HISTORY AND TRENDS IN INSECT PHYSIOLOGY

Insect Physiology Oscar Awards for:

LIFE TIME ACHIEVEMENT AWARDS

Best system for studying feeding

a. Vince Dethier using blowfly
b. Reg Chapman using locust
c. Louie Schoonhoven using Colorado potato beetle

Best system for studying molting

a. V. Wigglesworth using Rhodnius
b. Lynn Riddiford using tobacco hornworm
c. Carroll Williams using cecropia moth

WHO DEVELOPS WHAT WE CALL THE SCIENCE OF INSECT PHYSIOLOGY?

- **SCIENTISTS**

Scientists & topics in insect physiology

1. 1934-Wigglesworth textbook appears-The Principles of Insect Physiology-9 editions of this book
2. 1953-Roeder's edited book-Insect Physiology
3. 1963-Beament, Treherne & Wigglesworth start the series, Advances in Insect Physiology. 2003 is the 31st volume
4. 1964-Rockstein's edited series-3 vols.-The Physiology of Insecta
5. 1969-Chapman's textbook appears-The Insects-Structure and Function. American Elsevier, N.Y.
6. 1973-Rockstein's update series-7 vols.-The Physiology of Insecta
7. 1980-Mordue, Goldsworthy, Brady and Blaney. Insect Physiology text in paperback. John Wiley & Sons, N.Y.
8. 1984-Wigglesworth's paperback textbook. Insect Physiology, Chapman and Hall, N.Y.
9. 1985-Kerkut and Gilbert series-13 vols.-Comprehensive Insect Physiology, Biochemistry and Pharmacology. Pergamon Press, N.Y.
10. 2002-Klowden's textbook. Physiological Systems in Insects, Academic Press, N.Y.
11. 2004-Gilbert, L.I. (ed.). 2004. Comprehensive molelcular insect science, 7 vols. Elsevier Pergamon, St. Louis, MO

Where are the women?

- Lynn Riddiford-Carroll William's student
- Judy Willis
- Anne Fallon
- Barbara Stay-Carroll William's student

Vincent B. Wigglesworth
Father of Insect Physiology

Wrote the first book on insect phsyiology in 1939.

The Principles of Insect Physiology. Methuen & Co., New York

Also known as 'VBW'

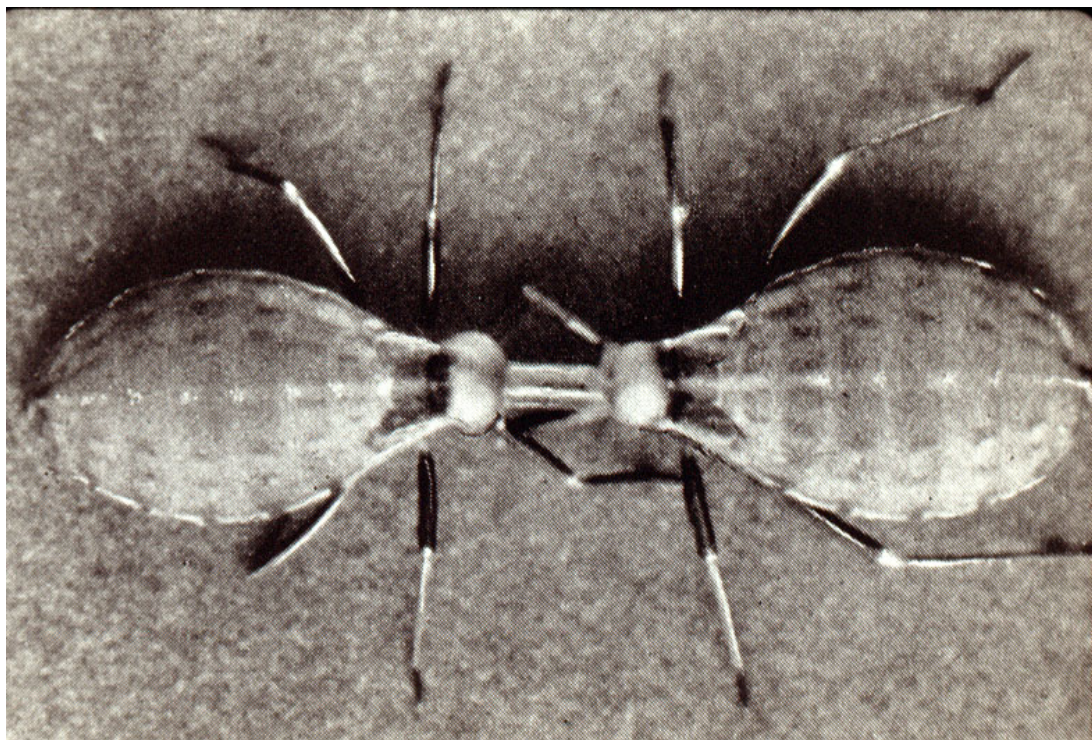
Areas he contributed to:

