tides. According to Udenfriend, some of these larger peptides are more active than the enkephalins themselves. Proenkephalin B contains the sequences of α-neo-endorphin, dynorphins A and B, and Leu-enkephalin.

The structures of these polypeptides show the potential for differential processing. Although the work is much less advanced than that on POMC, the Udenfriend group has evidence suggesting that proenkephalin A may undergo differential processing. At Stanford University, Jack Barchas and his colleagues have been studying the brain distributions of the peptides contained within the proenkephalin B molecule and have found indications that the manner in which this molecule is split may vary with its cellular location.

Whether the three genes have the same evolutionary ancestor is unclear. The overall organization of the three is similar. They resemble each other in size and in the positions of their introns. And all the polypeptides contain six cysteine residues which are clustered near the amino terminals. Evidence of repeated nucleotide sequences within the individual genes suggest that each arose by the duplication of a short primordial gene segment.

They may not all have arisen from the same segment, however. Except for the short sequences coding for the enkephalin moieties found in all the active opioid peptides, the nucleotide sequences of the genes are dissimilar. Roberts suggests, "It almost looks like convergent evolution, but these genes appear to be extremely old." Opioid peptides have even been found in single-celled organisms such as *Tetrahymena*. Their lengthy evolutionary history could have allowed many changes in nucleotide sequence to accumulate.

However the genes evolved, the result is that a large number of different but related neuropeptides can be made with a great deal of economy and the flexibility to allow the composition of the final mixture of products to vary in response to dissimilar circumstances.

—JEAN L. MARX

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Are the Ocean's Deserts Blooming?

According to the standard method the central oceans are impoverished, but new measurements show them to be many times more productive

Are the vast central regions of the ocean biological deserts? They are, according to measurements using carbon-14, the standard method of the past 30 years for measuring the primary production of the oceans. Although they cover almost half the area of the world ocean, these least productive or oligotrophic waters have been thought to account for only about 20 percent of the organic matter created through marine photosynthesis, or perhaps 10 percent of all primary production. But many biological oceanographers have grown leery of the carbon-14 method as various potential methodological problems have arisen, ranging from the inadvertent removal of some photosynthetic organisms to mass poisoning with trace metals.

Investigations of the carbon-14 method itself have not yet revealed the magnitude of the error in oligotrophic waters, but some physical oceanographers are claiming that their methods reveal such areas to be many times more productive than indicated by the carbon-14 method. A major difference between the two approaches is the scale of an experiment. Biological oceanographers pour a few hundred milliliters of seawater into a glass bottle, add carbon-14–labeled carbonate, and wait a few hours while the phytoplankton, floating microscopic plants, convert the carbonate into organic matter. Then, the experimenter filters the water and measures the decay of carbon-14 incorporated in the trapped particulate matter. Physical oceanographers, on the other hand, measure the effects of photosynthesis on tens or thousands of cubic kilometers of seawater over months, years, or decades.

In one such large-scale experiment, Eric Shulenberger of the Natural History Museum in San Diego and Joseph Reid of the Scripps Institution of Oceanography used a bottle, of sorts, that forms every summer over hundreds of kilometers of the central North Pacific. The sun-warmed water within 20 meters or so of the surface forms a stable layer or cap over the cooler water below, bottling up the oxygen produced there by photosynthesis. The bottle lasts several months, but fails to contain oxygen produced within the warm surface layer. That gas steadily leaks to the atmosphere.

Ignoring this leakage and other losses that would increase their measured productivity, Shulenberger and Reid calculated the rate of primary production that could account for the trapped oxygen. At oligotrophic sites north of Hawaii that were surveyed in 1975, the productivity implied by the trapped oxygen was two to seven times higher than carbon-14 values determined at the same sites. Because of the conservative assumptions, the gap between the results of the two methods may be even greater.

> The productivity measured by Jenkins is only double the accepted rate for such waters, but his measurement neglects most of the organic matter photosynthetically produced in the central ocean.

Recently, William Jenkins of the Woods Hole Oceanographic Institution experimented with a longer lasting bottle that stretches from one side of the subtropical North Atlantic to the other. In-

stead of measuring the rate of oxygen production in shallow water, Jenkins determined how fast oxygen had been consumed in deeper water. Organic matter that falls out of the shallow productive, or euphotic, zone consumes oxygen as as it is recycled to carbonate. The total consumption of oxygen was the difference between the measured amount of oxygen dissolved in water deeper than 100 meters and the maximum amount the water would have contained when it was last at the surface in contact with the atmosphere.

To determine a rate of oxygen consumption, Jenkins found how long ago water had been at the surface by measuring its tritium, the radioactive isotope of hydrogen produced by atmospheric nuclear testing, and its helium-3, the decay product of tritium. Added to the surface layer as a part of water molecules, the tritium tracer steadily decays as the water mixes to greater and greater depths. Water at a depth of 400 meters in Jenkins' eastern North Atlantic study area had been circling the great subtropical gyre for as much as 10 years since it was last at the surface.

