John Swallow, F.R.S. 1923–1994

John Swallow died suddenly following a heart attack at his home in Cornwall, England last December, 1994 aged 71. He was as busy as at any time in thinking about and illuminating the character of the large-scale circulation. I want to write about what made him such a fine oceanographer, colleague, and friend of many of us. For the record, I've included a chronology of the bare bones of his career and a complete list of his publications.

In 1954, at the National Institute of Oceanography, Wormley in the UK, some of us were trying to find a way to measure deep (slow) ocean currents. We had come up with what one could call a prehistoric version of the Pegasus system developed at the Woods Hole Oceanographic Institution in the 70's. It didn't succeed. The seals used on the equipment, based on shallow-water technology, were inadequate for deep water. It was difficult to make a taut mooring (dan buoys on thin piano wire were standard) and the broad spectrum down to tidal frequencies cast doubt on the profiling method that we had adopted.

However, out of disappointment came success. John Swallow had come to the lab with Maurice Hill of the Department of Geodesy & Geophysics at Cambridge to discuss the use of geophysics technology (sonar receivers and short-term deep-sea mooring techniques) to our experiment. Having nearly finished his Ph.D., and with impeccable timing by Dr. Deacon, the Director of NIO, he accepted the offer of a job at NIO to work on deep current measurements. Unusually for a graduate student, he had had several years at sea in HMS Challenger on its round-the-world surveying cruise. John was collecting seismic profiling data on sediment thickness for his Ph.D. This background of seismic observation brought a wealth of practical knowledge, some of it not widespread in physical oceanography, knowledge about moorings and navigation and O-rings and electronics. The war years, when he served with the Navy maintaining radar systems, were a very practical interruption of his university career. They were also his first introduction to the Indian Ocean at the Trincomalee naval base in Ceylon (Sri Lanka).

He himself remarked that his geophysical acquaintance with the effects of compressibility led to the critical idea that it was practical to build an instrument less compressible than seawater that could be stabilized at depth and that could be tracked over many weeks. This was to revolutionize our understanding of deep circulation, as the only instrument capable of measuring extremely small currents over periods of time. Even measurements with the new long-term deep current meters could not reach the threshold measurement of "Swallow" floats. The descendants of these early pieces of aluminum tube, the ALACE and RAFOS and MARVOR floats, have built on these early beginnings and made possible the precise global measurements of the deep water flow that are happening today.

Putting the technique to work effectively demonstrated another quality useful in experimental science. If a technique works, then first and foremost use it—make improvements when possible, but use it. The eastern Atlantic was not the ideal place to establish the new technique, radio-navigation was non-existent offshore, and as it turned out the "mean" currents were very small (1–2 cm/sec). So, with range fixing of the floats possible to a fraction of a km, the challenge was to convert that to an absolute reference frame. Trivial these days with the Global Positioning System, but not then. It was traditional in the Discovery Investigations and post-war in NIO to maintain echosounding watches in deep water and to extend the accuracy of the echo sounder, so there was the basis of a good map of the eastern Atlantic with the abyssal plain and its bumps mapped to the nearest metre or two. These small features in the deep sea floor provided the reference. Each fix took several hours instead of the few seconds we expect these days anywhere in the world.

In the mid 1950's Henry Stommel's ideas about deep circulation were ripe for testing. These led to a life-long collaboration between Henry and John. A joint cruise of *Atlantis* and *Discovery II* demonstrated a high-velocity deep southward flow under the Gulf Stream, consistent with the idea of an undercurrent. This was followed by the 15-month-long observations in the *Aries* in 1959–60, originally planned to examine Stommel's hypothesis of deep poleward flow in the ocean interior. This was an intensive period of sea-going, with the Bermuda Biological Station as home port. John's wife Mary, librarian of NIO and later co-editor of *Deep Sea Research*, whom he had married the year before, maintained the radio contact between the ship and the Bermuda Biological Station.

The deep water proved rather energetic, moving at 10–20 cm/sec, and was certainly not amenable to short-term observation of the mean flow. This led to a significant reorientation of the plans and redesign of the floats. They had been designed for use over many months with clocks controlling their duty cycle to preserve battery power. Both the intellectual challenge, confronted with the unexpected, and the technical challenge far from the lab, were met. He was quickly back at sea with a set of free-running floats, double in number through saved buoyancy, which in retrospect may well have been more robust than the initial design. The 15 months of observation that followed established the significance of mesoscale eddies in the ocean and over the next decades shifted the direction of theoretical and observational studies of deep-ocean dynamics.

This *Aries* experience illuminated others of John's characteristics. There were occasions when the *Aries* was short of a cook in the 6-man crew, or someone to fix the engines. On these occasions, between stations, we rediscovered his interest in food and cooking, already known to his shipmates on HMS *Challenger*. This interest kept us on schedule and gave us good food.

