDS: THE BUILDING BLOCKS OF MEMBRANES

PHOSPHOLIPIDS ARE ESSENTIAL COMPONENTS OF CELL MEMBRANES. THEY ARE AMPHIPATHIC MOLECULES, MEANING THEY HAVE BOTH HYDROPHILIC (WATER-LOVING) AND HYDROPHOBIC (WATER-FEARING) REGIONS. A PHOSPHOLIPID CONSISTS OF A GLYCEROL BACKBONE, TWO FATTY ACID TAILS (HYDROPHOBIC), AND A PHOSPHATE GROUP LINKED TO A VARIABLE POLAR GROUP (HYDROPHILIC). IN AN AQUEOUS ENVIRONMENT, PHOSPHOLIPIDS SPONTANEOUSLY ARRANGE THEMSELVES INTO A BILAYER, WITH THE HYDROPHOBIC TAILS FACING INWARD AND THE HYDROPHILIC HEADS FACING OUTWARD, FORMING THE FUNDAMENTAL STRUCTURE OF CELL MEMBRANES.

STERIODS: SIGNALING MOLECULES AND MEMBRANE COMPONENTS

STERIODS ARE LIPIDS CHARACTERIZED BY A CARBON SKELETON CONSISTING OF FOUR FUSED RINGS. CHOLESTEROL IS A PROMINENT EXAMPLE, ACTING AS A PRECURSOR FOR STEROID HORMONES (LIKE ESTROGEN AND TESTOSTERONE) AND ALSO BEING A COMPONENT OF ANIMAL CELL MEMBRANES, WHERE IT INFLUENCES FLUIDITY. OTHER STEROIDS, SUCH AS HORMONES, PLAY CRUCIAL ROLES IN REGULATING VARIOUS PHYSIOLOGICAL PROCESSES.

PROTEINS: THE WORKERS OF THE CELL

PROTEINS ARE ARGUABLY THE MOST VERSATILE AND ABUNDANT MACROMOLECULES IN CELLS, PERFORMING A STAGGERING ARRAY OF FUNCTIONS. THEY ARE POLYMERS MADE UP OF AMINO ACID MONOMERS, LINKED TOGETHER BY PEPTIDE BONDS. THE SEQUENCE OF AMINO ACIDS IN A POLYPEPTIDE CHAIN DETERMINES ITS UNIQUE THREE-DIMENSIONAL STRUCTURE, WHICH IN TURN DICTATES ITS SPECIFIC FUNCTION. PROTEINS ACT AS ENZYMES, STRUCTURAL COMPONENTS, TRANSPORTERS, SIGNALING MOLECULES, AND MUCH MORE.

AMINO ACIDS: THE MONOMERS OF PROTEINS

THERE ARE 20 DIFFERENT TYPES OF AMINO ACIDS, EACH WITH A CENTRAL CARBON ATOM (THE ALPHA-CARBON) BONDED TO AN AMINO GROUP ($-\text{NH}_2$), A CARBOXYL GROUP ($-\text{COOH}$), A HYDROGEN ATOM, AND A VARIABLE SIDE CHAIN, KNOWN AS THE R GROUP. THE R GROUP IS WHAT DISTINGUISHES ONE AMINO ACID FROM ANOTHER AND INFLUENCES ITS CHEMICAL PROPERTIES, SUCH AS POLARITY, CHARGE, AND SIZE. THESE PROPERTIES ARE CRITICAL FOR PROTEIN FOLDING AND INTERACTIONS.

THE LEVELS OF PROTEIN STRUCTURE

THE FUNCTION OF A PROTEIN IS INTIMATELY TIED TO ITS COMPLEX THREE-DIMENSIONAL STRUCTURE, WHICH IS ORGANIZED INTO FOUR LEVELS:

- **PRIMARY STRUCTURE:** THE LINEAR SEQUENCE OF AMINO ACIDS IN THE POLYPEPTIDE CHAIN. THIS SEQUENCE IS DETERMINED BY THE GENETIC CODE.
- **SECONDARY STRUCTURE:** LOCALIZED FOLDING OF THE POLYPEPTIDE CHAIN, PRIMARILY DUE TO HYDROGEN BONDING BETWEEN BACKBONE ATOMS. COMMON SECONDARY STRUCTURES INCLUDE ALPHA-HELICES AND BETA-PLEATED SHEETS.
- **TERTIARY STRUCTURE:** THE OVERALL THREE-DIMENSIONAL SHAPE OF A SINGLE POLYPEPTIDE CHAIN, RESULTING FROM INTERACTIONS BETWEEN THE R GROUPS OF AMINO ACIDS. THESE INTERACTIONS INCLUDE HYDROGEN BONDS, IONIC BONDS, HYDROPHOBIC INTERACTIONS, AND DISULFIDE BRIDGES.
- **QUATERNARY STRUCTURE:** THE ARRANGEMENT OF MULTIPLE POLYPEPTIDE SUBUNITS TO FORM A FUNCTIONAL PROTEIN COMPLEX. NOT ALL PROTEINS EXHIBIT QUATERNARY STRUCTURE.