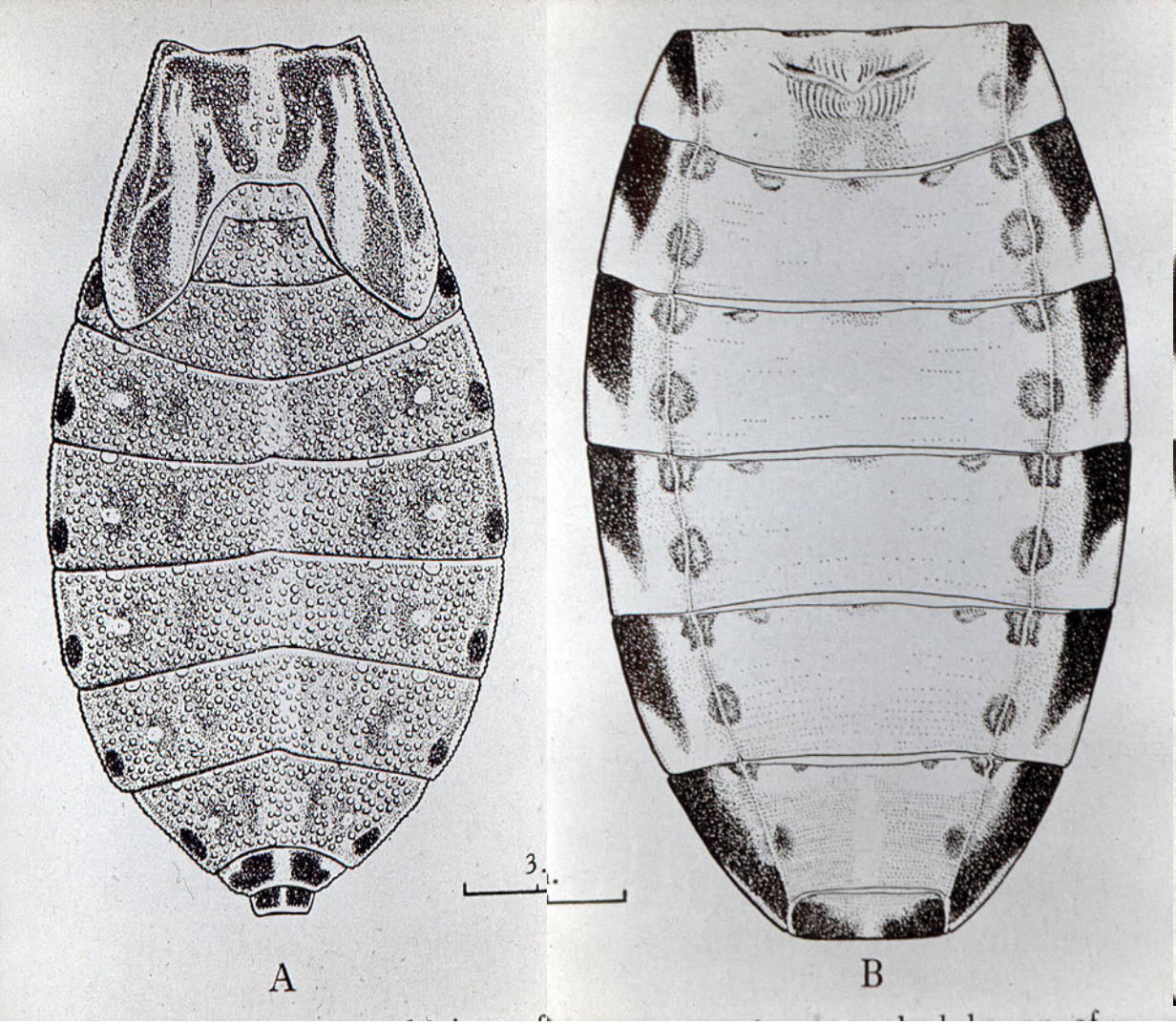
1. **Respiration in insect eggs**
2. **Molting**
3. **Cuticle**
4. **Every topic in insect physiology**

