

CAMPBELL BIOLOGY FUNGI CHAPTER MEDICINAL USES US

CAMPBELL BIOLOGY FUNGI CHAPTER MEDICINAL USES US DELVES INTO THE FASCINATING AND VITAL RELATIONSHIP BETWEEN THE FUNGAL KINGDOM AND HUMAN HEALTH, EXPLORING A RICH HISTORY OF MEDICINAL APPLICATIONS THAT CONTINUE TO EVOLVE. THIS COMPREHENSIVE EXPLORATION, INSPIRED BY THE FOUNDATIONAL KNOWLEDGE FOUND IN CAMPBELL BIOLOGY, HIGHLIGHTS HOW THESE OFTEN-OVERLOOKED ORGANISMS HAVE PROVIDED US WITH LIFE-SAVING TREATMENTS AND INNOVATIVE THERAPEUTIC AGENTS. WE WILL JOURNEY FROM ANCIENT REMEDIES TO MODERN PHARMACEUTICAL BREAKTHROUGHS, EXAMINING THE SPECIFIC COMPOUNDS AND MECHANISMS BY WHICH FUNGI EXERT THEIR BENEFICIAL EFFECTS. UNDERSTANDING THESE FUNGAL CONTRIBUTIONS IS CRUCIAL FOR APPRECIATING THE BREADTH OF THEIR IMPACT ON MEDICINE AND HUMAN WELL-BEING IN THE UNITED STATES AND GLOBALLY.

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INTRODUCTION TO FUNGI AND THEIR MEDICINAL POTENTIAL

THE FUNGAL KINGDOM, A DIVERSE GROUP OF EUKARYOTIC ORGANISMS INCLUDING YEASTS, MOLDS, AND MUSHROOMS, PLAYS AN INDISPENSABLE ROLE IN ECOSYSTEMS AS DECOMPOSERS AND SYMBIONTS. BEYOND THEIR ECOLOGICAL IMPORTANCE, FUNGI REPRESENT A TREASURE TROVE OF BIOACTIVE COMPOUNDS WITH PROFOUND IMPLICATIONS FOR HUMAN HEALTH. THE STUDY OF THESE MEDICINAL USES, OFTEN A KEY COMPONENT IN COMPREHENSIVE BIOLOGICAL EDUCATION LIKE THAT PRESENTED IN CAMPBELL BIOLOGY, UNDERSCORES THE VAST UNTAPPED POTENTIAL WITHIN FUNGAL SPECIES.

FOR CENTURIES, HUMANS HAVE INTUITIVELY OR SCIENTIFICALLY LEVERAGED FUNGI FOR THERAPEUTIC PURPOSES. FROM ANCIENT CIVILIZATIONS RECOGNIZING THE HEALING PROPERTIES OF MOLDS ON WOUNDS TO MODERN PHARMACEUTICAL COMPANIES ISOLATING POTENT MOLECULES, THE JOURNEY OF FUNGAL MEDICINE IS A TESTAMENT TO NATURE'S INGENUITY. THIS ARTICLE WILL EXPLORE THE FOUNDATIONAL KNOWLEDGE PRESENTED IN TYPICAL CAMPBELL BIOLOGY CURRICULA REGARDING FUNGI, SPECIFICALLY FOCUSING ON THEIR MEDICINAL APPLICATIONS RELEVANT TO THE UNITED STATES AND THE BROADER SCIENTIFIC COMMUNITY.

HISTORICAL SIGNIFICANCE OF FUNGI IN MEDICINE

THE DOCUMENTED HISTORY OF USING FUNGI FOR MEDICINAL PURPOSES STRETCHES BACK MILLENNIA. ANCIENT EGYPTIANS APPLIED MOLDY BREAD TO INFECTED WOUNDS, AND INDIGENOUS CULTURES WORLDWIDE HAVE LONG UTILIZED VARIOUS FUNGI IN THEIR TRADITIONAL HEALING PRACTICES. THESE EARLY OBSERVATIONS, THOUGH LACKING SCIENTIFIC EXPLANATION AT THE TIME, LAID THE GROUNDWORK FOR FUTURE DISCOVERIES.