PROTEIN DENATURATION

A PROTEIN'S FUNCTION IS HIGHLY DEPENDENT ON ITS NATIVE, FOLDED STATE. IF A PROTEIN IS EXPOSED TO CONDITIONS LIKE EXTREME pH, HIGH TEMPERATURE, OR CERTAIN CHEMICALS, IT CAN UNDERGO DENATURATION, LOSING ITS FUNCTIONAL THREE-DIMENSIONAL STRUCTURE. THIS LOSS OF STRUCTURE OFTEN LEADS TO A LOSS OF BIOLOGICAL ACTIVITY.

NUCLEIC ACIDS: DNA AND RNA

NUCLEIC ACIDS ARE ESSENTIAL MACROMOLECULES THAT CARRY AND TRANSMIT GENETIC INFORMATION. THE TWO MAIN TYPES ARE DEOXYRIBONUCLEIC ACID (DNA) AND RIBONUCLEIC ACID (RNA). THEY ARE POLYMERS COMPOSED OF NUCLEOTIDE MONOMERS.

NUCLEOTIDES: THE MONOMERS OF NUCLEIC ACIDS

EACH NUCLEOTIDE CONSISTS OF THREE COMPONENTS: A NITROGENOUS BASE, A FIVE-CARBON SUGAR (PENTOSE SUGAR), AND ONE OR MORE PHOSPHATE GROUPS. IN DNA, THE SUGAR IS DEOXYRIBOSE, AND THE NITROGENOUS BASES ARE ADENINE (A), GUANINE (G), CYTOSINE (C), AND THYMINE (T). IN RNA, THE SUGAR IS RIBOSE, AND THE BASES ARE ADENINE (A), GUANINE (G), CYTOSINE (C), AND URACIL (U), WHICH REPLACES THYMINE. THE NITROGENOUS BASES ARE CLASSIFIED AS PURINES (ADENINE AND GUANINE, WITH A DOUBLE-RING STRUCTURE) OR PYRIMIDINES (CYTOSINE, THYMINE, AND URACIL, WITH A SINGLE-RING STRUCTURE).

THE STRUCTURE OF DNA AND RNA

DNA TYPICALLY EXISTS AS A DOUBLE HELIX, WITH TWO POLYNUCLEOTIDE STRANDS RUNNING ANTIPARALLEL TO EACH OTHER. THE STRANDS ARE HELD TOGETHER BY HYDROGEN BONDS BETWEEN COMPLEMENTARY BASES: ADENINE ALWAYS PAIRS WITH THYMINE (A-T), AND GUANINE ALWAYS PAIRS WITH CYTOSINE (G-C). THIS BASE-PAIRING RULE IS FUNDAMENTAL TO DNA'S ABILITY TO REPLICATE AND STORE GENETIC INFORMATION. RNA IS USUALLY SINGLE-STRANDED, THOUGH IT CAN FOLD UPON ITSELF TO FORM COMPLEX THREE-DIMENSIONAL STRUCTURES. RNA PLAYS DIVERSE ROLES, INCLUDING CARRYING GENETIC INFORMATION FROM DNA TO RIBOSOMES (MESSENGER RNA OR mRNA), FORMING PART OF RIBOSOMES (RIBOSOMAL RNA OR rRNA), AND TRANSFERRING AMINO ACIDS TO RIBOSOMES DURING PROTEIN SYNTHESIS (TRANSFER RNA OR tRNA).

THE SEQUENCE OF NUCLEOTIDES IN DNA CONTAINS THE GENETIC INSTRUCTIONS FOR THE DEVELOPMENT, FUNCTIONING, GROWTH, AND REPRODUCTION OF ALL KNOWN ORGANISMS AND MANY VIRUSES. THIS INFORMATION IS TRANSCRIBED INTO RNA, WHICH IS THEN TRANSLATED INTO PROTEINS, THE MOLECULAR EFFECTORS OF MOST CELLULAR PROCESSES. THE STUDY OF NUCLEIC ACIDS IS THUS CENTRAL TO UNDERSTANDING HEREDITY AND MOLECULAR BIOLOGY.

FAQ

Q: WHAT ARE THE FOUR MAIN TYPES OF BIOMOLECULES DISCUSSED IN CAMPBELL BIOLOGY CHAPTER 6?

A: THE FOUR MAIN TYPES OF BIOMOLECULES DISCUSSED IN CAMPBELL BIOLOGY CHAPTER 6 ARE CARBOHYDRATES, LIPIDS, PROTEINS, AND NUCLEIC ACIDS.

