Foodborne Disease Handbook
Introduction to the Handbook

The *Foodborne Disease Handbook, Second Edition, Revised and Expanded*, could not be appearing at a more auspicious time. Never before has the campaign for food safety been pursued so intensely on so many fronts in virtually every country around the world. This new edition reflects at least one of the many aspects of that intense and multifaceted campaign: namely, that research on food safety has been very productive in the years since the first edition appeared. The *Handbook* is now presented in four volumes instead of the three of the 1994 edition. The four volumes are composed of 86 chapters, a 22% increase over the 67 chapters of the first edition. Much of the information in the first edition has been carried forward to this new edition because that information is still as reliable and pertinent as it was in 1994. This integration of the older data with the latest research findings gives the reader a secure scientific foundation on which to base important decisions affecting the public’s health.

We are not so naive as to think that only scientific facts influence decisions affecting food safety. Political and economic factors and compelling national interests may carry greater weight in the minds of decision-makers than the scientific findings offered in this new edition. However, if persons in the higher levels of national governments and international agencies, such as the Codex Alimentarius Commission, the World Trade Organization, the World Health Organization, and the Food and Agriculture Organization, who must bear the burden of decision-making need and are willing to entertain scientific findings, then the information in these four volumes will serve them well indeed.

During the last decade of the previous century, we witnessed an unprecedentedly intense and varied program of research on food safety, as we have already noted. There are compelling forces driving these research efforts. The traditional food-associated pathogens, parasites, and toxins of forty years ago still continue to cause problems today, but newer or less well-known species and strains present extraordinary challenges to human health.

These newer threats may be serious even for the immunocompetent, but for the immunocompromised they can be devastating. The relative numbers of the immunocompromised in the world population are increasing daily. We include here not just those affected by the human immunodeficiency virus (HIV), but also the elderly; the very young; the recipients of radiation treatments, chemotherapy, and immunosuppressive drugs; pa-
tients undergoing major invasive diagnostic or surgical procedures; and sufferers of debilitating diseases such as diabetes. To this daunting list of challenges must be added numerous instances of microbial resistance to antibiotics.

Moreover, it is not yet clear how the great HACCP experiment will play out on the worldwide stage of food safety. Altruism and profit motivation have always made strange bedfellows in the food industry. It remains to be seen whether HACCP will succeed in wedding these two disparate motives into a unifying force for the benefit of all concerned—producers, manufacturers, retailers, and consumers. That HACCP shows great promise is thoroughly discussed in Volume 2, with an emphasis on sanitation in a public eating place.

All the foregoing factors lend a sense of urgency to the task of rapidly identifying toxins, species, and strains of pathogens and parasites as etiologic agents, and of determining their roles in the epidemiology and epizootiology of disease outbreaks, which are described in detail throughout the *Foodborne Disease Handbook*.

It is very fortunate for the consumer that there exists in the food industry a dedicated cadre of scientific specialists who scrutinize all aspects of food production and bring their expertise to bear on the potential hazards they know best. A good sampling of the kinds of work they do is contained in these four new volumes of the *Handbook*. And the benefits of their research are obvious to the scientific specialist who wants to learn even more about food hazards, to the scientific generalist who is curious about everything and who will be delighted to find a good source of accurate, up-to-date information, and to consumers who care about what they eat.

We are confident that these four volumes will provide competent, trustworthy, and timely information to inquiring readers, no matter what roles they may play in the global campaign to achieve food safety.

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Most people prefer to think of marine environments farthest removed from human settlements as being pristine and pure; however, much of the ocean is under attack on several fronts. One of the foci of this fourth volume of the *Foodborne Disease Handbook* is the topic of pollutants, which are being deposited in the oceans in unprecedented quantities—as raw sewage (often with viable pathogens and parasites), industrial effluents containing toxic or radioactive chemicals, trash and garbage, pesticides in runoff from crop lands, and top soil, one of our most valuable natural resources.

Some of these potentially harmful organisms and chemicals enter the food webs of freshwater and marine organisms. Some of these organisms are harvested for human food and have the capacity and tendency to concentrate and sequester in their bodies many of the chemicals and pathogens present in the aquatic environments. The methods of how harmful organisms or hazardous chemicals are detected, analyzed, and identified, and how they can affect human health, are thoroughly reviewed in this volume.

In contrast, some marine organisms do not collect toxins from the environment but rather produce their own toxins as a part of normal metabolic processes. When such fish are used as human food, the result can be life-threatening. This volume discusses the species and toxins of importance, analytical methods, and epidemiological aspects of intoxication.

The seafood processor was one of the first food industries required to implement the HACCP principles. The development of the seafood HACCP program and its benefits to the consumer are discussed in this volume.

A cloud of controversy hovers over the concept of food irradiation. In this volume we present informative facts needed for the reader to come to an enlightened conclusion about the safety of food irradiation. We caution that no matter how successful irradiation might be, mishandling after irradiation treatment makes the product unsafe. We also discuss the continuing need to adhere to HACCP principles and essential sanitary standards that make it possible for HACCP to work.

Many, perhaps even most, of the food toxicity issues addressed in this volume are subtle and unknown to most of us. For example, the use of food additives, radioactive isotopes, pesticide chemicals applied to our crops, toxicants occurring naturally in some of our foods, and the therapeutic and growth-promoting drugs fed to domestic animals
are important topics of food toxicology. In addition, plasticizers in many kinds of vessels
used for food storage and handling may in some instances be a source of toxic chemicals.
Most consumers are quite unaware of rat hairs, beetle setae, and fly eggs in their food,
and less aware of what effect, if any, such adulterants might have on their health.

The editors and contributors to the fourth volume of the *Foodborne Disease Handbook*
have provided an abundance of facts and supporting explanatory information en-
abling readers to make confident decisions about their health. Moreover, all sectors of the
food industry have the tools needed to apply the sanitary practices and HACCP-driven
safeguards that will result in the prevention of foodborne diseases and help to make avail-
able wholesome foods for all consumers around the world. Volume 4 is a composite of
current information and policies that enable proper risk-assessment decisions to be made
regarding potential food toxicants derived naturally in the environment or through agricul-
tural production and food processing practices.

Y. H. Hui
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I. EPIDEMIOLOGY

Epidemiological studies aid treatment facilities in determining risk factors and who becomes exposed, and in establishing the probable outcomes of various treatments. A few organizations have attempted to gather such information and organize it into yearly reports. The American Association of Poison Control Centers (AAPCC) and some federal agencies work toward obtaining epidemiological information, while the AAPCC has an active role in assisting with the treatment of exposures Epidemiological studies assist government and industry in determining package safety, effective treatment measures, conditions of exposure, and frequency of exposure.

Studies on seafood and environmental exposures provide information on the type of people most commonly involved in exposures. Are they children, adults at home, outdoorsmen, industrial workers, or blue-collar workers. Studies can also tell us which bacterial species are most commonly involved. What symptoms are seen first, what is the onset
of symptoms, and are their any sequelae may also be determined and compared to current norms.

A. AAPCC

1. What Are Poison Centers and the AAPCC?

The group in the United States concerned, on a daily basis, with potential poisonings due to household agents, industrial agents, biologics, and food poisoning (including seafood poisoning) is the AAPCC. This is an affiliation of local and regional centers that provides information to health care professionals and the lay public concerning all aspects of poisoning. These centers also refer patients to treatment centers. This group of affiliated centers is often supported by government and private funds, as well as industrial sources.

Poison centers were started in the late 1950s; the first is thought to have been in the Chicago area. The idea caught on quickly and at the peak of the movement there were hundreds of centers throughout the United States. Unfortunately there were few or no standards for what could be called a poison center, including the type of staff, hours of operation, or information resources. One center may have had a dedicated staff of doctors, pharmacists, and nurses trained specifically in handling poison cases, while another had nothing but a book on toxicology in the emergency room or hospital library. In 1993 the Health and Safety Code (Sec. 777.002) specified that poison centers provide 24-hour service for public and health care professionals and meet the requirements established by the AAPCC. This action helped the AAPCC standardize the staffs and activities of the various poison centers.

The federal government does not fund poison centers, even though for every dollar spent on poison centers there is a savings of $2–$9 in unnecessary expenses (1,2). The federal agency responsible for the Poison Prevention Packaging Act is the U.S. Consumer Product Safety Commission (CPSC). The National Clearinghouse for Poison Control Centers initially collected data on poisonings and information on commercial product ingredients and toxic biological agents. For several years the National Clearinghouse provided product and treatment information to the poison centers.

At first most poison centers were funded by the hospital in which they were located. As the centers grew in size and the number of calls increased, both city and state governments took on the responsibility of contributing funds. In recent years local governments have found it very difficult to fund such operations and centers have had to look to private industry for additional funding. Government funding may take several forms, either as a line-item on a state’s budget, as a direct grant, or moneys distributed on a per call basis. Some states with fewer residents may contract with a neighboring state to provide services to its residents. Some states are so populous that more than one center is funded by the state. Industrial funding also varies, sometimes as a grant, sometimes as payment for handling the company’s poison and drug information-related calls, and sometimes as payment for collection of data regarding exposure to the company’s product. Every year the AAPCC reports a summary of all kinds of exposures.

2. Regional Centers

The number of listed centers has dropped significantly since its peak of more than 600. Many centers have been combined into regional organizations. These regional poison centers provide poison information, telephone management, and consultation, collect pertinent data, and deliver professional and public education. Cooperation between regional poison
centers and poison treatment facilities is crucial. Regional poison information centers, in cooperation with local hospitals, should determine the treatment capabilities of the hospitals in the region and identify and have a working relationship with their analytical toxicology, emergency and critical care, medical transportation, and extracorporeal services. This evaluation should be done for both adults and children.

A “region” is usually determined by state authorities in conjunction with local health agencies and health care providers. Documentation of these state designations must be in writing unless a state chooses (in writing) not to designate any poison center or accepts a designation by other political or health jurisdictions. Regional poison information centers should serve a population base of more than one million people and must receive at least 10,000 human exposure calls per year.

The number of certified regional centers in the United States is now less than 50. Certification as a regional center requires the following:

- Maintain a 24 hours/day, 365 days/year service.
- Provide service to both health care professionals and the public.
- Have available in the center at all times at least one specialist in poison information.
- Have on call by telephone at all times a medical director or qualified designee.
- Readily accessible service by telephone from all areas within the region.
- Comprehensive poison information resources and comprehensive toxicology information covering both general and specific aspects of acute and chronic poisoning should be available.
- A list of on-call poison center specialty consultants.
- Written operational guidelines that provide a consistent approach to evaluation, follow-up, and management of toxic exposures should be obtained and maintained. These guidelines must be approved in writing by the medical director of the program.
- A staff of certified professionals answering the phones (at least one of the persons on the phone has to be a pharmacist or nurse with 2000 hours and 2000 cases of supervised experience).
- A 24 hours/day physician (board certified) consultation service.
- An ongoing quality assurance program.
- Other criteria, determined by the AAPCC and established with membership approval.

