



Ted Wu

Man in the Swim

The aqueous environments of planet Earth have kept Theodore Yao-Tsu Wu, professor of engineering science, fascinated for 25 years. Not only the visible ones, which range from oceans down to ponds, but the flows within living creatures as well, and now even the propulsion of microorganisms.

In the course of his studies Wu has become an international authority on the design, stability, and propulsion of ships. He is equally recognized for his knowledge of tidal waves, and of how swimming creatures—from microorganisms up to whales—propel themselves. His theoretical work on microorganism propulsion, which is being done in cooperation with a physiologist and several engineering scientists, is expected to answer many heretofore unexplained mysteries about this vital area of life.

Wu's research interests have always been strongly theoretical—which is not surprising, considering his nationality. "China," he says, "has produced few experimental scientists, for the simple reason that, until recently, there was not enough scientific equipment in the country to work with."

Ted Wu was born in Changchow, a city 100 miles northwest of Shanghai, in 1924, when the country was in constant ferment. Internally, the Nationalists and the Communists were squaring off. Externally, Japan was a

growing threat (and soon precipitated the Sino-Japanese War).

Ted's life and schooling were marked with all the turbulence and disarray of leaves in a whirlwind. Even so, he received an excellent education because his father, a banker-economist, recognized his son's ability and insisted that he get the finest education possible—even if it meant sending him hundreds of miles from home to find it.

He rarely stayed in any school for very long, because the place would inevitably be in the path of Japanese aggression, and would have to pack up and relocate, or disband. He was fortunate enough in high school to spend both his sophomore and junior years in one school in Shanghai, though the school changed locations two times because of bombings, or because the buildings were requisitioned for military use by the Japanese army.

Ted had always been interested in science. Even back in the third grade he had looked up all the astronomy articles he could find. Now, with some of his classmates, he started a science newspaper for students of high school age or younger. With the whole educational situation at sixes and sevens, textbooks were becoming scarce, and many young people were unable to find reading material in basic subjects.

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extraterritorial section of Shanghai controlled by Great Britain and France—and not even a small science paper with the slightest hint of Chinese patriotism was allowed to be printed there. But the students found a printer who thought it would be a privilege to help bring more knowledge of science to Chinese boys and girls—even if he had to print in a basement, behind locked doors. The paper had a thriving, if sub rosa, circulation. Copies were read and passed on, often to young relatives and friends in other parts of China.

The paper went out of business when Ted and his classmates had to flee Shanghai. For their senior year they found a high school out in the provinces, in an area dominated by Chinese guerillas. The students found lodging where they could. Some lived with the guerillas and, as Ted understates it, "even saw a little action" with them, between classes.

Ted graduated from high school in 1942, and he and his friends decided to try to enter Chiao-Tung University, one of the nation's finest. Originally located in Shanghai, the school had been moved almost 3,000 miles west to the wartime capital of Chunking. There was no public transportation and no direct way to go. Where there was a road, it wound tortuously along the high rugged gorges of the Yangtze River. But to the group of 20 boys and girls who set out, the trip was the lark of their lives.

Sometimes they hitched rides on boats, but mostly they traveled on foot, often through what Wu describes as "delicate areas" where they had to hide by day and travel by night. Otherwise, they were up by dawn and walking until dark.

The trip took four months. When the group arrived in Chunking in November, their number had dwindled to eight; the others had decided to stay at various points along the way.

The term was well under way, but the Ministry of Education was so impressed by the group's demonstrated desire to attend the university that it offered them special entrance examinations.

Even with a late start, Ted finished the university course in three and a half years, and was elected student body president in his junior year.

By 1945 Japan was too busy reeling from defeat by the allied powers to do anything more about China. Life there began to smooth out, and the university quietly moved back to its old home. Ted spent his final semester in Shanghai, united with his family, who had long since been forced to move from Changchow to the larger city.

After his graduation, Ted stayed on an additional year as a teaching assistant. By now his interests had definitely turned toward aeronautics. This was a frustrating field for a young Chinese, because the air force had been all but wiped out by the Japanese as far back as 1937, and the outlook for any kind of an aeronautics industry in China was still in a murky future.

Ted thought he needed some practical engineering experience before he started on his postgraduate studies, but his parents and professors insisted he finish his education. Actually, the prospects of continuing his education in a more orderly manner were looking up—although not particularly in China. World War II was over, but the Nationalists and Communists, no longer having to coalesce against the Japanese, were at each other's throats again. The educational system in China was still in chaos. But it was becoming easier once more for Chinese students to attend universities in the United States.

One of Wu's friends was already enrolled for graduate work at Iowa State University. He wrote Ted recommending Iowa on two counts: It was one of the few universities admitting students quarterly, so Ted wouldn't have to wait out the year; and the Middle West was so friendly that it was an ideal spot for a Chinese to get acquainted with a new country and culture.

So Wu left his family and friends for his longest educational pursuit yet. Someone once asked Wu if it hadn't been difficult, making the big jump from China to Iowa.

"Yes," he said seriously, "it took me two weeks to feel at home."

He made all kinds of friends, both on campus and off, from the landlady to students from other countries, and he was continually and delightedly surprised at the openness of the Americans in contrast to the more reserved Chinese.

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It was almost incredible to be going to school in a peacetime atmosphere. He soaked up the material in his courses like a dry sponge. But the greatest excitement of the year was the new doors that opened in his two favorite subjects, physics and mathematics.

Even as a college student in China, Ted had his sights set on Caltech. Now, news of what the Institute was doing in aeronautics was one of the hottest items on the national academic grapevine. Theodore von Karman had infused the Caltech aeronautics department with a hard-to-match vitality. And when Ted was accepted at Caltech in 1949 to study under Paco Lagerstrom (now professor of applied mathematics), aeronautics was bursting with the knowledge of impending developments. Work was just starting on super- and hypersonic flow studies, investigations into missiles, supersonic flight, and space flight.

