

Senate Subcommittee on Oceans, Atmosphere, Fisheries and Transportation
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“The Blue Economy: The Role of the Oceans in our Nation’s Economic Future”

“Marine Products, Discovery and Commercialization”

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Introduction

Scientific and technological discovery and development, more than ever before, is perhaps the most important foundation of the economy of the United States of America. As we enter the decades to come, it is crucial that the US lead in marine biological research providing for the creation of new industries based upon discoveries made from the ocean.

The Oceans as Our Great Resource.

The world’s oceans occupy more than 70% of the surface of the Earth and 90% of the volume of its crust. While this is the largest ecosystem of planet Earth, we have only now realized that it is the most important of our biological resources.

Biological diversity is best viewed at the Phylum level, with humankind occupying the Phylum Chordata. There are 46 Phyla of biodiverse life on this planet, but these are unequally distributed between terrestrial and marine environments. On land, it is generally agreed that 17 Phyla are represented. In the ocean 44 Phyla are present, comprising our most diverse and complex biological community.

Why has it taken so long to accept this reality?

As terrestrial beings, humans have classically been unable to comprehend the scope of marine environments and the diverse biota that abound from the ocean surface to depths of greater than 13,000 meters. Humans are not adapted to life in the sea, hence they are less familiar with the oceans and even frightened to explore it.

Genetic Diversity = Chemical Diversity

Since genes are the molecular codes for new chemical compounds, it is clear that genetic diversity leads to chemical diversity. Thus, it is easily predicted that the oceans are our most prolific source for new chemical compounds. Sometimes called “natural products”, naturally-produced chemical compounds are the foundation of a large diversity of industries and products, including pharmaceuticals (50% of all drug are from Nature), cosmetic products (most contain natural chemicals), food flavorings and colorings, food additives (thickeners, vitamins, preservatives), biomaterials (polymers and biomaterials), and a host of others. If one examines the labels of virtually every consumer product we use, natural chemical compounds can be readily seen.

Values of Natural Products - Pharmaceuticals Top The List

It is difficult to estimate the overall economic importance of natural chemical compounds, but clearly it is immense. Some of the most significant areas include the discovery and development of new pharmaceuticals and personal care products. As the US population ages, they rely more than ever before on medications that can suppress or cure human diseases. Since the invention of the automobile, human life span has increased from 47 years to over 75 years; much of this life extension is due to effective medical care which emphasizes drug treatments for cancer, heart disease, diabetes, and many other human maladies. In 2007, the US pharmaceutical industry documented sales in excess of \$286 B USD [1]. Much of this came from sales of “blockbuster drugs” such as the cholesterol-lowering drug Lipitor, which generated \$7 B USD in 2007. Overall, there are more than 40 currently prescribed drugs that report sales in excess of \$ 1B USD per year [2].

The Impact of Pharmaceuticals on Human Life

While the economics of pharmaceutical sales is huge, the positive benefits on human health must be underscored. More than ever, difficult diseases are treated with the latest pharmaceutical discoveries. Diseases once considered fatal, are not treatable and often curable. *There is no question that the discovery and development of new drugs is one of our most important societal goals.*

Pharmaceutical Discovery in the Oceans

Considering that 50% of the current drugs are either of natural origin or fashioned from natural drugs, it is imperative that we carefully consider the sources we have that are undeveloped. The treatment of cancer and infectious diseases, in particular, rely on naturally-occurring chemical compounds (Taxol, Penicillin are prominent examples) for their effective control. Because of the difficulty in treating complex cancers, and the growing epidemic of drug-resistant infectious diseases (MRSA for example), these diseases provide the greatest societal need for new and more effective therapeutics.

Where will the new drugs in the next decades be derived?

Drug discovery is a very complex process involving many effective approaches including bioassay-guided synthesis and computer-assisted design. In the areas of cancer and infectious diseases, it is generally agreed that natural drugs provide perhaps the best opportunities.

Because of the enormous biodiversity, marine environments provide the most prolific sources for new, natural drugs. This has been recognized by academic scientists and pharmaceutical researchers, leading to two current drugs (for cancer and pain control) on the market, and more than 25 additional marine-derived drugs currently being evaluated in human clinical trials [3].

Despite the enormous benefits, the US pharmaceutical industry has been slow to embrace marine drug discovery. This has not been the case with the smaller biopharmaceutical industries (“Biotech”), which are less risk averse and can create and utilize new technologies in more dynamic ways. The linkages between academic scientists familiar with the ocean and its biodiversity, and biotech industries capable of development and sales, is a crucial one allowing the oceans to be explored. It is this aspect of science policy that should be underscored as the resources of the ocean are developed.

Secondary Benefits of Marine Drug Discovery

It is important to understand that the process of natural drug discovery has enormous additional benefits to medical research. Often, new drug candidates are discovered that, for numerous reasons, are recognized to be unsuitable for treating human disease. At the same time, these agents possess unique pharmacological properties and affect human biochemical pathways that were previously unknown or poorly understood. Known as “molecular probes”, these compounds have enormous utility in medical research. One such probe, known as aequorin or Green Fluorescent Protein (GFP), is a protein isolated from the jellyfish *Aequorea victoria*. GFP, which can be linked to drugs and other proteins, has revolutionized the study of human cell biology. This led to the award of the 2008 Nobel Prize to Chalfie, Shimomura and Tsien, for their discovery and development [4].

How Will Climate Change Impact Natural Drug Discovery?

The biodiversity we currently enjoy is not guaranteed as we recognize the impact of global climate change. Populations of marine organisms are already beginning to decline or to migrate to new environments. While we can measure the impact on macroscopic marine life, and have done so in many areas, the impact on microbial communities, because of their more limited temperature adaptation, is likely to be greater.

Why do we care?

Microorganisms are historically the most prolific sources for new drugs. The discovery of penicillin in 1929 heralded the great “antibiotic era”, which produced virtually all of the antibiotics we use today. Microbial antibiotics are produced by cultivation of bacteria

and fungi in large-scale fermentors. The oceans are a major, untapped resource for bacteria and other microorganisms. Seawater is composed of 28 million microscopic cells per ounce. The bottom sediments, which mimic the soil, contain more than 1 billion cells in the volume of an ordinary cube of sugar. This is an amazingly unique community that is distinct from its terrestrial counterparts. Currently, at least 2 anticancer drugs, produced by marine microbes, are in clinical trials for the treatment of various forms of cancer [5]. When one considers the medical emergency we face with drug-resistant infectious diseases, and the fact that microorganisms are the best source for new antibiotics, it is clear that marine bacteria and fungi represent the next great source for the discovery of new antibiotics to control human infectious diseases.

Recognizing the important role marine microorganism will play in the future, it is disconcerting to consider the impact of global climate change on their survival and distribution. As the temperature of seawater increases, temperature adapted microorganisms typically illustrate stress responses. Thus, in several ways, the diversity of the ocean and our ability to use this amazing resource are linked to our future success in controlling global change.

1. http://www.usatoday.com/money/industries/health/2008-03-12-drug-sales_N.htm
2. <http://www.drugs.com/top200.html>
3. D. Newman and G. Cragg, Chap. 12 in *Bioactive Natural Products, Detection, Isolation and Structure Determination*, Steven M. Colegate, Russell J. Molyneux, eds., CRC Press, 2007.
4. <http://www.conncoll.edu/ccacad/zimmer/GFP-ww/GFP-1.htm>
5. <http://www.nereuspharm.com/>