THE ADVENT OF MODERN SCIENTIFIC INVESTIGATION TRANSFORMED OUR UNDERSTANDING OF FUNGAL PHARMACOLOGY. THE ACCIDENTAL DISCOVERY OF PENICILLIN BY ALEXANDER FLEMING IN 1928 MARKED A WATERSHED MOMENT, USHERING IN THE AGE OF ANTIBIOTICS AND FUNDAMENTALLY CHANGING THE LANDSCAPE OF INFECTIOUS DISEASE TREATMENT. THIS DISCOVERY, A CORNERSTONE OF MICROBIOLOGY AND A FREQUENT TOPIC IN BIOLOGY TEXTBOOKS, DEMONSTRATED THE POTENT ANTIMICROBIAL CAPABILITIES OF FUNGAL METABOLITES.

EARLY OBSERVATIONS AND TRADITIONAL USE

ACROSS VARIOUS CULTURES, THE APPLICATION OF FUNGI FOR HEALING WAS WIDESPREAD. MUSHROOMS WERE USED TOPICALLY FOR THEIR ANTI-INFLAMMATORY OR WOUND-HEALING PROPERTIES, WHILE CERTAIN MOLDS WERE RECOGNIZED FOR THEIR ABILITY TO INHIBIT THE GROWTH OF PATHOGENIC BACTERIA. THESE PRACTICES, PASSED DOWN THROUGH GENERATIONS, HIGHLIGHT AN EMPIRICAL UNDERSTANDING OF FUNGAL BIOACTIVITY LONG BEFORE THE UNDERLYING BIOCHEMICAL MECHANISMS WERE UNDERSTOOD.

THE DISCOVERY OF PENICILLIN

ALEXANDER FLEMING'S SERENDIPITOUS OBSERVATION OF A MOLD INHIBITING BACTERIAL GROWTH IN A PETRI DISH LED TO THE ISOLATION OF PENICILLIN FROM THE FUNGUS *PENICILLIUM NOTATUM*. THIS MARKED THE FIRST WIDELY RECOGNIZED AND EFFECTIVE ANTIBIOTIC DERIVED FROM A FUNGUS, REVOLUTIONIZING MEDICINE AND SAVING COUNTLESS LIVES FROM BACTERIAL INFECTIONS. THE SUBSEQUENT MASS PRODUCTION OF PENICILLIN DURING WORLD WAR II SOLIDIFIED ITS IMPORTANCE AND PAVED THE WAY FOR FURTHER ANTIBIOTIC RESEARCH.

KEY MEDICINAL COMPOUNDS DERIVED FROM FUNGI

FUNGI ARE PROLIFIC PRODUCERS OF A VAST ARRAY OF SECONDARY METABOLITES, MANY OF WHICH POSSESS REMARKABLE PHARMACOLOGICAL PROPERTIES. THESE COMPOUNDS HAVE BEEN INSTRUMENTAL IN DEVELOPING CRITICAL MEDICATIONS THAT COMBAT A WIDE RANGE OF DISEASES, FROM INFECTIONS TO CARDIOVASCULAR CONDITIONS AND IMMUNE SYSTEM DISORDERS.

THE BIOCHEMICAL PATHWAYS RESPONSIBLE FOR PRODUCING THESE DIVERSE MOLECULES ARE A SUBJECT OF INTENSE STUDY, OFTEN EXPLORED IN ADVANCED BIOLOGY COURSES. UNDERSTANDING THESE PATHWAYS NOT ONLY HELPS IN THE ISOLATION AND SYNTHESIS OF EXISTING DRUGS BUT ALSO GUIDES THE SEARCH FOR NOVEL THERAPEUTIC AGENTS FROM UNEXPLORED FUNGAL SPECIES.

PENICILLIN: A REVOLUTIONARY ANTIBIOTIC

PENICILLIN, PRODUCED BY SPECIES OF *PENICILLIUM*, REMAINS ONE OF THE MOST SIGNIFICANT MEDICAL DISCOVERIES OF THE 20TH CENTURY. ITS ABILITY TO DISRUPT BACTERIAL CELL WALL SYNTHESIS MAKES IT HIGHLY EFFECTIVE AGAINST A BROAD SPECTRUM OF GRAM-POSITIVE BACTERIA, TRANSFORMING THE TREATMENT OF PREVIOUSLY LIFE-THREATENING INFECTIONS SUCH AS PNEUMONIA, SYPHILIS, AND STREP THROAT.