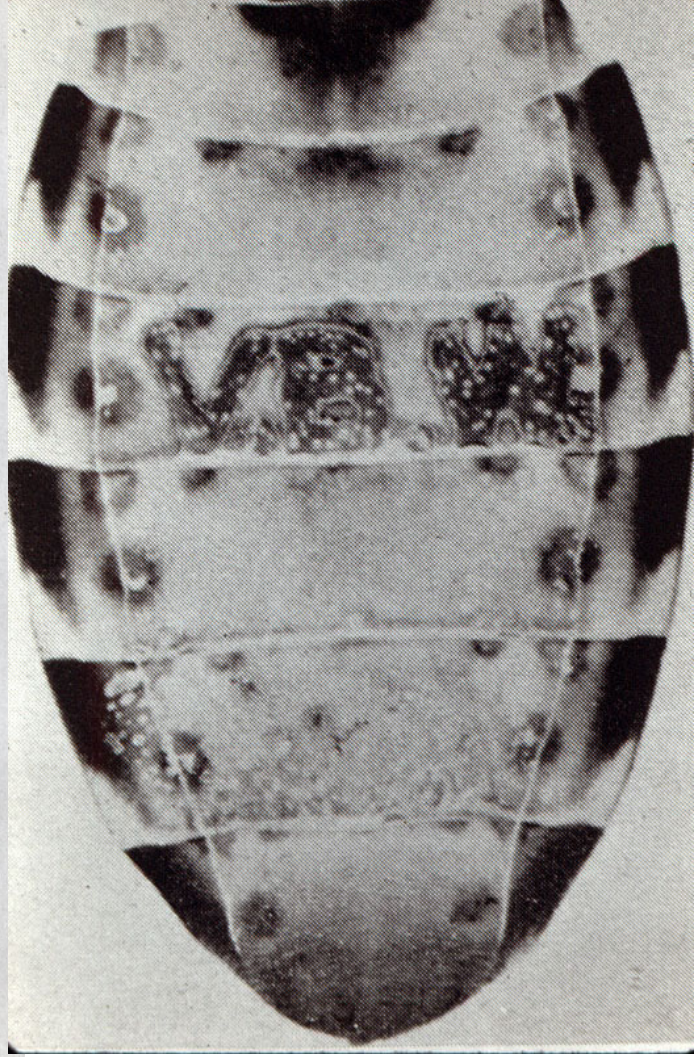
Wigglesworth did the classical experiment showing that JH could keep the epidermal cells from producing an adult cuticle at the last nymphal to adult molt in *Rhodnius prolixus*, commonly known as the kissing bug. His research animal was mainly this insect.

He was also a genius at doing simple experiments. Here he demonstrates that the brain hormone essential in the molt and which is released after blood feeding passes through the tube, thus it is hemolymph borne and a Hormone.

Parabiosis of 2 *Rhodnius* nymphs







In the last nymphal instar cuticle of *Rhodnius*, the cuticle shows dimpling while in the adult, the cuticle is smooth. By using a paint brush and JH, Wigglesworth wrote his name using JH and showed that at that molt, if the epidermal cells ‘saw’ JH they would produce a nymphal cuticle.

Was a student of A.G. Richards who was in the Dept. of Entomology at the Univ. of Minnesota. Rockstein became a Professor at the Univ. of Miami in Florida and focused his research on Aging in Insects. He encouraged me to write my grant on aging chemoreceptors in *Phormia*, which I received from the National Institute of Aging and a newly created agency. He was in the heart of the aged community in Florida.
His research was on house fly aging. He edited the twice published series “The Physiology of Insects.”