The regional poison information center must be an institutional member in good standing of the AAPCC. Many hospital emergency rooms still maintain a toxicology reference such as the POISINDEX® system to handle routine exposure cases, but they rely on regional poison centers to handle most of the calls in their area.

B. Who Staffs a Poison Center?

The staff of poison centers varies considerably from center to center. The three professional groups most often involved are physicians, nurses, and pharmacists. Who answers the phones is somewhat dependent on the local labor pool, moneys available, and the types of calls being received. Other persons who answer the phone include students in medically related fields, toxicologists, and biologists. Persons responsible for answering the phones are either certified by the AAPCC or are in the process of obtaining the certifi-
cation. Passage of an extensive examination on toxicology is required for initial certification, with periodic recertification required.

Regardless of who takes the initial call, there is a medical director and other physician backup available. These physicians have specialized training or experience in toxicology and are able to provide in-depth consultations for health care professionals calling the center.

1. Medical Director
A poison center medical director should be board certified in medical toxicology or in internal medicine, pediatrics, family medicine, or emergency medicine. The medical director should be able to demonstrate ongoing interest and expertise in toxicology as evidenced by publications, research, and meeting attendance. The medical director must have a medical staff appointment at a comprehensive poison treatment facility and must be involved in the management of poisoned patients.

2. Managing Director
The managing director must be a registered nurse, pharmacist, or physician, or hold a degree in a health science discipline. The individual should be certified by the American Board of Medical Toxicology (for physicians) or by the American Board of Applied Toxicology (for nonphysicians). The director must be able to demonstrate ongoing interest and expertise in toxicology.

3. Specialists in Poison Information
These individuals must be registered nurses, pharmacists, or physicians, or be certified by the AAPCC as a specialist in poison information. Specialists in poison information must complete a training program approved by the medical director and must be certified by the AAPCC as a specialist in poison information within two examination administrations of their initial eligibility. Specialists not currently certified by the association must spend an annual average of no less than 16 hours/week in poison center-related activities. Specialists currently certified by the AAPCC must spend an annual average of no less than 8 hours/week. Other poison information providers must have sufficient background to understand and interpret standard poison information resources and to transmit that information understandably to both health professionals and the public.

4. Consultants
In addition to physicians specializing in toxicology, most centers also have lists of experts in many other fields as well. Poison center specialty consultants should be qualified by training or experience to provide sophisticated toxicology or patient care information in their area(s) of expertise. In regard to seafood or environmental toxins, this would include specialists in pesticides, heavy metals, botanical exposures, marine toxins, and hydrocarbons, just to name a few. These experts should be willing to donate their expertise in identifying and handling cases within their specialty. Most poison centers do not have the money to pay a wide variety of consultants.

C. What Types of Calls Are Received?
All types of calls are received by poison centers, most of which are handled immediately, while others are referred to more appropriate agencies. Which calls are referred depends
on the center, its expertise, and the appropriateness of a referral. Below are lists of calls which generally fall into each group. Remember, there is considerable variation between poison centers; if there is doubt, call the poison center and they will tell you if your case is more appropriately referred. Poison centers do best on calls regarding acute exposures. Complicated calls regarding exposure to several agents over a long period of time which produce nonspecific symptoms are often referred to other medical specialists, to the toxicologist associated with the center, or to an appropriate government agency. The poison center will often follow-up on these cases to track outcome and the type of service given.

Types of calls usually accepted
- Drug identification
- Actual acute exposure to a drug or chemical
- Actual acute exposure to a biological agent (plants, mushrooms, various animals)
- Information regarding the toxic potential of an agent
- Possible food poisonings (including seafood poisoning)
- Exposure to environmental toxins

Types of calls often referred
- Questions regarding treatment of a medical condition (not poisoning)
- Questions on common bacterial, viral, or parasitic infections
- General psychiatric questions
- Proper disposal of household agents such as batteries, bleach, insecticides
- Use of insecticides (e.g., which insecticide to use, how to use it) unless related to a health issue (e.g., a person allergic to pyrethrins wanting to know which product does not contain pyrethrins)

1. Data Collection

Records of all calls/cases handled by the center should be kept in a form that is acceptable as a medical record. The regional poison information center should submit all its human exposure data to the association’s National Data Collection System. The regional poison information center shall tabulate its experience for regional program evaluation on at least an annual basis.

a. AAPCC Toxic Exposure Surveillance System (TESS) In 1983 the AAPCC formed TESS from the former National Data Collection System. Currently TESS contains nearly 16.2 million human poison exposure cases. Sixty-five poison centers, representing 181.3 million people, participate in the data collection. The information has various uses for both governmental agencies and industry, providing data for product reformulations, repackaging, recall, bans, injury potential, and epidemiology.

The summation of each year’s surveillance is published in the late summer or fall in the American Journal of Emergency Medicine.

D. How Are Calls Handled?

Most poison centers receive requests for information via the telephone. Calls come from both health care professionals and consumers. Only a few requests are received by mail or in person, these are often medicolegal or complex cases. Most centers can be reached by a toll-free phone number in the areas they serve, as well as by a local number. Busy centers have a single number that rings on several lines. Calls are often direct referrals from the 911 system.
Poison information specialists listen to the caller, recording the history of the case on a standardized form developed by the AAPCC. Basic information such as the agent involved, the amount of the agent, time of ingestion, symptoms, previous treatment, and current condition are recorded, as well as patient information such as sex, age, phone number, who is with the patient, relevant medical history, and sometimes patient address. All information is considered a medical record, and is therefore confidential.

The case is evaluated (using various references) as:

- Information only, no patient involved
- Harmless and not requiring follow-up
- Slightly toxic, no treatment necessary but a follow-up call is given
- Potentially toxic, treatment given at home and follow-up given to case resolution
- Potentially toxic, treatment may or may not be given at home, but it is necessary for the patient to be referred to a medical facility
- Emergency, an ambulance and/or paramedics are dispatched to the scene

Cases are usually followed until symptoms have resolved. In cases where the patient is referred to a health care facility, the receiving agency is notified. The history is relayed, toxic potential discussed, and suggestion for treatment given.

**E. What References Are Used?**

References used also vary from center to center, but virtually all centers use a toxicology system called POISINDEX® which contains lists of products, their ingredients, and suggestions for treatment. The system is compiled using medical literature and toxicology specialists throughout the world. Biological products such as plants, insects, mushrooms, and animal bites etc are handled similarly. There is an entry for each individual plant containing a description, the toxic agent present, potential toxic amounts, and so forth. The physician or poison information specialist is then referred to a treatment protocol that may be for a general class of agents; for example, exposure to malathion is referred to a protocol on organophosphate pesticides. An unknown skin irritation or potential infection would deserve a consult with an infectious disease specialist. Questions involving specific agents, such as lead or mercury, are directed to individual treatment protocols. POISINDEX® is available on microfiche, CD-ROM, over a network, or on a mainframe. It is updated every 3-months.

Various texts are also used, but much of this information is already in POISINDEX®. It is often difficult to identify some potentially toxic marine animals using a description given over the phone, so often the assistance of a marine biologist is used. If a type of marine food poisoning is involved, the help of an infectious disease consultant and an epidemiologist may be requested. Some poison centers have more experience with certain types of poisonings than do others, so often one center will consult another. These are often more complex cases, or cases involving centers in the same region. For example, a poison center in Utah may consult with one in California or Hawaii concerning a lionfish envenomization.

A recent trend has been for manufacturers to contract with one poison center to provide poison information services for the whole country. Product information is given
to only that center and exposures throughout the country can only be handled effectively in that one center.

**F. How Are Poison Centers Monitored for Quality?**

Most poison centers have a system of peer review in place. One person takes a call, another reviews it. Periodic spot reviews are done by supervisory and physician staff. General competence is ensured by certification and recertification via examination of physicians and poison information specialists.

**G. Professional and Public Education Programs**

The regional poison information center provides information on the management of poisoning to health professionals throughout the region. Public education programs aimed at educating both children and adults about poison safety and potential dangers should be provided.

In the past, some centers provided stickers or logos such as Officer Ugh, Safety Sadie, and Mr. Yuck that could be placed on or near potentially toxic substances. While the intent was to identify potentially toxic substances that children should stay away from, the practice has been much curtailed because in some cases the stickers actually attracted children.

Poison prevention week is held each year in the spring. National attention is focused on the problem of potentially toxic exposures. During this week many centers run special programs for the public. This may include lectures on prevention, potentially toxic agents in the home, potentially toxic biological agents, or general first aid methods. Although an important time for poison centers, public and professional education is a year-round commitment. Physicians are frequently involved in medical toxicology rounds, journal clubs, and lectures by specialty consultants. Health fairs, school programs, and various men’s and women’s clubs are used to educate the public. The extent of these activities is often determined by the amount of funding from government, private organizations, and public donations.

**H. Related Toxicology Organizations**

- **ACGIH** American Conference of Governmental and Industrial Hygienists  
  Address: Kemper Woods Center; Cincinnati, OH 45240  
  Phone: 513-742-2020  
  FAX: 513-742-3355

- **ABAT** American Board of Applied Toxicology  
  Address: Truman Medical Center, West, 2301 Holmes St., Kansas City, MO 64108  
  Phone: 816-556-3112  
  FAX: 816-881-6282

- **AACT** American Association of Clinical Toxicologists  
  Address: c/o Medical Toxicology Consultants, Four Columbia Dr., Suite 810, Tampa, FL 33606

