### Scientific Biography

### I. General Overview

*Long and short-term environmental changes affect and modify complex biological systems on a multitude of levels. From a strictly anthropocentric standpoint the understanding of such processes can assist in perceiving the current changes our ecosystems are undergoing. Our own habitat has entered an unfamiliar zone in terms of global carbon biogeochemical cycles, as atmospheric CO2 levels rose for the first time in 420,000 years above 280 ppmv. These changes are bound to have significant effects on the global climate as the deviation from the glacial interglacial steady state increases. I have chosen to study two systems, corals and marine phytoplankton, which may assist in elucidating complex systems reactions to environmental shifts. My choice to study these systems is due to their evident responses to environmental changes and their abundance throughout the geological record, thus providing contemporary physiologically measurable subjects that can be manipulated in the laboratory or tested in-situ. Additionally, these two systems leave behind skeletons that are harboring possible markers that can uncover past climatic events. Both systems have a substantial fossil record that can help unravel the evolutionary changes that occurred following these events. Yet another benefit arises from investigating these two systems simultaneously; a better understanding of the physiology of phytoplankton increases the chance of correctly interpreting data from the much more complex coral symbiosis.*

*My overarching research aspiration is to enhance our understanding of the fundamental effects of global climatic changes on the marine environment, through coral and phytoplankton systems.*

**II. Significant research achievements**

# a. Coral bleaching

The threat of coral bleaching on a global scale is a growing concern both because of the reduction in essential ecological services provided by zooxanthellae (symbiotic algae) containing corals within reef communities, and the potentially devastating economic impacts of their demise. Coral bleaching is the largest natural cause of coral death. During the 1997-1998 El Niño-Southern Oscillation (ENSO), 16% of the world's coral reefs died.

My current research aims to unravel the causes of the physiological causation of coral bleaching and the evolutionary and ecological impact of these processes on corals and reefs respectively. We have revealed (Tchernov et al. 2004) that the resilient clones of zooxanthellae show a genetically encoded adaptation to higher temperatures, resulting from changes in the lipid composition in the thylakoids that confer resistance to elevated temperature stress.

In addition, we are currently studying the response of coral tissue under thermal stress, and have found that the coral goes through programmed cell death (PCD). Interestingly, some corals, which proved to be resilient to thermal stress, are capable of biochemically inhibiting PCD (publication pending).

The coevolution (if indeed a reciprocal evolutionary change in interacting species has occurred) of scleractinian corals and zooxanthellae started as early as the Norian period (A sub-division of the late Triassic period, from 220.7 to 209.6 Ma.), however, very little is known about the evolutionary mechanism that led to the formation of this symbiosis and to the conditions that maintained it for such a long period. This leads to major questions, such as 1) Perhaps coral bleaching is just a selective mechanism that is an integral part of algae-coral coevolution? And 2) On the other hand, coral bleaching might be a consequence of the latest climatic changes brought about by anthropogenic activity?

I am currently developing a new paleo-proxy that could shed light on past bleaching events, through the detection of Boron 11 isotopes in the coral skeleton. This paleo-proxy coupled with Sr/Ca ratios and 14C or 230Th-234U-238U isotopic compositions may indicate the time, temperature, and severity of such events in the past. Such a proxy will create a new way to validate or dismiss any of the current hypotheses. Moreover, it would be possible to determine if during the last 150 years, the frequency of bleaching events is increasing, and what the occurrence rate of bleaching was during previous interglacial periods. In addition to bleaching, we are experiencing an acidification effect that is derived from the increased CO2 concentration in the atmosphere over the past 150 years.

**b. Ocean Acidification and its affect on Corals and Phytoplankton**

In addition to bleaching, we are experiencing an acidification effect that is derived from the increased CO2 concentration in the atmosphere over the past 150 years. It is important to understand how this phenomenon is affecting the inhabitants of the marine realm. In our current research (Fine and Tchernov 2007), we have discovered that corals can withstand low pH values (7.2-7.4 versus modern value 8.2). The corals lose their aragonite skeleton which disassociated while their polyp biomass increased fivefold. Moreover, the coral lost its colonial structure and separated into a multitude of single polyps. These polyps maintained their reproductive ability.

This find has vast implications on our understanding of coral evolution in light of the fact that marine pH has shifted dramatically during the earth's history. There are two major 'reef gaps'- a period in the geological record which is absent of coral fossils. One occurred during the Permian-Triassic mass extinction event (251 million years ago) and another occurred during the Triassic-Jurassic boundary extinction event (206 million years ago). The lack of fossilized coral in the geological record during those periods can now be better understood. Interestingly, molecular clocking has produced a phylogenetic tree that dates the origin of scleractinian corals at 280 million years ago, yet there is no such marker in the geological record. Again, our findings provide an explanation for this incongruency.

I am currently expanding this research to a multitude of species and testing both their physiological and biochemical reactions to acidification in an attempt to elucidate the mechanisms behind those very dramatic responses.

In addition, we have found that the colony separation into individual polyps is executed through apoptotic pathways. This finding is linked to the apoptotic response that we have discovered is heat-stress related and causes, in many cases, the annihilation of the whole colony. Therefore, these studies are providing a broader view of the evolution of corals in light of their changing environment over their history.