Morris ‘rocky’ Rockstein

Reg Chapman was a distinguished Professor in England. Later he became a director at the Centre for Overseas Pest Research in London where he researched the role of various factors on feeding behavior in the desert locust, *Locusta migratoria*. **Why a lab. in London's center on locusts?**

He became very active in research and topics concerning insect-plant interactions. He and his wife, Liz Bernays, wrote the book, *Host-plant selection by phytophagous insects* in 1994. He and Liz left England and joined the faculty at Berkeley. Later, both moved to the Insect Science Group at the Univ. of Arizona in Tucson.

Reginald F. Chapman (1930–2003)

Chapman is known for his books, *The Insects-structure and function.*

4th edition, 1998. Reggie died in 2003. I spent my first sabbatical in London with he and Liz.

‘Vince’ was in the group that made major impacts on insect physiology. He was with the same age group as other giants in the field, such as Carroll Williams, Ken Roeder, Stanley Beck, Jan deWilde. He was a little younger than Wigglesworth. Dethier made his fame in developing *Phormia regina* as the model system for studies designed to elucidate the factors involved in regulating feeding in insects. He was extremely clever in understanding the hot topics in human behavior and then applied the same questions to his fly. I did a postdoc. with Dethier when he was at Princeton. He then came to Umass and died here. He is known for his book “*To Know a Fly*.”

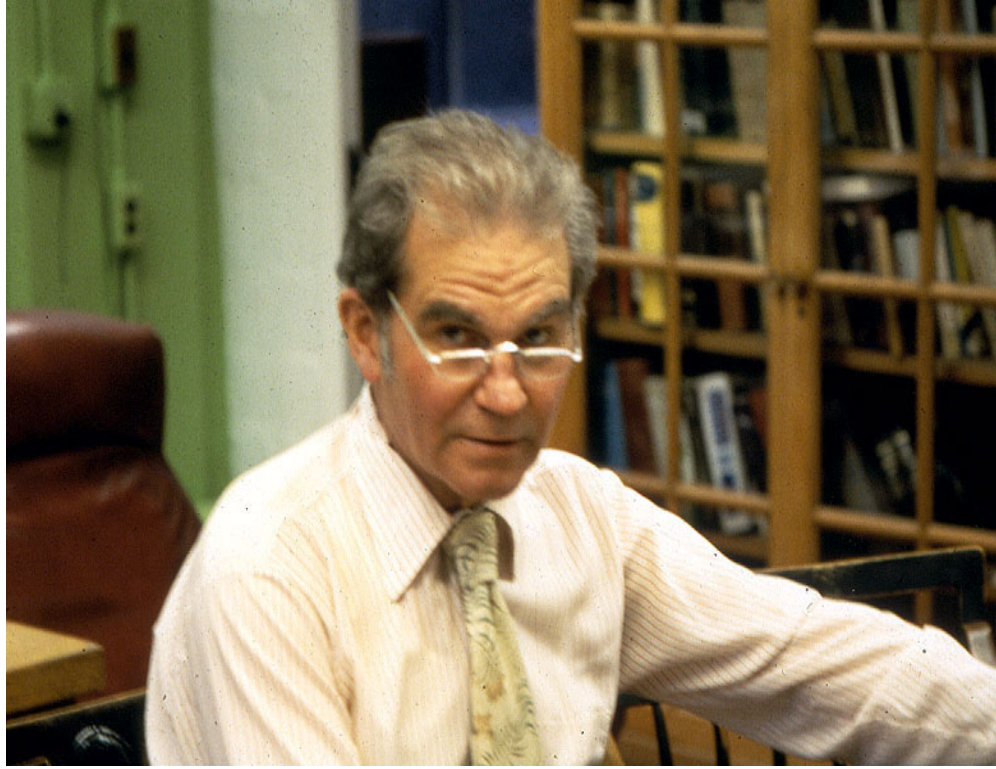
Vincent Gaston Dethier
“the fly man”

Dethier or de Wilde-Effects of diapause on feeding in *Phormia regina*

The deceased entomologist, Professor Jan de Wilde has been voted Greatest Wageninger in the poll organised by Wb. The charismatic professor De Wilde (1916-1983) was a pioneer in biological pest control, and set up the Entomology department in Wageningen. De Wilde received 264 of the 740 votes.