- **AAPCC** American Association of Poison Control Centers
<table>
<thead>
<tr>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
<th>FAX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spoerke</strong></td>
<td>Address: 3201 New Mexico Ave. NW, Washington, DC 20016</td>
<td>202-362-7217</td>
<td>202-362-8377</td>
</tr>
<tr>
<td><strong>ABEM</strong> American Board of Emergency Medicine</td>
<td>Address: 300 Coolidge Rd., East Lansing, MI 48823</td>
<td>517-332-4800</td>
<td>517-332-2234</td>
</tr>
<tr>
<td><strong>ACEP</strong> American College of Emergency Physicians (Toxicology Section)</td>
<td>Address: P.O. Box 619911, Dallas, TX 75261-9911</td>
<td>800-798-1822</td>
<td>214-580-2816</td>
</tr>
<tr>
<td><strong>ACMT</strong> American College of Medical Toxicology (formerly ABMT)</td>
<td>Address: 777 E. Park Dr., P.O. Box 8820, Harrisburg, PA 17105-8820</td>
<td>717-558-7846</td>
<td>717-558-7841</td>
</tr>
<tr>
<td><strong>ACOE</strong> American College of Occupational and Environmental Medicine</td>
<td>Address: 55 West Seegers Rd., Arlington Heights, IL 60005</td>
<td>708-228-6850</td>
<td>708-228-1856</td>
</tr>
<tr>
<td><strong>ACSN</strong> Association of Clinical Scientists</td>
<td>Address: Dept. of Laboratory Medicine, University of Connecticut Medical School, 263 Farmington Ave., Farmington, CT 06030-2225</td>
<td>203-679-2328</td>
<td>203-679-2328</td>
</tr>
<tr>
<td><strong>ACT</strong> American College of Toxicology</td>
<td>Address: 9650 Rockville Pike, Bethesda, MD 20814</td>
<td>301-571-1840</td>
<td>301-571-1852</td>
</tr>
<tr>
<td><strong>AOEC</strong> Association of Occupational and Environmental Clinics</td>
<td>Address: 1010 Vermont Ave. NW, #513, Washington, DC 20005</td>
<td>202-347-4976</td>
<td>202-347-4950</td>
</tr>
<tr>
<td><strong>ASCEPT</strong> Australian Society of Clinical and Experimental Pharmacologists and Toxicologists</td>
<td>Address: 145 Macquarie St., Sydney N.S.W 2000 Australia</td>
<td>61-2-256-5456</td>
<td>61-2-252-3310</td>
</tr>
<tr>
<td><strong>BTS</strong> British Toxicology Society</td>
<td>Address: MJ Tucker, Zeneca Pharmaceuticals, 22B11 Mareside, Alderley Park, Macclesfield, Cheshire, SK10 4TG UK</td>
<td>0428 65 5041</td>
<td></td>
</tr>
<tr>
<td><strong>CAPCC</strong> Canadian Association of Poison Control Centers</td>
<td>Address: Hopital Sainte-Justine, 3175 Cote Sainte-Catherine, Montreal, Quebec H3T1C5, Canada</td>
<td>514-345-4675</td>
<td>514-345-4822</td>
</tr>
</tbody>
</table>
CSVVA (CEVAP)  Center for the Study of Venoms and Venomous Animals
Address: UNESP, Alameda Santos, N 647, CEP 01419-901, Sao Paulo, SP, Brazil
Phone 55-011-252-0233
FAX: 55-011-252-0200

EAPCCT  European Association of Poison Control Centers
Address: J. Vale, National Poisons Information Centre, P O Box 81898 Dep, N-0034 Oslo, Norway
Phone: 47-260-8460

HPS  Hungarian Pharmacological Society
Address: Central Research Institute for Chemistry, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 17, Pusztaszeri ut 59-67
Phone: 36-1-135-2112

ISOMT  International Society of Occupational Medicine and Toxicology
Address: USC School of Medicine, 222 Oceanview Ave., Suite 100, Los Angeles, CA 90057
Phone: 213-365-4000

JSTS  Japanese Society of Toxicological Sciences
Address: Gakkai Center Building, 4-16, Yayoi 2-chome, Bunkyo-ku, Tokyo 113, Japan
Phone: 3-3812-3093
FAX: 3-3812-3552

SOT  Society of Toxicology
Address: 1101 14th St., Suite 1100, Washington, DC 20005-5601
Phone: 202-371-1393
FAX: 202-371-1090
e-mail: sothq@toxicology.org

SOTC  Society of Toxicology of Canada
Address: P.O. Box 517, Beaconsfield, Quebec H9W 5V1, Canada
Phone: 514-428-2676
FAX: 514-482-8648

STP  Society of Toxicologic Pathologists
Address: 875 Kings Hw., Suite 200, Woodbury, NJ 08096-3172
Phone: 609-845-7220
FAX: 609-853-0411

SSPT  Swiss Society of Pharmacology and Toxicology
Address: Peter Donatsch, Sandoz Pharma AG, Toxicologue 881/130, CH-4132 Muttenz, Switzerland
Phone: 41-61-469-5371
FAX: 41-61-469-6565

WFCT  World Federation of Associations of Clinical Toxicology Centers and Poison Control Centers
Address: Centre Anti-Poisons, Hopital Edonard Herriot, 5 pl d’Arsonval, 69003 Lyon, France
Phone: 33 72 54 80 22
FAX: 33 72 34 55 67
I. International Affiliations

The AAPCC and its members attend various world conferences to learn of toxicology problems and new methods used by other agencies. An especially close relationship has formed between the American and Canadian poison center associations. Once a year the AAPCC and CAPCC hold a joint scientific meeting and invite speakers and other toxicology specialists from throughout the world to attend.

J. Toxicology and Poison Center Web Sites

Association of Occupational and Environmental Clinics: This group is dedicated to higher standards of patient-centered, multidisciplinary care emphasizing prevention and total health through information sharing, quality service, and collaborative research.
Address: lo478x@gwis.circ.gwu.edu

Finger Lakes Regional Poison Center.
Address: pwax@ed.urmc.rochester.edu

Medical/Clinical/Occupational Toxicology Professional Groups A list of primarily U.S. professional groups interested in toxicology. There is a description of each group, addresses, phone numbers, and contact names.
Keyword: poison centers, toxicology
Address: http://www.pitt.edu/~martint/pages/motoxorg.htm

Poison Net A mailing list dedicated to sharing information, problem solving, and networking in the areas of poisoning, poison control centers, hazardous materials, and related topics. The list is intended for health care professionals, not the lay public. The moderators do not encourage responses to individual poisoning cases from the public.
Keywords: poisoning, poison control centers

II. POISON INFORMATION CENTERS IN THE UNITED STATES

The Poison Control Center telephone numbers and addresses listed below are thought to be accurate as of the date of publication. Poison Control Center telephone numbers and addresses may change. The address and phone number of the Poison Control Center nearest you should be frequently checked. If the number listed does not reach the poison center, contact the nearest emergency service, such as 911 or your local hospital emergency room. The author disclaims any liability resulting from or relating to any inaccuracies or changes in the phone numbers provided below. This information should NOT be used as a substitute for seeking professional medical diagnosis, treatment, and care. (* Indicates a regional center designated by the American Association of Poison Control Centers.)
The Role of Poison Centers

ALABAMA

*Birmingham
Regional Poison Control Center*
Children’s Hospital of Alabama
1600 Seventh Ave., South Birmingham,
AL 35233-1711
800-292-6678 (AL only)
205-933-4050

*Tuscaloosa
Alabama Poison Control System, Inc.
408A Paul Bryant Dr. East
Tuscaloosa, AL 35401
800-462-0800 (AL only)
205-345-0600

ALASKA

*Anchorage
Anchorage Poison Center
Providence Hospital
P.O. Box 196604
3200 Providence Dr.
Anchorage, AK 99519-6604
800-478-3193 (AK only)

*Fairbanks
Fairbanks Poison Center
Fairbanks Memorial Hospital
1650 Cowles St.
Fairbanks, AK 99701
907-456-7182

ARIZONA

*Phoenix
Samaritan Regional Poison Center*
Good Samaritan Medical Center
1130 East McDowell Rd., Suite A-5
Phoenix, AZ 85006
602-253-3334

*Tucson
Arizona Poison and Drug Information Center*
Arizona Health Sciences Center, Room 1156
1501 N. Campbell Ave.
Tucson, AZ 85724
800-362-0101 (AZ only)
602-626-6016

ARKANSAS

*Little Rock
Arkansas Poison and Drug Information Center
University of Arkansas
College of Pharmacy
4301 West Markham, Slot 522
Little Rock, AR 72205
800-482-8948 (AR only)
501-661-6161

CALIFORNIA

*Fresno
Fresno Regional Poison Control Center*
Fresno Community Hospital and Medical Center
2823 Fresno St.
Fresno, CA 93721
800-346-5922 (CA only)
209-445-1222

*Los Angeles
Los Angeles County University of Southern California Regional Poison Center*
1200 North State, Room 1107
Los Angeles, CA 90033
800-825-2722
213-222-3212

*Orange
University of California Irvine Medical Center Regional Poison Center*
101 The City Dr. South
Route 78
Orange, CA 92668-3298
800-544-4404 (CA only)
714-634-5988

*Richmond
Chevron Emergency Information Center
15299 San Pablo Ave.
P O. Box 4054
Richmond, CA 94804-0054
800-457-2202
510-233-3737 or 3738
Sacramento
Regional Poison Control Center*
University of California at Davis Medical Center
2315 Stockton Blvd., Rm. HSF-124
Sacramento, CA 95817
800-342-3293 (northern CA only)
916-734-3692

San Diego
San Diego Regional Poison Center*
University of California at San Diego Medical Center
225 West Dickinson St.
San Diego, CA 92013-8925
800-876-4766 (CA only)
619-543-6000

San Francisco
San Francisco Bay Area Poison Center*
San Francisco General Hospital
1001 Potrero Ave., Rm. 1E86
San Francisco, CA 94122
800-523-2222
415-476-6600

San Jose
San Jose Regional Poison Center
Santa Clara Valley Medical Center
751 South Bascom Ave.
San Jose, CA 95128
800-662-9886, 9887 (CA only)
408-299-5112, 5113, 5114

COLORADO

Denver
Rocky Mountain Poison Center*
1010 Yosemite Circle
Denver, CO 80230
800-332-3073 (CO only)
303-629-1123

CONNECTICUT

Farmington
Connecticut Poison Control Center
University of Connecticut Health Center
263 Farmington Ave.
Farmington, CT 06030
800-343-2722 (CT only)
203-679-3456

DELAWARE

Wilmington
Poison Information Center
Medical Center of Delaware
Wilmington Hospital
501 West 14th St.
Wilmington, DE 19899
302-655-3389

DISTRICT OF COLUMBIA

Washington
National Capital Poison Center*
Georgetown University Hospital
3800 Reservoir Rd. NW
Washington, DC 20007
202-625-3333

FLORIDA

Jacksonville
Florida Poison Information Center
University Medical Center
655 West Eighth St.
Jacksonville, FL 32209
904-549-4465 or 764-7667

Tallahassee
Tallahassee Memorial Regional Medical Center
1300 Miccosukk Rd.
Tallahassee, FL 32308
904-681-5411

Tampa
Tampa Poison Information Center*
Tampa General Hospital
Davis Islands
P.O. Box 1289
Tampa, FL 33601
800-282-3171 (FL only)
813-253-4444

GEORGIA

Atlanta
Georgia Regional Poison Control Center*
Cerady Memorial Hospital
The Role of Poison Centers

80 Butler St. SE
Box 26066
Atlanta, GA 30335-3801
800-282-5846 (GA only)
404-616-9000

Macon
Regional Poison Control Center
Medical Center of Central Georgia
777 Hemlock St.
Macon, GA 31208
912-744-1146, 1100, 1427

Savannah
Savannah Regional Poison Control Center
Memorial Medical Center Inc.
4700 Waters Ave.
Savannah, GA 31403
912-355-5228 or 356-5228