THE DEVELOPMENT OF PENICILLIN AND ITS ANALOGS HAS LED TO A CONTINUOUS EFFORT TO COMBAT ANTIBIOTIC RESISTANCE. HOWEVER, ITS LEGACY AS THE FIRST MAJOR FUNGAL-DERIVED ANTIBIOTIC CANNOT BE OVERSTATED, FUNDAMENTALLY ALTERING PUBLIC HEALTH OUTCOMES AND LONGEVITY.

IMMUNOSUPPRESSANTS FROM FUNGI

FUNGI ARE ALSO THE SOURCE OF POTENT IMMUNOSUPPRESSIVE DRUGS, ESSENTIAL FOR ORGAN TRANSPLANTATION AND THE TREATMENT OF AUTOIMMUNE DISEASES. CYCLOSPORINE, ISOLATED FROM THE FUNGUS *TOLYPOCLADIUM INFLATUM*, IS A PRIME EXAMPLE.

CYCLOSPORINE WORKS BY INHIBITING T-CELL ACTIVATION, THEREBY PREVENTING THE RECIPIENT'S IMMUNE SYSTEM FROM REJECTING A TRANSPLANTED ORGAN. THIS HAS MADE ORGAN TRANSPLANTATION A VIABLE AND INCREASINGLY SUCCESSFUL

MEDICAL PROCEDURE, OFFERING NEW HOPE TO PATIENTS WITH END-STAGE ORGAN FAILURE. OTHER FUNGAL-DERIVED IMMUNOSUPPRESSANTS ARE ALSO UNDER INVESTIGATION FOR VARIOUS CLINICAL APPLICATIONS.

STATINS: CHOLESTEROL-LOWERING POWERHOUSES

CARDIOVASCULAR DISEASE REMAINS A LEADING CAUSE OF MORTALITY, AND STATINS ARE A CORNERSTONE OF TREATMENT FOR HYPERCHOLESTEROLEMIA. INTERESTINGLY, MANY OF THE MOST WIDELY PRESCRIBED STATINS, SUCH AS LOVASTATIN AND MEVASTATIN, WERE ORIGINALLY ISOLATED FROM FUNGI.

THESE FUNGAL METABOLITES INHIBIT HMG-CoA REDUCTASE, A KEY ENZYME IN THE CHOLESTEROL BIOSYNTHESIS PATHWAY IN THE LIVER. BY REDUCING CHOLESTEROL PRODUCTION, STATINS SIGNIFICANTLY LOWER LDL ("BAD") CHOLESTEROL LEVELS, THEREBY REDUCING THE RISK OF HEART ATTACK AND STROKE. THE DISCOVERY OF FUNGAL STATINS HAS HAD A MONUMENTAL IMPACT ON GLOBAL PUBLIC HEALTH.

ANTIVIRAL AND ANTICANCER AGENTS

BEYOND ANTIBIOTICS AND IMMUNOSUPPRESSANTS, FUNGI HAVE ALSO YIELDED COMPOUNDS WITH ANTIVIRAL AND ANTICANCER PROPERTIES. FOR INSTANCE, CERTAIN COMPOUNDS DERIVED FROM MUSHROOMS HAVE DEMONSTRATED IMMUNOMODULATORY EFFECTS, POTENTIALLY ENHANCING THE BODY'S ABILITY TO FIGHT CANCER.

RESEARCH IS ONGOING TO IDENTIFY AND DEVELOP NOVEL ANTIVIRAL AGENTS FROM FUNGAL SOURCES, PARTICULARLY IN THE FACE OF EMERGING VIRAL THREATS. THE COMPLEX CHEMICAL STRUCTURES PRODUCED BY FUNGI OFFER UNIQUE OPPORTUNITIES FOR DEVELOPING DRUGS THAT TARGET VIRAL REPLICATION OR BOOST HOST IMMUNE RESPONSES.

FUNGI IN TRADITIONAL AND FOLK MEDICINE PRACTICES

LONG BEFORE THE ADVENT OF MODERN PHARMACOLOGY, VARIOUS CULTURES RECOGNIZED THE MEDICINAL VALUE OF FUNGI. THESE TRADITIONAL PRACTICES, WHILE OFTEN ANECDOTAL, PROVIDED THE INITIAL CLUES THAT GUIDED SCIENTIFIC INVESTIGATION.