De Wilde was a pioneer in the field of insect diapause. He used the Colorado potato beetle as his model system. I visited Wageningen to see if I would do my postdoc with de Wilde or Dethier. I remember having lunch with he and his student, Louie Schoonhoven. As we walked back to the lab. de Wilde took off into a field because he smelled something in bloom. He also was involved in research on insect/plant interactions. Schoonhoven became involved in using electrophysiological techniques to look at various plant compounds on insect gustation.

Carroll Williams was a giant in the field of insect physiology. He was a master at devising unique techniques to study how hormones travel from the site of production to their target site and was a master at promoting his science to the general public. In the 1950's he characterized JH and was co-discoverer of the '**paper factor'**, which ultimately led to the formation of Zoecon and the idea of Third Generation Pesticides. He produced some giants in the field such as Howard Schneiderman who later became president of Monsanto, Lynn Riddiford, and Fotis Kafatos.



Williams told his students never to become involved in writing books because it took too much time away from research. I knew him well and played tennis in Hartford with a heart specialist who said Williams was the brightest in all of the students in med school. **TELL GRADUATION STORY**

Williams used Cecropia for most of his research on insect hormones and endocrine glands. The larva are about 4 inches long while the pupa is the size of a small chicken egg. **Why do people pick certain model systems over others?**

These ingenious experiments were not only clever but were written up in Life magazine. The pupa on the left never molted into an adult because the movement of the ball injured the epidermal cells that grew onto the glass tube producing a wounding factor that prevented molting. The 2nd one shows that the brain hormone stimulating the ecdysial glands to produce ecdysone, thus the molt, passes through the tube into the abdomen. The 3rd shows that the pupa was separated before the hormone was released; in fact, it could not reach the abdomen.

Famous insect physiologist from Prague, Czech Republick. He was discovered by the late Carroll Williams of Harvard. In 1964 he came to Harvard and he and Williams discovered the ‘Paper factor’. The chemical was really identified by William Bowers, a chemical ecologists. The chemical was juvabione and dihydrojuvabione and mimicked the action of JH. This launched a major effort in the agrochemical industry to find other analogs that could serve as control agents for insect pests. It led to the development of Zoecon, in Palo Alto, CA.

Pyrrhocoris apterus was the model system

Photo showing Carroll Williams and John Law packing an extraction tube with brown paper towels for the extraction of a yellow fluid that contained the JH mimic found in American evergreen trees, but is lacking in European trees. This photo and the fact that the New York Times contained the factor gave Williams a lot of publicity. There is a great need in science for good scientists to be able to make that important contact with the public. In fact, all scientists should learn how to do this. It is the public that supports our research. Law later moved to Univ. of Arizona and continued his work in chemistry. Law gave a talk here at Umass in the molecular/cell biology program several years ago. **After his seminar, someone asked him what his research over his career had done to help control insects. His response was "nothing."**

At the festschrift for Vince Dethier, here at the Univ. of Massachusetts, prople from all over the world came to celebrate his years of research. The woman in blue is Carroll William's wife. Next to her in the green is the famous and wealthy Miriam Rothschild, while next to her is Carroll Williams. Standing is John Kennedy, well known behaviorists, who wrote a wonderful article on "Behavior As Physiology"in the 1967 book, *Insects and Physiology* that was dedicated to Sir Vincent B. Wigglesworth.

The two men in the front at Vince Dethier's festschrift are on the left, Bob O'Connell who is now at the Univ. of Mass. Medical School in Worcester where he works on the neurobiology of olfaction in both insects and vertebrates. Next to him is John Hildebrand who is one of the best known insect neurobiologists. He is at the Univ. of Arizona in Tucson where he continues to research the neurobiology of olfaction in the tobacco hornworm, *Manduca sexta*.

This is a photo showing some of the insect physiologists who were at the Woods Hole meeting that Dr. Yin and I attended. Second row-the man with the mustache is Steve Tobe who is known for his work on popularizing the *in vitro*, radiochemical, JH assay. First row-man in the white shirt is Hans Laufer who was at the Univ. of Conn. when I was there and is involved in hormone research in crabs. Next is Judy Willis (now at North Carolina), Noel Granger and the hard working and excellent woman physiologist, Lynn Riddiford (Williams student who was at).