HAWAII

Honolulu
Kapiolani Women’s and Children’s
Medical Center
1319 Punahou St.
Honolulu, HI 96826
800-362-3585, 3586 (HI only)
808-941-4411

IDAHO

Boise
Idaho Poison Center
St Alphonsus Regional Medical Center
1055 North Curtis Rd.
Boise, ID 83706
800-632-8000 (ID only)
208-378-2707

ILLINOIS

Chicago
Chicago and NE Illinois Regional Poison
Control Center
Rush Presbyterian–St. Luke’s Medical
Center
1653 West Congress Pky.
Chicago, IL 60612
800-942-5969 (Northeast IL only)
312-942-5969

Normal
Bromenn Hospital Poison Center
Virginia at Franklin
Normal, IL 61761
309-454-6666

Springfield
Central and Southern Illinois Poison
Resource Center
St John’s Hospital
800 East Carpenter St.
Springfield, IL 62769
800-252-2022 (IL only)
217-753-3330

Urbana
National Animal Poison Control Center
University of Illinois Department of
Veterinary Biosciences
2001 South Lincoln Ave., 1220 VMBSB
Urbana, IL 61801
800-548-2423 (Subscribers only)
217-333-2053

INDIANA

Indianapolis
Indiana Poison Center*
Methodist Hospital
1701 North Senate Blvd.
Indianapolis, IN 46202-1367
800-382-9097
317-929-2323

IOWA

Des Moines
Variety Club Drug and Poison Information
Center
Iowa Methodist Medical Center
1200 Pleasant St.
Des Moines, IA 50309
800-362-2327
515-241-6254
Iowa City
University of Iowa Hospitals and Clinics
200 Hawkins Dr.
Iowa City, IA 52246
800-272-6477 or 800-362-2327 (IA only)
319-356-2922

Sioux City
St. Luke's Poison Center
St. Luke's Regional Medical Center
2720 Stone Park Blvd.
Sioux City, IA 51104
800-352-2222 (IA, NE, SD)
712-277-2222

KANSAS

Kansas City
Mid America Poison Center
Kansas University Medical Center
39th and Rainbow Blvd., Rm. B-400
Kansas City, KS 66160-7231
800-332-6633 (KS only)
913-588-6633

Topeka
Stormont Vail Regional Medical Center
Emergency Department
1500 West 10th
Topeka, KS 66604
913-354-6100

Wichita
Wesley Medical Center
550 North Hillside Ave.
Wichita, KS 67214
316-688-2222

LOUISIANA

Houma
Terrebonne General Medical Center Drug
and Poison Information Center
936 East Main St.
Houma, LA 70360
504-873-4069

Monroe
Louisiana Drug and Poison Information
Center
Northeast Louisiana University School of
Pharmacy, Sugar Hall
Monroe, LA 71209-6430
800-256-9822 (LA only)
318-362-5393

MAINE

Portland
Maine Poison Control Center
Maine Medical Center
22 Bramhall St.
Portland, ME 04102
800-442-6305 (ME only)
207-871-2950

MARYLAND

Baltimore
Maryland Poison Center*
University of Maryland School of
Pharmacy
20 North Pine St.
Baltimore, MD 21201
800-492-2414 (MD only)
410-528-7701

KENTUCKY

Ft. Thomas
Northern Kentucky Poison Information
Center
St Luke Hospital
85 North Grand Ave.
Ft. Thomas, KY 41075
513-872-5111

Louisville
Kentucky Poison Control Center of Kosair
Children’s Hospital
315 East Broadway
P.O Box 35070
Louisville, KY 40232
800-722-5725 (KY only)
502-589-8222

*Please note that the phone number listed for Maryland Poison Center is marked as an asterisk (*) indicating it may not be fully functional or available for use.
The Role of Poison Centers

MASSACHUSETTS

Boston
Massachusetts Poison Control System*
The Children’s Hospital
300 Longwood Ave.
Boston, MA 02115
800-682-9211 (MA only)
617-232-2120 or 735-6607

St. Paul
Minnesotal Regional Poison Center*
St Paul—Ramsey Medical Center
640 Jackson St.
St Paul, MN 55101
800-222-1222 (MN only)
612-221-2113

MICHIGAN

Adrian
Bixby Hospital Poison Center
Emma L. Bixby Hospital
818 Riverside Ave.
Adrian, MI 49221
517-263-2412

Jackson
University of Mississippi Medical Center
2500 North State St.
Jackson, MS 39216
601-354-7660

Hattiesburg
Forrest General Hospital
400 S 28th Ave.
Hattiesburg, MS 39402
601-288-4235

MISSISSIPPI

Detroit
Poison Control Center
Children’s Hospital of Michigan
3901 Beaubien Blvd.
Detroit, MI 48201
800-462-6642 (outside metropolitan Detroit)
313-745-5711

Grand Rapids
Blodgett Regional Poison Center
1840 Wealthy St. S.E.
Grand Rapids, MI 49506
800-632-2727 (MI only)

Kalamazoo
Bronson Poison Information Center
252 East Lovell St.
Kalamazoo, MI 49007
800-442-4112 616 (MI only)
616-341-6409

MISSOURI

Kansas City
Poison Control Center
Children’s Mercy Hospital
2401 Gillham Rd.
Kansas City, MO 64108-9898
816-234-3000 or 234-3430

St. Louis
Regional Poison Center*
Cardinal Glennon Children’s Hospital
1465 South Grand Blvd.
St. Louis, MO 63104
800-392-9111 (MO only)
800-366-8888 (MO, West IL)
314-772-5200

MINNESOTA

Minneapolis
Hennepin Regional Poison Center*
701 Park Ave. S.
Minneapolis, MN 55415
612-347-3144
612-347-3141 (Petline)

MONTANA

Denver
Rocky Mountain Poison and Drug Center
Denver, CO 80204
800-525-5042 (MT only)
NEBRASKA

Omaha
The Poison Center*
Children’s Memorial Hospital
8301 Dodge St.
Omaha, NE 68114
800-955-9119 (WY, NE)
402-390-5400, 5555

NEW MEXICO

Albuquerque
New Mexico Poison and Drug Information Center*
University of New Mexico
Albuquerque, NM 87131
800-432-6866 (NM only)
505-843-2551

NEVADA

Las Vegas
Humana Hospital-Sunrise*
3186 Maryland Pky.
Las Vegas, NV 89109
800-446-6179 (NV only)

Reno
Washoe Medical Center
77 Pringle Way
Reno, NV 89520
702-328-4144

NEW YORK

Buffalo
Western New York Poison Control Center
Children’s Hospital of Buffalo
219 Bryant St.
Buffalo, NY 14222
800-888-7655 (NY only)
716-878-7654

Mineola
Long Island Regional Poison Control Center*
Winthrop University Hospital
259 First St.
Mineola, NY 11501
516-542-2323, 2324, 2325

New York City
New York City Poison Control Center*
455 First Ave., Rm. 123
New York, NY 10016
212-340-4494
212-764-7667

Nyack
Hudson Valley Regional Poison Center
Nyack Hospital
160 North Midland Ave.
Nyack, NY 10920
800-336-6997 (NY only)
914-353-1000

Rochester
Finger Lakes Regional Poison Control Center
University of Rochester Medical Center
601 Elmwood Ave.
Rochester, NY 14642
800-333-0542 (NY only)
716-275-5151

NEW HAMPSHIRE

Lebanon
New Hampshire Poison Center
Dartmouth-Hitchcock Medical Center
1 Medical Center Dr.
Lebanon, NH 03756
800-562-8236 (NH only)
603-650-5000

NEW JERSEY

Newark
New Jersey Poison Information and Education Systems*
201 Lyons Ave.
Newark, NJ 07112
800-962-1253 (NJ only)
201-923-0764

Phillipsburg
Warren Hospital Poison Control Center
185 Rosberg St.
Phillipsburg, NJ 08865
800-962-1253
908-859-6768
The Role of Poison Centers

Syracuse
Central New York Poison Control Center
SUNY Health Science Center
750 E Adams St.
Syracuse, NY 13210
800-252-5655
315-476-4766

NORTH DAKOTA

Fargo
North Dakota Poison Center
St Luke’s Hospital
720 North 4th St.
Fargo, ND 58122
800-732-2200 (ND only)
701-234-5575

NORTH CAROLINA

Asheville
Western North Carolina Poison Control Center
Memorial Mission Hospital
509 Biltmore Ave.
Asheville, NC 28801
800-542-4225 (NC only)
704-255-4490 or 258-9907

Charlotte
Carolinas Poison Center
Carolinas Medical Center
100 Blythe Blvd.
Charlotte, NC 28232-2861
800-848-6946
704-355-4000

Durham
Duke Regional Poison Control Center
P.O. Box 3007
Durham, NC 27710
800-672-1697 (NC only)
919-684-8111

Greensboro
Triad Poison Center
Moses H Cone Memorial Hospital
1200 North Elm St.
Greensboro, NC 27401-1020
800-953-4001 (NC only)
919-574-8105

Hickory
Catawba Memorial Hospital Poison Control Center
810 Fairgrove Church Rd. SE
Hickory, NC 28602
704-322-6649

OHIO

Akron
Akron Regional Poison Center
281 Locust St.
Akron, OH 44308
800-362-9922 (OH only)
216-379-8562

Canton
Stark County Poison Control Center
Timken Mercy Medical Center
1320 Timken Mercy Dr. NW
Canton, OH 44667
800-722-8662 (OH only)
216-489-1304

Cincinnati
South West Ohio Regional Poison Control System
and Cincinnati Drug and Poison Information Center*
University of Cincinnati College of Medicine
231 Bethesda Ave., ML #144
Cincinnati, OH 45267-0144
800-872-5111 (Southwest OH only)
513-558-5111

Cleveland
Greater Cleveland Poison Control Center
2074 Abington Rd.
Cleveland, OH 44106
216-231-4455

Columbus
Central Ohio Poison Center*
700 Children’s Dr.
Columbus, OH 43205
800-682-7625 (OH only)
614-228-1323
Dayton
West Ohio Regional Poison and Drug Information Center
Children’s Medical Center
One Children’s Plaza
Dayton, OH 45404-1815
800-762-0727 (OH only)
513-222-2227

Lorain
County Poison Control Center
Lorain Community Hospital
3700 Kolbe Rd.
Lorain, OH 44053
800-821-8972 (OH only)
216-282-2220

Sandusky
Firelands Community Hospital Poison Information Center
1101 Decatur St.
Sandusky, OH 44870
419-626-7423

Toledo
Poison Information Center of Northwest Ohio
Medical College of Ohio Hospital
3000 Arlington Ave.
Toledo, OH 49614
800-589-3897 (OH only)
419-381-3897

Youngstown
Mahoning Valley Poison Center
St Elizabeth Hospital Medical Center
1044 Belmont Ave.
Youngstown, OH 44501
800-426-2348 (OH only)
216-746-2222