MUSHROOMS AND MOLDS WERE FREQUENTLY USED IN POULTICES, TEAS, AND OTHER PREPARATIONS TO TREAT A WIDE ARRAY OF AILMENTS. THE EMPIRICAL KNOWLEDGE EMBEDDED IN THESE TRADITIONS HIGHLIGHTS THE DEEP AND ENDURING CONNECTION BETWEEN HUMANS AND THE MEDICINAL PROPERTIES OF FUNGI.

EDIBLE MUSHROOMS AND THEIR HEALTH BENEFITS

MANY EDIBLE MUSHROOM SPECIES, SUCH AS REISHI (*GANODERMA LUCIDUM*) AND SHIITAKE (*LENTINULA EDODES*), HAVE BEEN CONSUMED FOR CENTURIES NOT ONLY FOR THEIR NUTRITIONAL VALUE BUT ALSO FOR THEIR PURPORTED HEALTH-PROMOTING PROPERTIES. THESE MUSHROOMS ARE RICH IN POLYSACCHARIDES, ANTIOXIDANTS, AND OTHER BIOACTIVE COMPOUNDS THAT ARE BELIEVED TO SUPPORT IMMUNE FUNCTION AND OVERALL WELL-BEING.

MEDICINAL MUSHROOMS IN ASIAN TRADITIONS

IN TRADITIONAL EAST ASIAN MEDICINE, SPECIFIC MUSHROOMS HAVE BEEN USED TO TREAT A VARIETY OF CONDITIONS. FOR EXAMPLE, CORDYCEPS ARE TRADITIONALLY USED TO ENHANCE ENERGY AND VITALITY, WHILE TURKEY TAIL (*TRAMETES VERSICOLOR*) IS KNOWN FOR ITS POTENTIAL IMMUNE-BOOSTING EFFECTS. MODERN RESEARCH IS BEGINNING TO VALIDATE SOME OF

THESE TRADITIONAL USES BY IDENTIFYING SPECIFIC ACTIVE COMPOUNDS WITHIN THESE FUNGI.

CURRENT RESEARCH AND FUTURE PROSPECTS IN FUNGAL MEDICINE

THE EXPLORATION OF FUNGAL MEDICINAL COMPOUNDS IS A DYNAMIC AND EXPANDING FIELD. ADVANCES IN GENOMICS, METABOLOMICS, AND BIOTECHNOLOGY ARE ACCELERATING THE PACE OF DISCOVERY, ENABLING RESEARCHERS TO IDENTIFY NOVEL BIOACTIVE MOLECULES AND UNDERSTAND THEIR MECHANISMS OF ACTION MORE EFFECTIVELY.

THE VAST MAJORITY OF FUNGAL SPECIES REMAIN UNCHARACTERIZED FOR THEIR MEDICINAL POTENTIAL, SUGGESTING THAT COUNTLESS FUTURE THERAPEUTIC AGENTS ARE WAITING TO BE DISCOVERED. THIS ONGOING RESEARCH HOLDS IMMENSE PROMISE FOR DEVELOPING NEW TREATMENTS FOR DISEASES THAT CURRENTLY LACK EFFECTIVE THERAPIES.

DRUG DISCOVERY AND DEVELOPMENT PIPELINES

PHARMACEUTICAL COMPANIES AND ACADEMIC INSTITUTIONS ARE ACTIVELY ENGAGED IN SCREENING FUNGAL BIODIVERSITY FOR NEW DRUG LEADS. THIS INVOLVES COLLECTING FUNGAL SAMPLES FROM DIVERSE ENVIRONMENTS, CULTURING THEM, AND ANALYZING THEIR METABOLIC PROFILES FOR THE PRESENCE OF NOVEL BIOACTIVE COMPOUNDS. HIGH-THROUGHPUT SCREENING TECHNOLOGIES ARE CRUCIAL IN THIS PROCESS.