Riddiford/Truman couple. This is probably the most famous couple that has gained great recognition in insect physiology. Lynn was Carroll Williams' student and Jim did his Ph.D. with George Craig, noted mosquito physiologists, at Notre Dame. Jim did a postdoc in Williams' lab. and met Lynn. We tried to hire them here but they went to the Univ. of Washington in Seattle.

Lynn is known for her work on metamorphosis while Jim did excellent research in the area of behavioral physiology. Both used the model system of the tobacco hornworm, *Manduca sexta*, while Williams used *Hyalophora cecropia*. **Why did Jim And Lynn switch systems?**

Thomas A. Miller is at the Univ. of California in Riverside and researches the areas listed below. He was instrumental in putting together the series of books by Springer-Verlag on various techniques used in insect physiology. He also has a website on insect physiology that may prove useful in the course.

T.A. Miller

- **Circulatory system of insects**
- **Physiology of cotton pests**
- **Genetic control of insects**
- **Insect Symbiosis**

Photo of Dr. Yin and myself at the JH meeting at Woods Hole. My research interest is mainly feeding behavior. I spent a year's postdoc with Dethier (the leading authority on feeding behavior in Flies) and did a sabbatical with Liz and Reg Chapman in London (the leading lab. for studies on feeding behavior in the locust). The question that I often discussed with everyone was "How does nutrition impact egg development in insects?" It is a well known factor to insect ecologists that insects need protein to develop eggs; but, no one had connected the path from food to the egg. Thus, when Yin replaced Hagedorn here in our department I had a colleague that could do Insect Endocrinology. Thus, we formed a team and discovered the insect midgut hormone. Dr. Yin also discovered JH III in flies.

Major Research Trends in Insect Physiology

- Cuticle
- Metamorphosis
- Hormones
- Blood cells and Immunity
- Neuropeptides and Biogenic Amines
- Physiology of Reproduction
- Photoperiodism and Biological Clocks
- Sensory Physiology
- Diapause
- Nutrition
- Genomics
- Proteomics

What influences these major trends in research?

- Major discoveries in the science itself or in the instrumentation to solve new problems
- Money
- Scientists who attempt to solve real world problems

Trends are often driven by a need for better and safer control strategies

Cuticle----------pesticides
Metamorphosis----------3rd gen pesticides
Hormones----------3rd gen pesticides
Blood cells and Immunity----------parasites/diseases
Neuropeptides and Biogenic Amines---biorationals
Physiology of Reproduction----------chemosterilants
Photoperiodism and Biological Clocks-physiol. control
Sensory Physiology----------pher/traps/repellents
Diapause----------physiol. control
Nutrition----------insect culturing
Genomics----------genetic control
Proteomics----------prot. involvement

What drives one's research focus?

- Purely academic to solve problems with one organism or another-no link to organism
- Organism oriented and use it as model system for basic questions
- Follow the money tree for grants
- It has been estimated that only 1 out of every 10 Ph.D.'s will continue to conduct research following their degree. **WHY?**

Major model systems in insect physiology

- Desert locust, *Locusta migratoria*
- Queen blowfly, *Phormia regina*
- Cecropia moth, *Hyalophora cecropia*
- Kissing bug, *Rhodnius prolixus*
- Mosquito, *Aedes aegypti*
- Colorado potato beetle, *Leptinotarsa decemlineata*
- Tobacco hornworm, *Manduca sexta*
- Cockroach, *Periplaneta americana*
- Fruit fly, *Drosophila melanogaster*

We will discuss each system with respect to:

1. Structures involved
2. How the system functions
3. Instrumentation or techniques used
4. Major reseachers and their experiments
5. How information on that system fits into both basic and applied areas

What insect system is causing many individuals to leave there systems and is having a major impact on producing insect physiologists?

- *Drosophila melanogaster*, the fruit fly

Why is this happening?

800,000 to 3 million insect species

- Very **few** insect model systems for the studies in insect physiology.
- Thus, when we talk about a topic we are missing a lot of diversity that may exist in the real world used by insects to solve the problems they face.
- Recent findings of mucin and possible breathing apparatus in insects.

IMPORTANT AND USEFUL WEBSITES:

1. Excellent source of information on *Drosophila*
http://www.sdbonline.org/fly/aimain/1aahome.htm