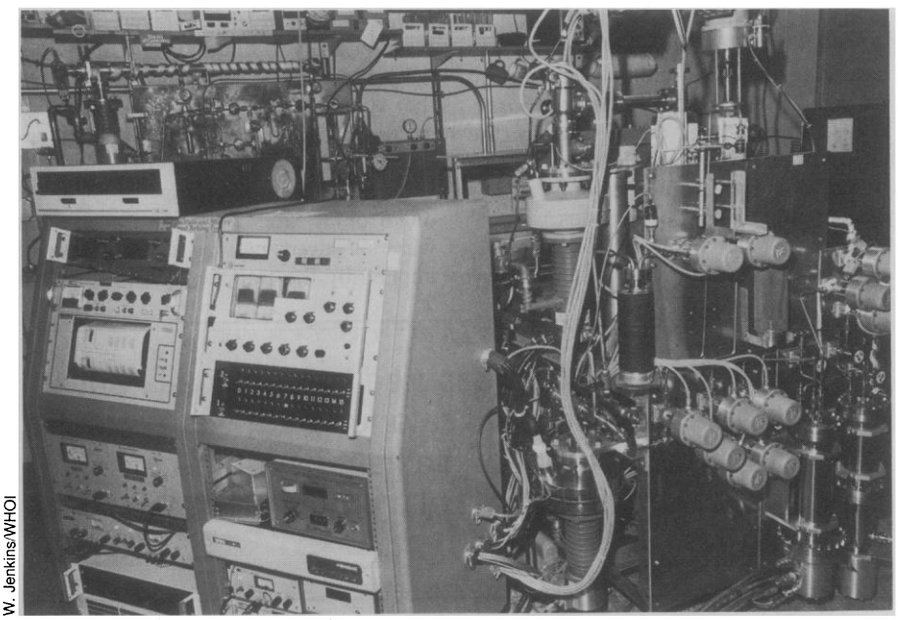
The rate of oxygen consumption measured by Jenkins implies that every year 55 ± 5 grams of organic carbon sank from each square meter of the oligotrophic waters of the subtropical Atlantic. That figure is in surprisingly close agreement with an estimate made 30 years ago by Gordon Riley of Dalhousie University, without the aid of such a short-lived tracer.

The productivity measured by Jenkins is only double the accepted rate for such waters, he notes, but his measurement neglects most of the organic matter photosynthetically produced in the central ocean. Perhaps 80 or 90 percent of it, according to current thinking, is consumed, broken down, and recycled by everything from bacteria to whales before it ever has a chance to fall from the euphotic zone. Thus, this large-scale experiment, as well as that performed by Shulenberger and Reid, provides a measurement of net production; gross primary production, the total production of marine photosynthesis, could be five to ten times higher still. That would approach the theoretical limits of photosynthesis in the central oceans, based on the sunlight absorbed by phytoplankton and the photosynthetic efficiency of chlorophyll. Biological oceanographers had assumed that the central oceans' less-than-optimum rates reflected the limited availability of nutrients.

One possible explanation for the large gap between methods is that there is nothing wrong with the carbon-14 method—it accurately measures whatever happens in a particular tiny sample of seawater. Instead, the problem might be that even thousands of quarter-liter samplings from dozens of different research ships cannot accurately sample an entire ocean. Primary production outside of the tropics tends to come in seasonal bursts. If oceanographers have not sampled often enough to accurately assess the bursts or have sampled too often between patches of intense production, they will have underestimated true production. Large-scale experiments that average production over seasons or years and over thousands of kilometers do not have that sampling problem.

Another possible explanation would be that the carbon-14 method does not even measure all of the production in a glass bottle. Suggested shortcomings in the method have been numerous. Phytoplankton cells could rupture under the strain of filtration, spilling labeled organic matter into solution. If too coarse, a filter might not retain the smallest photosynthesizing organisms. Recently, blue-green algae about a micrometer across—the size of bacteria—have been found to be abundant in oligotrophic waters and major contributors to primary production. The mere act of enclosing a bit of the ocean in a bottle might have ill effects, through the disruption of delicate phytoplankton or some unspecified effect of the bottle wall. Bottles or other equipment might even leach toxic metals into the seawater, sickening or killing phytoplankton.

In the summer of 1982, a group of oceanographers evaluated many of these potential problems in a study of plankton rate processes in oligotrophic oceans (PRPOOS). According to PRPOOS coordinator Richard Eppley of Scripps, none of their variations of the carbon-14 method or alternative methods produced results that conflicted with the standard carbon-14 method. That was not the final test, however, because productivity in the study area off Hawaii was relatively high for a central ocean, due to the proximity of the islands. The real problems with carbon-14 measurements will be found in truly oligotrophic waters if anywhere, researchers believe. The PRPOOS group plans to tackle such waters in the summer of 1984. Until then, doubts about the central oceans' label as deserts will persist.—**RICHARD A. KERR**



W. Jenkins/WHOI

Mass spectrometer system for tritium-helium-3 dating

In order to use oxygen consumption in deep water as a measure of primary production, this system is used to determine the "age" of a seawater sample, the time since it was last at the ocean surface. The piping system to the right separates helium from all other gases in the sample, and the mass spectrometer on the left measures the amount of helium-3 with a sensitivity of 1×10^{-16} cubic centimeter (STP), or about 3000 atoms. The two canisters at the lower right are cold traps capable of temperatures of 50 and 10 K. Helium trapped at 10 K is warmed to 40 K, driving it out of the trap and leaving neon behind. The original helium is extracted directly from a seawater sample, but tritium (hydrogen-3) is determined by measuring its helium-3 decay product after a year of storage. At the concentrations of tritium remaining in the North Atlantic from atmospheric nuclear testing, this method can detect an age difference as small as about 1 month.

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