The 63–64 cruise of the new *Discovery* to the Indian Ocean in the International Indian Ocean Expedition marked the early beginnings of the main work of the last 30 years of his career before and after retirement. The monsoon regime gave rise to insights into western boundary and equatorial currents under a dominant seasonal forcing. These led to strong theoretical interest in the detailed description of the processes. Practically, there were real problems in making good hydrographic profiles in a current of 5 knots shearing to near zero at 100m. Did one let the ship drift with big wire angles to get a good localized vertical profile in the deep water? Spice and excitement were added to the occasion by having our biologists aft working their nets at the same time as the hydro work forr'd. Leadership of high quality is called for in such multidisciplinary cruises.

The return home through the Red Sea was the occasion for one of those occasions of special excitement that are particularly rewarding through their infrequency. The presence of anomalous water of higher temperature at the bottom of the Red Sea had been known but the high temperature brine of the "Discovery Deep" in the Red Sea median valley was quite unsuspected. It was to provide a nice field demonstration of one of the modes of double diffusion, which was being studied actively at WHOI and Cambridge.

Back in the North Atlantic, work with Val Worthington in the Labrador Sea in winter led on a few years later to the idea of studying, with WHOI and with the group at the Muséum National d'Histoire Naturelle, the onset of deep convection in the NW Mediterranean. The MEDOC (MEDiterranée OCcidentale, or maybe, MEDiterranean OCeanography) experiment proved to be a good vintage. The formation regions of deep water in the open ocean were rather remote and difficult to observe, particularly in winter. There were very few observations to support the process. The thought that the NW Mediterranean off the Rhone fan might be a mini-laboratory for the process proved fruitful. A combination of strong evaporation and winter cooling from the Mistral led to the notion of a pre-conditioning phase involving rapid cooling and evaporation of the surface followed by deep overturning in narrow chimneys to depths of 2000m and greater in a day or two. This was a good paradigm for the open ocean. The sub-zero temperatures and gales also gave all on the *Charcot, Discovery*, and *Atlantis II* an alternative view of the climate of the Riviera. It was still preferable to high latitudes in winter. The planning meeting for that multiship programme took place on just one day at the Institute of Oceanographic Sciences (formerly the NIO), Wormley.

A decade on from the *Aries* work there was the opportunity to take part in the Mid Ocean Dynamics Experiment (MODE) in the west Atlantic. This experiment was specifically designed to study the mesoscale in a two-degree box over several months in 1973. It involved a mix of many US labs, of theoreticians and experimentalists, and of new and standard techniques that provided a wealth of data. John brought the *Discovery* along and used his short range floats to make a more intensive "mini-mode" study of a small part of the area. The larger area was covered by moored current meter arrays and the longer-range sofar floats.

Following MODE John's interests turned more to the Indian Ocean and he embarked on a 20-year-long collaboration with Michèle Fieux, Fritz Schott, Bob Molinari, John Bruce, Bruce Warren, and others which ranged widely over the Indian Ocean. The Somali current, the equatorial regime and the fine structure of the currents there in the vertical, and most recently the Indonesian throughflow were illuminated in a series of 38 papers and reports.

He was always ready to spend time on meetings planning for specific scientific programs, most recently for the current Indian Ocean phase of the World Ocean Circulation Experiment and the Joint Global Ocean Flux Study.

Retirement in 1983 was in name only in terms of work. Seagoing continued and publications if anything increased. Very recently he was contemplating the purchase of a computer but his contributions to the collaborations were perhaps even enhanced by the lack of distraction that the purchase might have brought to his working day.

He and Mary made their home in Cornwall, looking out on Dartmoor (when the mist wasn't down), and close to that of their much loved Lucy, Mary's daughter, who sadly died a year before John. It was a place for colleagues to visit and to work in peace, and in which to enjoy great hospitality.

James Crease
April 1995

Career

St Johns College Cambridge 1941–43
Admiralty Signals and Radar Establishment, Haslemere & Trincomalee Royal Naval Base, Ceylon (Sri Lanka) 1943–47
Research Student, Dept. of Geodesy and Geophysics, Cambridge 1947–54
Ph.D. Cambridge 1955
Scientific Officer-Deputy Chief Scientific Officer at NIO/IOS, UK 1954–1983
Rossby Fellow, Woods Hole Oceanographic Institution 1973–74

Honours and Awards

1960 Albatross Award of the American Miscellaneous Society (an Albatross acknowledges a Swallow!)
1962 Bigelow Medal, Woods Hole Oceanographic Institution
1965 Murchison Grant, Royal Geographical Society
1968 Fellow of Royal Society of London
1978 Sverdrup Gold medal of the American Meteorological Society
1984 Prince Albert I of Monaco Medal
1994 Stommel Medal, Woods Hole Oceanographic Institution