BIOTECHNOLOGY AND FUNGAL METABOLITES

BIOTECHNOLOGY PLAYS A PIVOTAL ROLE IN UNLOCKING THE POTENTIAL OF FUNGAL METABOLITES. TECHNIQUES SUCH AS GENETIC ENGINEERING AND SYNTHETIC BIOLOGY CAN BE USED TO OPTIMIZE THE PRODUCTION OF VALUABLE COMPOUNDS, MAKING THEM MORE ACCESSIBLE AND COST-EFFECTIVE FOR THERAPEUTIC USE. THIS INCLUDES ENGINEERING FUNGAL STRAINS TO PRODUCE HIGHER YIELDS OR TO SYNTHESIZE ENTIRELY NEW MOLECULES.

TARGETING EMERGING DISEASES

THE ONGOING SEARCH FOR NEW ANTIFUNGAL AGENTS TO COMBAT RESISTANT FUNGAL INFECTIONS AND THE DEVELOPMENT OF NOVEL ANTIVIRAL AND ANTICANCER DRUGS ARE KEY AREAS OF FOCUS. FUNGI OFFER A UNIQUE CHEMICAL DIVERSITY THAT CAN BE EXPLOITED TO DEVELOP TREATMENTS AGAINST PATHOGENS THAT HAVE EVOLVED RESISTANCE TO EXISTING DRUGS.

CHALLENGES AND OPPORTUNITIES IN FUNGAL DRUG DISCOVERY

DESPITE THE IMMENSE POTENTIAL, SEVERAL CHALLENGES EXIST IN THE FIELD OF FUNGAL DRUG DISCOVERY. THESE INCLUDE THE DIFFICULTY IN CULTURING MANY FUNGAL SPECIES, THE COMPLEX CHEMISTRY OF FUNGAL METABOLITES, AND THE LENGTHY AND EXPENSIVE PROCESS OF DRUG DEVELOPMENT AND REGULATORY APPROVAL.

HOWEVER, THESE CHALLENGES ARE MATCHED BY SIGNIFICANT OPPORTUNITIES. THE EXPLORATION OF UNDER-RESOURCED FUNGAL ECOSYSTEMS, THE APPLICATION OF ADVANCED ANALYTICAL TECHNIQUES, AND COLLABORATIVE RESEARCH EFFORTS ARE PAVING THE WAY FOR FUTURE BREAKTHROUGHS. THE ECONOMIC AND HEALTH BENEFITS OF SUCCESSFULLY BRINGING A NEW FUNGAL-DERIVED DRUG TO MARKET ARE SUBSTANTIAL.

CULTURING AND ISOLATION DIFFICULTIES

A SIGNIFICANT HURDLE IS THAT MANY FUNGI, PARTICULARLY THOSE FROM UNIQUE OR EXTREME ENVIRONMENTS, ARE DIFFICULT TO CULTIVATE IN LABORATORY SETTINGS. THIS MAKES IT CHALLENGING TO PRODUCE SUFFICIENT QUANTITIES OF THEIR METABOLITES FOR STUDY. DEVELOPING NOVEL CULTURING TECHNIQUES AND EXPLORING CULTIVATION-INDEPENDENT METHODS ARE ACTIVE AREAS OF RESEARCH.

COMPLEXITY OF FUNGAL CHEMISTRY

FUNGAL SECONDARY METABOLITES OFTEN POSSESS INTRICATE CHEMICAL STRUCTURES, WHICH CAN MAKE THEIR SYNTHESIS AND MODIFICATION CHALLENGING. UNDERSTANDING THESE COMPLEX STRUCTURES AND THEIR STRUCTURE-ACTIVITY RELATIONSHIPS IS CRUCIAL FOR OPTIMIZING THEIR THERAPEUTIC EFFICACY AND SAFETY PROFILES. ADVANCED SPECTROSCOPIC AND CHROMATOGRAPHIC TECHNIQUES ARE ESSENTIAL FOR THIS WORK.

THE PROMISE OF UNDISCOVERED FUNGAL DIVERSITY

THE SHEER DIVERSITY OF THE FUNGAL KINGDOM MEANS THAT A VAST NUMBER OF SPECIES AND THEIR ASSOCIATED METABOLITES REMAIN UNEXPLORED. THIS REPRESENTS A SIGNIFICANT OPPORTUNITY FOR DISCOVERING NOVEL COMPOUNDS WITH UNIQUE MECHANISMS OF ACTION, WHICH COULD LEAD TO TREATMENTS FOR A WIDE RANGE OF UNMET MEDICAL NEEDS.

FAQ

Q: WHAT IS THE MOST WELL-KNOWN MEDICINAL COMPOUND DERIVED FROM FUNGI?