Wu was struck by the Institute's smallness after sprawling Iowa State. And he had never been anywhere where people worked so hard or seemed so centered on what they were doing.

As much as he became immersed in his graduate work in hydrodynamics, there was one important diversion. Chin-Hua Shih, a chemistry student he had met during his last year at Chiao-Tung University, was now in graduate school at UCLA. In June of 1950 they were married. After she got her PhD degree, Chin-Hua joined the chemistry division at Caltech, and is now a research fellow.

Milton Plesset, professor of engineering science at Caltech, was on the committee for Ted's doctoral examination, and he still smiles when he remembers how "Ted was completely self-possessed because he knew his subject so thoroughly.

"We've been friends and associates for 21 years now," he says, "and it's been a pleasure—but no surprise—to see where Ted's come in that time."

Plesset considers Wu number one in the world in the field of surface hydrodynamics—the interface between the media of water and air.

"In ship theory, sea waves, cavity flow, and all other kinds of surface hydrodynamics, I can't think of anyone anywhere with his mastery of the subject, or who has made such creative contributions," Plesset says.

For a number of years Wu's research involved propulsion of slender bodies. He first became interested in this because of his work in that part of hydrodynamics

dealing with ship theory, where the study of slender bodies is a classic area. If ship bodies are to be designed to give maximum performance in the water, where better to look than at fish and their propulsion?

This logically took Wu into probing how fish swim. His fresh insightful theory work, tested against working models of fish observed in Caltech's hydraulics laboratory, agreed in large part with the experimental data obtained, suggested further paths of investigation, and brought forth some of the first understanding of physical principles underlying the movement of aquatic animals.

Wu's colleagues in this research effort were Milton Plesset; Chris Brennen, a senior research fellow in engineering science; research fellows Allen Chwang, John Blake, and Howard Winet, who is also a physiologist; and a group of graduate students.

His current research on the propulsion of small organisms is a different field for Wu, and one which, until recently, has been very limited. Now it is gaining in interest—and to an important degree because of Ted's theoretical work.

For the most part, microorganisms have been of concern only to biologists. In recent years a few theoretical men in fluid mechanics, like Wu, have felt they could contribute to analyzing and understanding the reasons for the varied and amazingly rapid propulsion systems of microorganisms.

Winet, Chwang (a former graduate student of Wu's), and Brennen are working with Wu in this new study. Brennen originally came from Oxford to work with Wu on cavity flow, but he soon became caught up in microorganism propulsion. The group has also added John Blake, a fellow of Trinity College, Cambridge, who formerly worked with Sir James Lighthill, a leader and pioneer in the field. Another participant this year is J. A. Sparenberg, a visiting associate at Caltech on leave from the Mathematics Institute of the Groningen University of the Netherlands.

Ted and his group, and colleagues in other countries—as well as an increasing number of biologists—feel that such studies will throw light on many physiological flows where further research is needed. They could, for instance, bring to light more information about why sperm swim as they do, the flow of ovum, and the interaction between sperm and ovum during fertilization. They could help us



THE MEN WHO WORK WITH WU: Christopher Brennen, senior research fellow in engineering science; Allen Chwang and John Blake, research fellows in engineering science; Milton Plesset, professor of engineering science; and Howard Winet, physiologist and research fellow in engineering science.

understand blood and lymph flows, and mass transport in the lung and kidneys. They might help explain the motility of bacteria, and give us more information on how to inhibit some bacteria without inhibiting others. The interaction with the biological stimulæ that create the movement in microorganisms is not known, but eventually it may be, because of better understanding of their propulsion.

Wu also believes that developments in this research may cast more light on the evolutionary thesis and “whether more than a billion years of continuous competition between various species of animals must necessarily have eliminated the less effective species in favor of those having the ability to utilize their optimal movements.”

Because of the physics, engineering, and biology inherent in this new approach, Wu’s associates have had their ups and downs in learning to work together. For one thing, the different “languages” of engineering, physics, and biology have been barriers to understanding.

“The language of biology is particularly diffuse in comparison to the others,” Winet says. “In everybody’s own specialty, one word can convey so much meaning, or lack of it. When we started working together on the microorganism studies, the difference between a genus and a species could be a *cause célèbre*! And a simple physical

principle could be a source of misunderstanding. There were many stumbling blocks to our interdisciplinary approach, but I’m sure everybody in our group thinks it’s been worth it.”

As a matter of fact, Chwang has been taking some biology so that he can meet Winet more than halfway.

Meanwhile, Wu keeps things both buoyed up and toned down. By nature a non-confronter, he turns negatives into positives, and also, his co-workers say, has a unique way of translating ideas into terms which they all understand. In fact, they admit, it has been Wu’s stability, kindness, and respect for others that has made them a successful working group.

His colleagues, his students, and anybody else who has ever needed anything from Ted are quick to volunteer that his helpful nature extends far beyond his research group. What seems to be a deep sense of the importance of the succeeding generations brings out in him a special sense of duty to the young, whether they are his own daughter and son—Melba, 13, and Fonda, 11—or students.

Francis Clauser, the chairman of the division of engineering and applied science, says, “I know Ted plays a greater role in the outside life of a lot of the students here than we know about. I just get glimpses once in a while. I know he’s brought students to this country, arranged scholarships—things I doubt he’d tell you about.”

Plesset agrees, saying that sometimes Wu gives so much he is sometimes imposed upon. “Anyway,” Plesset says, “I know we’re all richer for having him with us.”

—Janet Lansburgh