Zanesville
Bethesda Poison Control Center
Bethesda Hospital
2951 Maple Ave.
Zanesville, OH 43701
800-686-4221 (OH only)
614-454-4221

OKLAHOMA

Oklahoma City
Oklahoma Poison Control Center
Children’s Memorial Hospital
940 NE 13th St.
Oklahoma City, OK 73104
800-522-4611 (OK only)
405-271-5454

OREGON

Portland
Oregon Poison Center
Oregon Health Sciences University
3181 SW Sam Jackson Park Rd.
Portland, OR 97201
800-452-7165 (OR only)
503-494-8968

PENNSYLVANIA

Hershey
Central Pennsylvania Poison Center*
Milton Hershey Medical Center
Pennsylvania State University
P.O. Box 850
Hershey, PA 17033
800-521-6110
717-531-6111

Lancaster
Poison Control Center
St. Joseph Hospital and Health Care Center
250 College Ave.
Lancaster, PA 17604
717-299-4546

Philadelphia
Philadelphia Poison Control Center*
One Children’s Center
34th and Civic Center Blvd.
Philadelphia, PA 19104
215-386-2100

Pittsburgh
Pittsburgh Poison Center*
One Children’s Place
3705 Fifth Ave. at DeSoto St.
Pittsburgh, PA 15213
412-681-6669

Williamsport
The Williamsport Hospital Poison Control Center
The Role of Poison Centers

777 Rural Ave.
Williamsport, PA 17701
717-321-2000

800 East 21st St.
P.O. Box 5045
Sioux Falls, SD 57117-5045
800-952-0123 (SD only)
800-843-0505 (IA, MN, NE)
605-336-3894

RHODE ISLAND

Providen
Rhode Island Poison Center*
593 Eddy St.
Providence, RI 02903
401-444-5727

SOUTHERN CAROLINA

Charlotte
Carolinas Poison Center
Carolinas Medical Center
1000 Blythe Blvd.
Charlotte, NC 28232-2861
800-848-6946

Columbia
Palmetto Poison Center
University of South Carolina
College of Pharmacy
Columbia, SC 29208
800-922-1117 (SC only)
803-765-7359

SOUTH DAKOTA

Aberdeen
Poison Control Center
St Luke’s Midland Regional Medical Center
305 S. State St.
Aberdeen, SD 57401
800-592-1889 (SD, MN, ND, WY)
605-622-5678

Rapid City
Rapid City Regional Poison Control Center
835 Fairmont Blvd.
P.O. Box 6000
Rapid City, SD 57709
605-341-3333

Sioux Falls
McKennan Poison Center
McKennan Hospital

TENNESSEE

Knoxville
Knoxville Poison Control Center
University of Tennessee Memorial Research Center and Hospital
1924 Alcoa Hwy.
Knoxville, TN 37920
615-544-9400

Memphis
Southern Poison Center, Inc.
Lebanheur Children’s Medical Center
848 Adams Ave.
Memphis, TN 38103-2821
901-528-6048

Nashville
Middle Tennessee Regional Poison Center, Inc.
501 Oxford House
1161 21st Ave. S, B-101VUII
Nashville, TN 37232-4632
800-288-9999 (TN only)
615-322-6435

TEXAS

Conroe
Montgomery County Poison Information Center
Medical Center Hospital
504 Medical Center Blvd.
Conroe, TX 77304
409-539-7700

Dallas
North Central Texas Poison Center*
Parkland Memorial Hospital
5201 Harry Hines Blvd.
P.O. Box 35926
Dallas, TX 75235
800-441-0040 (TX only)
214-590-5000
El Paso
El Paso Poison Control Center
Thomas General Hospital
4815 Alameda Ave.
El Paso, TX 79905
915-533-1244

Galveston
Texas State Poison Control Center
University of Texas Medical Branch
8th and Mechanic St.
Galveston, TX 77550-2780
800-392-8548 (TX only)
713-654-1701 (Houston)
409-765-1420 (Galveston)

Lubbock
Methodist Hospital Poison Control
3615 19th St.
Lubbock, TX 79413
806-793-4366

UTAH
Salt Lake City
Utah Poison Control Center*
Intermountain Regional Poison Control Center
410 Chipeta Way, Suite 230
Salt Lake City, UT 84108
800-456-7707 (UT only)
801-581-2151

VERMONT
Burlington
Vermont Poison Center
Medical Center Hospital of Vermont
111 Colchester Ave.
Burlington, VT 05401
802-658-3456

VIRGINIA
Charlottesville
Blue Ridge Poison Center*
University of Virginia Health Sciences Center

Box 67
Charlottesville, VA 22901
800-451-1428 (VA only)
804-924-5543

Richmond
Virginia Poison Center
Virginia Commonwealth University
MCV Station Box 522
Richmond, VA 23298-0522
800-552-6337 (VA only)
804-786-9123

WASHINGTON
Washington
P.O. Box 5371
Seattle, WA 98105-0371
800-732-6985 (Within WA)
206-526-2121

WEST VIRGINIA
Charleston
West Virginia Poison Center*
West Virginia University
3110 MacCorkle Ave. SE
Charleston, WV 25304
800-642-3625 (WV only)
304-348-4211

Parkersburg
St. Joseph’s Hospital Center
19th St. and Murdoch Ave.
Parkersburg, WV 26101
304-424-4222

WISCONSIN
Madison
Regional Poison Control Center
University of Wisconsin Hospital
600 Highland Ave.
Madison, WI 53792
608-262-3702
REFERENCES

Fish Toxins

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I. INTRODUCTION

Fish toxins are of two types: the small, molecular oral biotoxins that are poisonous to eat, and the large molecular venoms that are injected into the body by means of a specialized device known as the venom apparatus. Thus all venoms are poisons, but not all poisons are venoms. In this chapter, only the oral biotoxins are discussed in regard to the names of the transvectors, their geographical distribution, clinical characteristics, and a brief statement of the toxin involved.

Reports of food poisoning of marine origin are increasing in frequency and outbreaks appear to be spreading geographically. Part of this increase may be credited to heightened awareness, more travel to areas of the world where marine toxicity is endemic, and a greater opportunity for exposure to oral fish toxins. There also has been an increase in
the importation of toxic marine food products into North America, Europe, Russia, Taiwan, Japan, and elsewhere. However, travel and awareness are only two facets of the overall epidemiology of the marine food biotoxication problem. There is evidence that suggests that pollution may be an added factor that needs to be taken into consideration.

II. TOXIGENESIS

Toxicity in marine organisms is the result of a progression of biochemical events taking place in the body of the target organism. Various combinations of atoms of carbon, hydrogen, oxygen, nitrogen, chlorine, sulfur, and phosphorus are synthesized by the organism into complex biotoxin molecules that may have extreme complexity and toxicity. The process by which this is accomplished is referred to as biogenesis, biosynthesis, or, more specifically, as toxigenesis. In actuality, very little is known about the precise chemical processes involved. There is a growing amount of chemical data that suggests that in some instances marine bacteria play a role in toxin biosynthesis.

Oral marine biotoxins may develop in the bodies of marine organisms as a result of naturally occurring precursor chemical agents, or they may develop as a result of human-induced chemical pollutants. In either case, the resulting biotoxins are capable of producing serious public health problems. These problems may occur in endemic areas wherever marine biotoxins exist or in far-removed areas to which toxic marine products have been transported. The increase of marine biotoxications worldwide are of grave economic and public health significance.

III. DYSTROPHICATION AND TOXIGENESIS

There is an aspect of ecotoxicology that appears to have a bearing on the topic of foodborne marine intoxicants, that is, the matter of ocean eutrophication and its resultant dystrophication due to pollution. The process of ocean eutrophication is a phenomenon that has been well documented (1–3). Eutrophication is a process of nutrient enrichment involving ocean ecosystems. Dystrophication generally is looked upon as a posteutrophication process in which there is oxygen depletion resulting from the action of aerobic bacteria upon organic matter accompanied by other poorly defined chemical alterations in the marine environment. These two processes generally are looked upon as an aging activity in a body of water.

A vast array of chemical agents, military and industrial pollutants, pesticides, and heavy metals are entering the marine environment and contributing to the eutrophication process. This ocean enrichment process is taking on global proportions and is of growing concern to marine toxicologists. More detailed information on this subject has been published in Ref. 4.

Current evidence suggests that the combined onslaught of all of these chemical substances entering the ocean environment undoubtedly contributes to the degradative enrichment process. This involves a series of chemical and physical vector forces that presently appear to defy analysis. The ever-increasing chemical contamination of the ocean environment strongly suggests that the growing number of outbreaks of oral intoxications may be related events.
The bacterial degradation of organic matter by proteolytic bacteria produces a decrease in dissolved oxygen and may increase the growth of sulfate bacteria and the production of hydrogen sulfate and sulfur. Pollutants of various types may upset the phytoplanktonic cycle and alter the work of chemical mediators, resulting in eutrophication and dystrophication. All of these factors may cause an increase in toxic phytoflagellate blooms and various forms of bacterial toxigenesis.

Yasumoto et al. (5,6) and Noguchi et al. (7) reported that the bacterial *Pseudomonas* and *Vibrio* species were found in association with toxic pufferfish and toxic phytoflagellates. The investigators concluded that the bacteria were responsible for the production of tetrodotoxin and saxitoxin. Kotaki et al. (8) isolated the bacterium *Moraella* species and concluded that it was responsible for the biosynthesis of saxitoxin in cultures of the toxic dinoflagellate *Protogonyaulax (Gonyaulax) tamarensisis*.

The studies cited above provide substantial evidence that microbial organisms are responsible for the production of such toxins as tetrodotoxin, saxitoxin, and some of their congeners. It is possible that the ciguatoxin complex, palytoxin, and probably other marine toxins yet to be identified may also be the products of bacterial activity acting in association with a variety of marine plants and animals (5,6,9–21); Aubert feels that it is difficult to explain the toxigenesis of phytoplankton by any other means than by bacteria (M. Aubert, personal communication, 1991). Bacterial toxigenesis has now become an area of major epidemiological concern in dealing with outbreaks of organic marine biotoxinations.

There are various ways of classifying food-borne outbreaks resulting from the ingestion of toxic fishes. Here the outbreaks are arranged phylogenetically according to the fish transvectors involved. All of the fish presented in the sections below are members of the phylum Chordata.

### IV. ICHTHYOSARCOTOXIC FISH

Ichthyosarcotoxic fish are those that contain a poison within the flesh of the fish (i.e., the musculature, viscera, skin, or slime) which, when ingested, causes a biotoxication. This category should not be confused with that which causes ichthyootoxism, in which the poison is restricted to the gonads or roe of the fish.