Q: HOW ARE CARBOHYDRATES CLASSIFIED, AND WHAT ARE THEIR PRIMARY FUNCTIONS?

A: CARBOHYDRATES ARE CLASSIFIED AS MONOSACCHARIDES (SIMPLE SUGARS), DISACCHARIDES (TWO MONOSACCHARIDES LINKED), AND POLYSACCHARIDES (COMPLEX CARBOHYDRATES). THEIR PRIMARY FUNCTIONS INCLUDE PROVIDING ENERGY (E.G., GLUCOSE, STARCH, GLYCOGEN) AND STRUCTURAL SUPPORT (E.G., CELLULOSE, CHITIN).

Q: WHAT MAKES LIPIDS UNIQUE COMPARED TO OTHER BIOMOLECULES?

A: LIPIDS ARE UNIQUE BECAUSE THEY ARE GENERALLY HYDROPHOBIC (INSOLUBLE IN WATER), A CHARACTERISTIC ARISING FROM THEIR LARGE NONPOLAR HYDROCARBON REGIONS. THEY INCLUDE FATS, PHOSPHOLIPIDS, AND STEROIDS, AND SERVE ROLES IN ENERGY STORAGE, MEMBRANE STRUCTURE, AND SIGNALING.

Q: WHAT ARE THE BUILDING BLOCKS OF PROTEINS, AND HOW DOES THEIR STRUCTURE RELATE TO THEIR FUNCTION?

A: PROTEINS ARE POLYMERS MADE OF AMINO ACID MONOMERS. THE SEQUENCE OF AMINO ACIDS (PRIMARY STRUCTURE) DETERMINES THE PROTEIN'S UNIQUE THREE-DIMENSIONAL SHAPE (SECONDARY, TERTIARY, AND SOMETIMES QUATERNARY STRUCTURE), WHICH IS ESSENTIAL FOR ITS SPECIFIC BIOLOGICAL FUNCTION.

Q: CAN PROTEIN STRUCTURE BE IRREVERSIBLY ALTERED?

A: YES, PROTEINS CAN UNDERGO DENATURATION, WHERE THEIR THREE-DIMENSIONAL STRUCTURE IS DISRUPTED BY FACTORS LIKE HEAT OR EXTREME PH. WHILE SOME DENATURATION IS REVERSIBLE, SEVERE DENATURATION CAN LEAD TO IRREVERSIBLE LOSS OF FUNCTION.

Q: WHAT ARE THE FUNDAMENTAL COMPONENTS OF A NUCLEOTIDE?

A: A NUCLEOTIDE, THE MONOMER OF NUCLEIC ACIDS, CONSISTS OF A NITROGENOUS BASE, A FIVE-CARBON SUGAR (DEOXYRIBOSE IN DNA, RIBOSE IN RNA), AND AT LEAST ONE PHOSPHATE GROUP.

Q: WHAT IS THE KEY STRUCTURAL DIFFERENCE BETWEEN DNA AND RNA, AND HOW DOES IT AFFECT THEIR FUNCTION?

A: THE KEY STRUCTURAL DIFFERENCE IS THE SUGAR COMPONENT: DNA USES DEOXYRIBOSE, WHILE RNA USES RIBOSE. DNA IS TYPICALLY DOUBLE-STRANDED AND SERVES AS THE GENETIC BLUEPRINT, WHILE RNA IS USUALLY SINGLE-STRANDED AND PLAYS VARIOUS ROLES IN PROTEIN SYNTHESIS AND GENE EXPRESSION.

Q: HOW ARE POLYMERS LIKE CARBOHYDRATES AND PROTEINS FORMED FROM THEIR RESPECTIVE MONOMERS?

A: POLYMERS ARE FORMED FROM MONOMERS THROUGH DEHYDRATION REACTIONS, WHERE A WATER MOLECULE IS REMOVED AS A NEW COVALENT BOND IS CREATED BETWEEN MONOMERS. THIS PROCESS IS ALSO KNOWN AS A CONDENSATION REACTION.

Q: WHAT ARE SATURATED AND UNSATURATED FATS, AND WHAT IS THE SIGNIFICANCE OF THIS DIFFERENCE?

A: SATURATED FATS HAVE HYDROCARBON CHAINS WITH ONLY SINGLE BONDS BETWEEN CARBON ATOMS AND ARE TYPICALLY SOLID AT ROOM TEMPERATURE. UNSATURATED FATS HAVE ONE OR MORE DOUBLE BONDS IN THEIR HYDROCARBON CHAINS, LEADING TO KINKS AND MAKING THEM TYPICALLY LIQUID AT ROOM TEMPERATURE. THIS DIFFERENCE AFFECTS THEIR PHYSICAL PROPERTIES AND HOW THEY ARE PROCESSED BY THE BODY.

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