A: THE MOST WELL-KNOWN MEDICINAL COMPOUND DERIVED FROM FUNGI IS PENICILLIN, THE FIRST WIDELY USED ANTIBIOTIC, DISCOVERED BY ALEXANDER FLEMING.

Q: HOW DO FUNGI CONTRIBUTE TO MODERN MEDICINE IN THE UNITED STATES?

A: FUNGI CONTRIBUTE SIGNIFICANTLY TO MODERN MEDICINE IN THE US BY PROVIDING ESSENTIAL COMPOUNDS FOR ANTIBIOTICS, IMMUNOSUPPRESSANTS (CRITICAL FOR ORGAN TRANSPLANTS), CHOLESTEROL-LOWERING DRUGS (STATINS), AND ONGOING RESEARCH INTO ANTIVIRAL AND ANTICANCER AGENTS.

Q: ARE THERE SPECIFIC TYPES OF MUSHROOMS COMMONLY USED FOR MEDICINAL PURPOSES?

A: YES, CERTAIN TYPES OF MUSHROOMS, OFTEN REFERRED TO AS "MEDICINAL MUSHROOMS," ARE COMMONLY USED. EXAMPLES INCLUDE REISHI, SHIITAKE, CORDYCEPS, AND TURKEY TAIL, WHICH ARE UTILIZED FOR THEIR PURPORTED IMMUNE-MODULATING AND HEALTH-PROMOTING PROPERTIES.

Q: WHAT IS THE ROLE OF FUNGI IN IMMUNOSUPPRESSION THERAPY?

A: FUNGI, SUCH AS THE ONE THAT PRODUCES CYCLOSPORINE (TOLYPOCLADIUM INFLATUM), ARE VITAL SOURCES OF IMMUNOSUPPRESSANT DRUGS. THESE MEDICATIONS ARE ESSENTIAL FOR PREVENTING ORGAN REJECTION IN TRANSPLANT RECIPIENTS AND FOR MANAGING AUTOIMMUNE DISEASES.

Q: CAN FUNGI PRODUCE COMPOUNDS THAT HELP LOWER CHOLESTEROL?

A: ABSOLUTELY. MANY STATINS, WHICH ARE CRUCIAL FOR LOWERING CHOLESTEROL LEVELS AND REDUCING THE RISK OF CARDIOVASCULAR DISEASE, WERE ORIGINALLY DISCOVERED IN FUNGI. LOVASTATIN IS A PRIME EXAMPLE.

Q: WHAT ARE THE CHALLENGES IN DISCOVERING NEW MEDICINAL COMPOUNDS FROM FUNGI?

A: KEY CHALLENGES INCLUDE THE DIFFICULTY IN CULTURING MANY FUNGAL SPECIES IN A LAB SETTING, THE COMPLEX CHEMICAL STRUCTURES OF FUNGAL METABOLITES WHICH CAN BE HARD TO SYNTHESIZE, AND THE EXTENSIVE, COSTLY PROCESS OF DRUG DEVELOPMENT AND APPROVAL.

Q: WHAT IS THE FUTURE OUTLOOK FOR FUNGAL-DERIVED MEDICINES?

A: THE FUTURE OUTLOOK IS VERY PROMISING. ONGOING RESEARCH, DRIVEN BY ADVANCEMENTS IN GENOMICS AND BIOTECHNOLOGY, IS CONTINUOUSLY UNCOVERING NEW BIOACTIVE COMPOUNDS FROM FUNGI, OFFERING POTENTIAL TREATMENTS FOR A WIDE RANGE OF DISEASES, INCLUDING THOSE WITH CURRENTLY LIMITED THERAPEUTIC OPTIONS.

Q: BEYOND ANTIBIOTICS AND STATINS, WHAT OTHER MEDICAL APPLICATIONS DO FUNGAL COMPOUNDS HAVE?

A: FUNGAL COMPOUNDS ARE ALSO BEING RESEARCHED AND UTILIZED FOR THEIR ANTIVIRAL, ANTICANCER, AND NEUROPROTECTIVE PROPERTIES. THEIR COMPLEX CHEMICAL STRUCTURES OFFER UNIQUE AVENUES FOR DRUG DISCOVERY IN THESE AREAS.

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