#### A. Lampreys and Hagfish: Cyclostome Fish

The cyclostome fish are members of the class Agnatha. The cyclostomes, which include the lampreys and hagfish, are a group of fishlike vertebrates having an eel-like form, cartilaginous or fibrous skeleton, no definite jaws or bony teeth, and a primitive type of cranium. There are no pelvic girdles, paired limbs or true ribs. There are 6–14 pairs of gill pouches opening either directly into the pharynx or into a separate respiratory tube. Only a single nostril is present. Because of their structural simplicity, cyclostomes generally are considered the most primitive of true vertebrates. The hagfish are strictly inhabitants of temperate and subtropical inshore marine waters of the Atlantic and Pacific Oceans.

Hagfish are members of the family Myxinidae. The skin of the hagfish is richly supplied with large mucous cells. A large hagfish is said to be capable of filling a two-gallon bucket with slime. The slime is reputed to be toxic. Hagfish are rarely eaten as food.
Representative Species

Family: Myxinidae (hagfish)
Distribution: North Atlantic.

Family: Petromyzonidae (lampreys)
Species: *Petromyzon marinus* Linnaeus. Sea lamprey. Length 33 in. (84 cm).
Distribution: Coasts and rivers of both sides of the Atlantic, rivers of the Mediter-
raean.

Cyclostome Poisoning

Clinical Characteristics: Poisoning from cyclostomes is rare because they seldom are eaten. The slime is said to be toxic to eat. Symptoms consist of nausea, vomiting, dysenteric diarrhea, tenesmus, abdominal pain, and weakness (22–26). There are no recent accounts of cyclostome poisoning.

Treatment: Treatment is symptomatic. See Refs. 27–29.

Prevention: Most cyclostome poisonings are said to be caused because of failure to deslime the fish. For prevention, some authors claim that if the fresh fish is covered with salt and left in a concentrated brine solution for several hours prior to cooking, the fish is safe to eat (30,31).

B. Sharks, Skates, Rays, and Chimaeras: Elasmobranch Fish

The elasmobranch fishes include the sharks, skates, rays, and chimaeras, all of which are members of the class Chondrichthyes. The poisoning is referred to as elasmobranch poisoning when it involves sharks, skates, or rays. When involving chimaeras, also known as the elephantfish or ratfish, the intoxication is known as chimaera poisoning.

The sharks, skates, and rays are fishlike vertebrates with well-developed lower jaws and bony teeth; two pairs of appendages supported by pectoral and pelvic girdles; a cartilaginous skeleton that, while more or less calcified, lacks any true bone; scales, essentially toothlike in structure, known as placoid scales; two nostrils, each single and partially subdivided; and blind olfactory sacs, not opening into the mouth. The posterior end of the vertebral column is either straight or heterocercal. A sympathetic nervous system, pancreas, spleen, and contractile arterial cone are present. There is a series of two, three, or more heart valves and a swim bladder is present. There are five to seven pairs of gills and five to seven gill clefts, each of the latter opening separately to an exterior dorsal fin or fins, and spines, if present, are rigid and not erectile. The skin is with or without dermal denticles, teeth are numerous, and the upper jaw or palatoquadrate cartilage is not fused to the cranium, although it may be attached locally to it. The nostril cartilage is fused to the cranium. At least some of the vertebrae of the trunk region have transverse ribs and the two halves of the pelvic girdle are fused into a single bar. The anus and urogenital canals discharge into a common cloaca and the males are without prepelvic or frontal tenacula.

1. Poisonous Sharks

Representative Species

Family: Isuridae (mackerel sharks)
Species: *Carcharodon carcharias* (Linnaeus). Great white shark. Length 20 ft (6 m).
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Distribution: Cosmopolitan: tropical, subtropical, and warm temperate seas worldwide.
Family: Carcharhinidae (requiem sharks)
Species: *Carcharhinus melanopterus* (Quoy and Gaimard). Black-tip reef shark.
   Length 6.5 ft (2 m).
Distribution: Tropical-Indo Pacific region.
Species: *Carcharhinus amboinensis* Müller and Henle. Pig-nosed Shark. Length 82 in. (2.8 m).
Species: *Carcharhinus leucas* (Valenciennes). Bull head shark. Length 12 ft (3.6 m).
Distribution: Warm waters of the Atlantic, Pacific, and Indian Oceans.
Family: Hexanchidae (cow sharks)
Species: *Heptranchias perlo* (Bonnaterre). Seven-gilled shark. Length 6.3 ft (2 m).
Distribution: Atlantic, Mediterranean, South Africa, and Japan.
Family: Dalatidae (sleeper sharks).
Species: *Somniosus microcephalus* (Bloch and Schneider). Greenland shark. Length 6.3 ft (2 m).
Distribution: Arctic Atlantic, North Sea, east to the White Sea, and west to the Gulf of St. Lawrence.
Family: Sphyrnidae (hammerhead sharks).
Species: *Sphyrna zygaena* (Linnaeus). Scalloped hammerhead shark. Length 14 ft (4 m).
Distribution: Tropical to warm temperate belt of the Atlantic and Pacific Oceans.

Elasmobranch Poisoning

The elasmobranch form of ichthyosarcotoxism is most commonly caused by eating shark livers and the flesh of some of the tropical sharks. Skates and rays are seldom involved in food poisoning.

**Clinical Characteristics:** The ingestion of fresh Greenland shark flesh is toxic to both dogs and man. The symptoms consist of nausea, vomiting, diarrhea, difficulty in walking, convulsions, respiratory distress, and muscular twitching. The local natives gradually build up a tolerance to the poison. The toxicity of Greenland shark poisoning is believed to be due to large amounts of trimethylamine oxide (32).

Serious intoxications have resulted from eating the tropical sharks *Carcharodon carcharias, Carcharhinus melanopterus, Carcharhinus amboinensis, Carcharhinus leucas, Heptranchias perlo*, and *Sphyrna zygaena*. The symptoms resulting from the ingestion of shark liver may be severe, developing within 30 minutes after eating. The symptoms consist of nausea, vomiting, diarrhea, abdominal pain, headache, joint aches, tingling about the mouth, and a burning sensation of the tongue, throat, and esophagus. As time progresses, the symptoms involving the nervous system may worsen, resulting in muscular incoordination and difficulty in breathing due to muscular paralysis, followed by coma, and finally death.

Ingestion of the flesh of certain species of tropical and arctic sharks may be dangerous to eat, but the symptoms usually are mild, consisting mainly of a gastrointestinal upset.
Treatment: Treatment is symptomatic. See ciguatera fish poisoning. See Refs. (27–29).

Prevention: Avoid eating the liver of any shark unless it is known for certain to be edible. The livers of tropical and arctic sharks are known to be especially dangerous to eat. The flesh of tropical and arctic sharks is potentially poisonous and should be eaten with caution.

2. Poisonous Chimaeras

The chimaeroids—elephantfish or ratfish—differ from the sharks, skates, and rays in that they have only four pairs of gills and four pairs of gill clefts, with only one opening to the exterior on each side of the head. The dorsal fin and spine are erectile. In the adult, the skin is naked, without dermal denticles. Teeth are represented by six pairs of grinding plates; the upper jaw or platorate cartilage is fused with the cranium and the rostral cartilage is articulated to the cranium, not fused. Ribs are lacking and the two halves of the pelvic girdle separate. There is no cloaca, and the urogenital aperture is distinct from the anus and posterior to it. The males have an erectile prepelvic tenaculum, usually with a frontal tenaculum on the head (33).

Representative Species

Family: Chimaeridae (Chimaeras)
Species: Chimaera monstrosa Linnaeus. Length 39 in. (1 m).
European chimaera.
Distribution: North Atlantic and Mediterranean.

Chimaera Poisoning

The musculature and viscera of some of the elephantfish and ratfish have been found to be toxic, but the nature of the chimaera poison is unknown.

Clinical Characteristics: The symptomatology of chimaera poisoning in humans is unknown.

Treatment: Treatment is symptomatic.
Prevention: Chimaeras should not be used for human consumption.

C. Ciguatoxic Fish

Ciguatoxic fish cause one of the most widespread and serious forms of ichthyosarcotoxism known. More than 400 species of fish are alleged to have transvectored the ciguatoxin complex poisons that serve as the causative toxins in ciguatera fish poisoning. The fish involved are for the most part tropical or warm, temperate zone reef or inshore species found between 35°N latitude and 34°S latitude in the Caribbean and tropical Pacific and Indian Oceans. Occasionally, offshore fish may be involved, but by far the bulk of the outbreaks have occurred in insular areas. Historically, ciguatera-like symptoms have resulted from eating marine turban shells (Turbo pica) in the Caribbean (25,34,35), and similar outbreaks have been caused by eating coconut crabs in Tahiti and in the Ryukyu Islands (36,37). No freshwater fish have been incriminated.

Many of the ciguatoxic fish are valuable food fish that on occasion become toxic within a few hours of ingesting toxic dinoflagellates or algae in association with toxic dinoflagellates. Carnivorous fish may become toxic as a result of ingesting toxic herbivores. Thus ciguatera is a toxic food chain problem. Once a fish becomes poisonous, the
toxicity within the body of the fish may continue for a period of many years. One of the species of dinoflagellates that has been incriminated in ciguatera fish poisoning is *Gambierdiscus toxicus* Adachi and Fukuyo. Several other dinoflagellate species are highly suspect as causative agents of ciguatera fish poisoning, including *Amphidinium carterae* Hulbert, *Ostreopsis ovata* Fukuyo, *Prorocentrum concavum* Fukuyo, *P. lima* (Ehrenberg) Dodge, and *P. mexicanum* Tafall (38). There is growing evidence that suggests that the primary causative agent in this toxicity cycle may be bacteria that live in a symbiotic relationship with dinoflagellates or possibly macroalgae (see Sec. III).

Ciguatoxic fish are a group of phylogenetically diversified species, most of which are members of the class Osteichthyes, the bony fish. The biology of these fish is as diversified in habitat, habits, feeding, and reproduction as it is in morphology. Consequently, it is impossible to present a stereotyped characterization of a ciguatoxic fish. Moreover, you cannot detect a ciguatoxic fish by its appearance. In one part of an island, any given fish species may be edible, whereas on the opposite side of the island or on an adjacent reef, the same species may be deadly poisonous. This is the major problem in ciguatera fish poisoning.

The members of the class Osteichthyes are characterized as having a skeleton, in part or all with true bone; the skull has sutures; and the teeth are fused to the bones. The soft fin rays usually are segmented. Nasal openings on each side usually are double and more or less dorsal in position. The biting edge of the upper jaw usually is formed by dermal bones, the premaxillae and the maxillae. A swim bladder or a functional lung usually is present. There is an intestinal spiral valve in only a few lower groups. Internal fertilization is relatively rare, and there is a pelvic copulation device in only one group (phallothoids). The embryos are not encapsulated in a case (39).