I am also pursuing questions related to how acidification impacts phytoplankton in the water column as a means to create a dependable tool for paleoreconstruction of past climates. A major determinant of global climate is the atmospheric CO2 concentration. A possible tool for making such assessments is through the use of various forms of organic phytoplankton remains in the sediments. These methods have been developed and tested during the last decade and found to be lacking in several aspects, mainly these methods did not consider significant physiological characteristics of phytoplankton such as active carbon transport. I have developed a model that may be capable of extracting paleo atmospheric CO2 concentration values from the stable carbon isotope composition of phytoplankton, considering the typical physiological parameters for each species. The model is based on both in situ and in vivo measurements. This work is summarized in two separate manuscripts (Tchernov and Lifshultz *in revision*, and Tchernov et al. *submitted*) that show the impact of temporal and spatial changes in the water on the stable carbon isotopes composition of phytoplankton.

**c. Deep Coral Physiology**

Most of the world's reefs lie below a depth of 50 meters, and normally continue to 150 meters, particularly in the Indo-Pacific realm. This means that most of the reef has never been thoroughly investigated due to technological limitations. Recently, due to advancements in SCUBA technology (namely, more accessible and affordable TRIMIX and rebreather systems) it has become possible to study the coral reefs at these depths in Eilat. Because this is an entirely new research area, there is a substantial amount of work underway analyzing and understanding the basic physiology of the organisms living in those deep reefs.

Our findings include the description of a totally new photosynthetic pathway and organization. Deep corals and also macroalgae seem to have an extremely low photosynthetic rate and an almost complete absence of PS1 functional response. In the case of corals, this makes this symbiosis questionable in terms of the benefit of the hosts. We believe that the host is actually contributing carbohydrates to the algal symbionts. If this is true, it redefines the nature of the symbiosis between corals and their algal symbionts.

Surprisingly, the photosynthetic organisms that dwell at those depths have not lost their ability to produce high rates of photosynthesis at high light intensities, and do not show the characteristic non-photochemical quenching evident from corals and macro algae living in shallower depths.

We are currently in the final stages of fortifying and retesting these results using different techniques prior to publishing. Because of the novelty of this research, in the process of analysis we have developed new techniques and machinery that enable us to acquire data. For example, we have now a membrane inlet mass spectrometer that is linked to both a fast repetition rate fluorometer and a pulse-amplitude modulated fluorometer, especially modified for this purpose. I believe that this is a promising new research direction that will be the foundation for a wide range of studies in the future.

**III. Scientific public service:**

Since October 2004, I have been serving as the administrative director of the Interuniversity Institute for Marine Sciences (IUI). This institute hosts seven universities and one college in their hands-on marine research and provides courses which teach over 250 students per year. The IUI is the only marine biology facility in the country that is under academic criteria and is directly budgeted via VATAT. We are currently employing six resident scientists and over forty students. In addition, the institute hosts over 30 Israeli research groups that perform active research from this facility. The IUI hosts several international expeditions and courses each year including a wide variety of foreign institutions. My responsibilities as administrative director include not only pure administrative task such as managing fifty-five employees, an annual budget of over ten million sheckels, but also to represent our institute to the municipalities and educational bodies pursuing its development and growth.

#### IV. Future plans

My future research plans include the expansion and continuation of research described above. The following interrelated themes summarize the focus of my research for the near future:

1. *Ocean acidification*

Anchored in the findings thus far, I am turning to a wide-range of species and genuses to try and learn about the more general responses to a low pH environment. I also intend to investigate the biochemical and molecular pathways that lead to these acute responses. My overarching goal is to form a sound evolutionary study that will reflect on their response to their changing environmental conditions.

(2) *Coral Bleaching*

The research to date has shed light on the fundamental physiological reason that bleaching occurs under thermal stress. From this point forward, I will pursue the impact of bleaching on the host and the differential response that occurs amongst different species. I believe that a better understanding of the mechanistic processes of cell death in corals is crucial to our understanding of both coral ecology and their evolution.

(3) *Paleoproxy* *development*

a) Coral paleo-bleaching proxy. At this point in time, we are in the midst of a controlled experiment that will be the basis for the Boron isotope method for paleo-bleaching determination. I plan to begin collecting cores from several locations in the world's oceans that represent different environmental conditions and analyze them for both Boron isotope ratio and other paleo proxies. I am highly committed to continuing this research as it will be able to produce conclusive answers to whether coral bleaching is related to anthropogenic fossil fuel consumption or rather, that it is part of a naturally occurring pattern.

b) Paleoclimate reconstruction via phytoplankton. I intend to continue my research on coccolithosphores and diatoms and further characterize their responses to environmental changes and the impact it has on their isotopic composition. My ultimate goal is to refine my model for paleoreconstruction via ODP cores and their algal remains.

(4) *Deep Reef Investigations.*

The deep reef represents a nearly endless source for novel and relevant research. I choose to focus on the photosynthetic questions that challenge the organisms at those depths. I will further investigate the photosynthetic apparatus of both the algal symbionts of corals and macro algae in order to elucidate the photosynthetic mechanism that is manifested in those organisms. My final goal is to create a bioenergetic model that will explain the way these creatures operate in the deep, along with a precise photosynthetic mechanism.