**Representative Species**

An attempt to list all of the ciguatoxic fish species that have been incriminated to date would not be feasible; consequently, only a small representative group of species is listed below. The fish are arranged in alphabetical order according to their family names and within the family by their generic names.

Family: Acanthuridae (surgeonfish)
Distribution: Indo-Pacific.
Family: Balistidae (leatherjackets, filefish, triggerfish)
Species: *Alutera scripta* (Osbeck). Scribbled filefish. Length 19 in. (50 cm).
Distribution: All warm seas.
Species: *Balistoides conspicillum* Bloch and Schneider. Clown triggerfish (Fig. 11).
Length 13.7 in. (35 cm).
Distribution: Tropical Pacific from Polynesia to Madagascar, China, Japan.
Family: Carangidae (jacks, pompanos)
Species: *Caranx hippos* (Linnaeus). Jack, crevalle. Length 29.5 in. (75 cm).
Distribution: Tropical Atlantic.
Species: *Caranx melamygus* Cuvier. Blue jack. Length 25.5 in. (65 cm).
Distribution: Tropical Pacific.
Family: Lutjanidae (snappers)
Species: *Lutjanus bohar* (Forskål). Red two-spotted snapper. Length 35.5 in. (90 cm).
Distribution: Tropical Indo-Pacific.
Species: *Lutjanus gibbus* (Forskål). Humpback snapper. Length 15.5 in. (40 cm).
Distribution: Tropical Indo-Pacific.
Distribution: Indo-Pacific.
Family: Mugilidae (mullets).
Species: *Chelon vaigiensis* (Quoy and Gaimard). Mullet. Length 12 in. (30.5 cm).
Distribution: Indo-Pacific.
Distribution: Cosmopolitan in warm temperate seas.
Family: Mullidae (goatfish, surmullets)
Distribution: Indo-Pacific.
Species: *Parupeneus chryserydros* (Lacèpède). Goatfish. Length 13 in. (33 cm).
Distribution: Indo-Pacific, East Africa.
Family: Muraenidae (moray eels)
Species: *Gymnothorax javanicus* (Bleeker). Giant brown moray eel. Length 5 ft (1.5 m).
Distribution: Indo-Pacific.
Species: *Gymnothorax meleagris* (Shaw and Nodder). White-mouthed moray eel. Length 39 in. (1 m).
Distribution: Indo-Pacific, Japan.
Family: Scombridae (tunas, mackerels, albacore)
Species: *Acanthocybium solandri* (Cuvier). Wahoo. Length 78 in. (2 m).
Distribution: Circumtropical.
Species: *Scomberomorus cavalla* (Cuvier). King mackerel. Length 59 in. (1.5 m).
Distribution: Tropical Atlantic.
Family: Serranidae (sea basses, grouper)
Species: *Cephalopholis argus* (Bloch and Schneider). Peacock grouper. Length 20 in. (51 cm).
Distribution: Indo-Pacific.
Species: *Epinephalus fuscoguttatus* (Forskål). Brown marbled grouper. Length 23.5 in. (60 cm).
Distribution: Indo-Pacific.
Distribution: Western tropical Atlantic.
Species: *Plectropomus oligacanthus* Bleeker. Blue-lined coral grouper. Length 21 in. (55 cm).
Distribution: Indo-Pacific.
Species: *Variola louti* (Forskål). Lyretail grouper. Length 23 in. (60 cm).
Distribution: Indo-Pacific.
Family: Siganidae (rabbitfish).
Distribution: Indo-Pacific.
Species: *Siganus puellus* (Schlegel). Rabbitfish. Length 10 in. (27 cm).
Distribution: Indo-Pacific.
Family: Sphyraenidae (Barracuda)
Species: Sphyraena barracuda (Walbaum). Great barracuda. Length 5.2 ft (1.6 m).
Distribution: All warm seas, except eastern Pacific.

Ciguatera Fish Poisoning

Ciguatera fish poisoning results from the ingestion of any of a large variety of shore and reef fish which are usually subtropical or tropical in their distribution. The degree of freshness of the fish has no bearing on its toxicity. The victim becomes poisoned as a result of ingesting a toxin within the flesh of the fish. Ciguatera is not a form of ordinary bacterial food poisoning.

Ciguatera fish poisoning involves a complex of poisons: ciguatoxin, molecular formula $C_{60}H_{86}O_{9}$, molecular weight 1112, median lethal dose (LD$_{50}$) 0.45 g/kg mouse intraperitoneal (IP) (40–45); maitotoxin, molecular formula $C_{60}H_{25}S_{2}O_{7}$, approximate molecular weight 3396.1, LD$_{50}$ toxicity 0.13 g/kg mouse IP (46); scaritoxin, molecular formula and toxicity unknown (47). Ciguatoxin and maitotoxin are two of the most toxic marine poisons known.

Ciguatoxin acts by increasing the membrane permeability to sodium ions of excitable neurons by opening the voltage-dependent sodium channels (43,48,49). Repeated doses of ciguatoxin to mice on an experimental basis have been found to produce severe ultrastructural morphological changes in the cardiac muscle cells and endothelial lining cells of blood capillaries in the heart. Damage to the capillaries was followed by effusion of serum and erythrocytes into the interstitial spaces of the myocardium. Swelling of the endothelial lining cells of capillaries caused narrowing of the lumen and accumulation of blood platelets in capillaries, which resulted in multiple single-cell necrosis of cardiac muscle cells (50). These experimental findings in mice may possibly explain some of the clinical cardiac findings in individuals that have suffered multiple exposures to ciguatera fish poisoning.

The most toxic part of the fish is usually the liver, followed by the intestines, then the testes, ovaries, and the muscle. As noted in Sec. IV.C, the toxin originates in the food web of the fish.

There is no evidence of a seasonal incidence in ciguatoxicity, but the spawning season in some of the larger predacious fish may be a more dangerous period than the other seasons of the year. There is no way to detect a ciguatoxic fish by its appearance.

Clinical Characteristics: Ciguatera fish poisoning produces a constellation of 175 gastrointestinal, cardiovascular, and neurological symptoms, some of which are pathognomonic for the disease. The onset of the poisoning may occur within minutes and up to 48 hours after the fish is ingested.

The initial symptoms generally consist of paresthesias and tingling or numbness of the lips, tongue, and extremities. The neurosensory symptoms may be accompanied by nausea, abdominal pain, vomiting, diarrhea, salivation, general malaise, and muscle and joint pain. The gastrointestinal symptoms are present in about 75% of cases, but usually resolve within 24 hours.

There is a neurosensory symptom that is of diagnostic importance in ciguatera poisoning: the reversal of temperature sensation in which cold objects (water, ice, etc.) feel hot, produce a stinging sensation, or are painful upon contact. Warm objects may feel cold. This temperature-reversal sensation appears in more than 89% of cases. Cardiovascular symptoms usually consist of bradycardia and hypotension, which later may change to
tachycardia and hypertension. Cardiovascular symptoms generally resolve within 48 hours, but may persist for several weeks.

Neurological symptoms of perioral and extremity paresthesias, ataxia, pruritus, mental depression, hysteria, maculopapular skin eruptions, blisters, desquamation, loss of hair and nails, cranial nerve palsy, vertigo, tremors, chills, headache, sweating, dysuria, hiccups, visual blurring, superficial hyperesthesia, motor weakness, respiratory distress, myalgia, arthralgia, temperature reversal, hyporeflexia, metallic taste, loose or painful sensation of the teeth, and extraocular muscle pain may be present. Their occurrence and duration vary with the individual. Seldom is fever present. Extreme muscle weakness is a common complaint. Paralysis of the extremities may occur. Physical findings are variable and non-specific in ciguatera poisoning.

The severity of the case varies with the individual’s sensitivity to the toxin, the toxicity of the fish, and the amount of toxic fish eaten. Recovery varies greatly from case to case, and can be from 48 hours to several days, weeks, months, and, in some cases, years. Fatalities are uncommon, but do occur. Fatalities may be due to cardiovascular collapse or respiratory paralysis. Exposure to the ciguatoxin complex does not confer immunity. There are no accurate statistics worldwide as to the incidence or mortality rate of ciguatera fish poisoning. There is a gross underreporting of outbreaks even in regions in which ciguatera is endemic. The subject of ciguatera fish poisoning has been under intensive investigation by numerous workers over an extended period of time (25,48,51–90).

**Treatment:** The treatment of ciguatera fish poisoning is largely symptomatic, but there are a few specific modalities that may be especially helpful. The identity of the fish is of minor value because about 400 different species of tropical reef fish have been incriminated thus far and the amount of toxin in the fish varies greatly from one specimen to the next. The diagnosis of ciguatera fish poisoning is based on the symptomatology presented. Gastric lavage or vomiting induced by sticking ones finger down the throat, or using apomorphine or ipecac, should be done as soon as possible. This should be followed by the administration of a slurry of charcoal to absorb the poison in the intestinal tract. Nausea and vomiting can be controlled by using an antiemetic drug such as prochlorperazine. Hypotension can usually be helped with the use of a pressor drug such as dopamine or dobutamine. Calcium gluconate may also be helpful in treating the hypotension and myocardial insufficiency. Bradycardia may be controlled with the use of atropine. Cool showers and the use of hydroxyzine may be helpful in relieving the pruritus. Intravenous sodium ascorbate (25 g diluted in 250 ml of normal saline per day for 10 days) and vitamin B complex have been employed in relieving some of the toxic effects of ciguatoxin. Mannitol has been found to provide symptomatic relief in many cases (121,130).

The fruit of the nono tree (*Morinda citrifolia* Linnaeus) has been used for centuries by South Pacific islanders to treat the symptoms of ciguatera fish poisoning (2). The juice of this fruit is now sold in the United States and elsewhere throughout the world under the trade name ‘‘Noni.’’ The usual dosage is 3–4 ounces of the juice per day. The product is nontoxic and should be tried.

A variety of other therapies have been employed, but none of them have been shown to be completely effective. See Refs. 27–29.

**Prevention:** There is no reliable method of detecting a ciguatoxic fish by its appearance. However, there are a few basic guidelines that are helpful. Such large, predacious reef fish as snapper, barracuda, grouper, and jacks should be eaten with caution. The larger the fish is the greater is the potential of ciguatoxication if the fish is captured in an endemic
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region. Large fish generally accumulate the toxic products from the various trophic levels in the food chain below them. Ciguatera is essentially the end result of a toxic biochemical magnification problem in which humans are the final recipient of the toxic agents from all of the marine organisms in the trophic levels below them.

When catching fish in a suspected ciguatoxic region, it is always advisable to seek the advice of the locals as to the edibility of the fish. The viscera (i.e., liver, gonads, and intestines) of many tropical reef fish are toxic and should not be eaten. Such ordinary cooking procedures as frying, baking, boiling, or drying do not render a fish safe to eat. If in doubt concerning the toxicity of the fish, eat only a small amount and wait for a period of several hours before eating additional quantities of the fish. Tropical moray eels frequently are toxic, maybe deadly, and should not be eaten. Offshore fish generally are safer to eat than inshore reef species.

Bioassay methods have been used to detect ciguatoxic fish utilizing a variety of test animals, including brine shrimp, ants, flies, cats, dogs, mongooses, rats, guinea pigs, plants, chickens, frogs, and so on. See Ref. 48 for a review of these bioassay methods. Cats have been found to be extremely sensitive to ciguatoxin. All of these bioassay methods tend to be cumbersome, time consuming, and, in most instances, expensive.

Several immunoassay methods have been developed for the detection of ciguatoxic fish. One of the first of these techniques utilized a radioimmunoassay method for the detection of minute quantities of antigens and antibodies (91–94). This test was refined further into an enzyme immunoassay method (95) that was found to be easier to run, less expensive, more feasible for screening all sizes and varieties of fish, and could be used to test liver and musculature. A more inexpensive, but still reliable assay is the stick test developed by Hokama (79,96,97) and Hokama et al. (98). The stick test measures ciguatoxin and polyether compounds, including okadaic acid. The stick test has been used commercially to a limited extent in Hawaii. The stick test appears to be the most reliable and practical assay method currently available for the screening of ciguatoxic fish. Unfortunately the stick test is generally not available in most endemic ciguatoxic regions of the world.

D. Clupeotoxic Fish

Clupeotoxic fish are members of the order Clupeiformes which includes the herrings, anchovies, and related species. Clupeiform fishes become poisonous after eating toxic dinoflagellates such as Ostreopsis siamensis Schmidt (99). Undoubtedly other species of dinoflagellates are also involved but have yet to be incriminated. This form of poisoning is rare and resembles ciguatera, but it is very rapid in its action and has a high mortality rate.

The members of the order Clupeiformes include the families Clupeidae, the herrings; Engraulidae, the anchovies; Elopidae, the tarpons; Albulidae, the bonefish; Pterothrissidae, the deep-sea bonefish; and Alepocephalidae, the deep-sea slickheads. However, the families most commonly incriminated in human clupeotoxications are members of the Clupeidae and Engraulidae. The clupeiform fish are characterized as follows. They are soft-rayed fish with the anterior vertebrae simple, unmodified, and without auditory ossicles; symplectic bone is present and there are no interclavicles. The recessus lateralis is present, and the infraorbital canal merges with the preopercular canal within a chamber of the neurocranium. Parasphenoid teeth are absent. There is no large foramen on the anterior ceratohyal, the parietals are separated by the supraoccipital, and the opercular bones are
distinct. The pharyngeal bones are simple above and below, with the lower not falciform. The bones of the jaws are developed; the maxillary is broad, always distinct from the premaxillary, and forms part of the margin of the upper jaw. There are no barbs. The shoulder girdle is well developed and connected with the cranium by a bony posttemporal. There are four gills with a slit behind the fourth. The air bladder, if present, has a pneumatic duct. The dorsal and anal fins are without true spines; the ventral fins are abdominal and the adipose fin can be present or absent. This is a large group of fish comprising most of the marine soft-rayed fish. Most are plankton feeders with numerous, long gill rakers.

Representative Species

**Family**: Clupeidae (sardines, herrings)

**Species**: *Clupanodon thrissa* (Linnaeus). Thread herring. Length 9 in. (25 cm).
**Distribution**: Indo-Pacific, China, Japan, Korea.

**Species**: *Clupea sprattus* Linnaeus. Sprat. Length 6 in. (15 cm).
**Distribution**: Northeastern Atlantic, Mediterranean.

**Species**: *Harengula ovalis* (Bennett). Sardine. Length 6 in. (15 cm).
**Distribution**: Indo-Pacific, Red Sea.

**Species**: *Opisthonema oglinum* (LeSueur). Atlantic thread herring. Length 9 in. (25 cm).
**Distribution**: West Indies, north to Cape Cod.

**Family**: Engraulidae

**Species**: *Engraulis encrasicholus* (Linnaeus). Anchovy. Length 7 in. (20 cm).
**Distribution**: Eastern Atlantic and Mediterranean.

**Species**: *Thrissina baelama* (Forskal). Anchovy. Length 4 in. (12 cm).
**Distribution**: Indo-Pacific, Red Sea, enters river mouths.

**Clupeotoxism**

Clupeotoxications result from eating clupeiform fish such as sardines, herring, and anchovies. Most poisonings have occurred in tropical island areas and were caused by eating fish captured close to shore. It is believed that clupeotoxism is seasonal and most likely to occur during the summer months. Clupeotoxin has been isolated (99), but its molecular structure has not been elucidated.

**Clinical Characteristics**: The symptoms and signs of clupeotoxism are distinct and usually violent. The first indication of an intoxication is a sharp metallic taste that may be present immediately following ingestion of the fish, followed by nausea, dryness of the mouth, vomiting, malaise, abdominal pain, and diarrhea. The gastrointestinal upset may be accompanied by a feeble pulse, tachycardia, chills, cold and clammy skin, vertigo, a drop in blood pressure, cyanosis, and other evidences of vascular collapse. Within a very short period of time, or concurrently, a variety of neurological disturbances ensue, such as nervousness, dilated pupils, violent headaches, numbness, tingling, hypersalivation, muscle cramps, respiratory distress, progressive muscular paralysis, convulsions, coma, and death. Death may occur in less than 15 minutes. Ferguson (101) claimed that the poison was so rapid in its action that natives died while in the very act of eating the yellow-billed sprat (*Clupea thrissa*). Pruritus and various types of skin eruptions, including desquamation and ulcerations, have been reported in victims that have survived. There are no accurate statistics available regarding the mortality rate of clupeotoxism, but judg-
ing from the documented case reports, the fatality rate is very high and the victims generally die within minutes to hours.

It is believed that clupeotoxism in some instances may be related to ciguatera poisoning, but this has not been documented. Some cases appear to exhibit ciguatera-like symptoms. Since clupeoid fish are primarily plankton feeders, it is likely that some of these fish are ingesting highly toxic dinoflagellates.

*Treatment:* Follow the treatment recommended for ciguatera fish poisoning. See Refs. 27–29.

*Prevention:* There are no reliable methods of detecting a clupeotoxic fish and preventing intoxication. Outbreaks of this intoxication are rare and there are insufficient data concerning the nature of the poison. No screening methods have been developed for the testing of clupeotoxic fish. Most of the clupeotoxic fish are generally valuable food fish.

### E. Gempylotoxid Fish

The gempylids, escolars, or pelagic mackerels are a small group of predacious oceanic fish. They have a band-shaped body, large, sharp teeth, and are distinguished from the true mackerels by the complete absence of a later keel or ridge on the caudal peduncle. Two dorsal fins are present, the first of which is spinous and longer than the second. Gempylids produce an oil that has a pronounced purgative effect.

**Representative Species**

- **Family:** Gempylidae (castor oil fish)
- **Species:** *Ruvettus pretiosus* Cocco. Castor oil fish. Length 4.2 ft (1.3 m).
- **Distribution:** Tropical Atlantic and Indo-Pacific.

**Gempylid Poisoning**

The gempylid poisoning form of ichthyosarcotoxism is caused by ingesting the flesh or sucking the rich, oily bones of the fish. People suffering from constipation in the South Pacific islands use gempylid fish for its relief.

*Clinical Characteristics:* Ingestion of the oil contained in the flesh and bones of gempylid fish causes diarrhea, which, although pronounced, is generally without pain or cramping (26,102,103). No other untoward effects have been reported. Gempylotoxism has also been referred to as gempylid diarrhea. The oil is similar to castor oil, comprised mainly of oleic acid, but it has different pharmacodynamic properties (104,105).

*Treatment:* No treatment is required.

*Prevention:* Avoid eating gempylid fish.

### F. Scombrotoxic Fish

Scombrotoxism, or scombroid poisoning, is caused by perciform fish of the suborder Scombroidei, all of which are members of the single family Scombridae, the tunas and related species. One of the members of the order Beloniformes, family Scomberesocidae, the Japanese saury (*Cololabis saira*) has also been incriminated in scombroid poisoning. Recently, such other fish species as mahi-mahi, jack, bluefish, herring, sardines, and anchovies have been reported to cause scombroid poisoning (87). Scombroid poisoning accounts for about 5% of food-borne poisonings in the United States.

Scombroid fish are characterized by their adaptation for swift locomotion, having
a sharp profile anteriorly and a slender tail with a widely forked caudal. There is a series of detached finlets on the back behind the second dorsal fin and on the undersurface behind the anal fin, a feature that distinguishes them from most other fish. Scombroids have two dorsal fins, of which the first is composed of spines and the second of soft rays. The fins fit into grooves or depressions on the body, the bones of the head lie flat, and the gill covers fit tightly against the sides. The scales are usually small, thin, and metallic in appearance, offering a minimum of friction in the water. Scombroids are the epitome of grace, form, and speed.

Tunas and related species are largely oceanic, migrating great distances through the open seas. Mackerels are largely inhabitants of littoral waters. Scombroids are distributed widely throughout all temperate and tropical seas, and some occasionally are found in arctic and antarctic waters. They usually swim in large schools. Scombroids generally swim near the surface of the water during spawning season. During the warmer months they approach the shore, but retire to deeper water during the cold months. They feed on the plankton swimming in the deeper water during the day, and rise to the surface at night. Scombroids are predatory and voracious feeders. In addition to plankton, they also feed on a wide variety of moderate-size fish. Some of the tunas can be found at depths of 200 m or more, whereas other scombroids seldom descend below 40 m.

The sauries of the family Scomberesocidae resemble the needlefish, but have short jaws and are identified by a series of five to seven finlets following both the dorsal and anal fins. There are four species and none attain a length much beyond 35 cm. Sauries inhabit temperate and tropical waters. They are very abundant in some regions and constitute an important food fishery in Japan. Sauries feed on plankton and small fish. The sauries also have been incriminated in scombroid fish poisoning, but outbreaks have been limited to Japan.

**Representative Species**

**Family: Scomberesocidae (sauries)**
- Distribution: Japan.

**Family: Scombridae (tunas, mackerels, albacore)**
- Distribution: Cosmopolitan in warm seas.
- Distribution: Cosmopolitan in warm seas.
- Species: *Thunnus thynnus* (Linnaeus). Bluefin tuna. Length 10 ft (3 m).
- Distribution: Cosmopolitan in subtropical and temperate seas.

**Scombroid (Histamine) Poisoning**

Scombroid poisoning is caused by the improper preservation of scombroid fish or other fish species that results in certain bacteria, mainly species of the family Enterobacteriaceae (*Clostridium, Lactobacillus, Proteus, Vibrio*), acting on histidine in the muscle of the fish converting it to histamine. The toxicity of histamine is enhanced by the presence of certain potentiators (e.g., cadaverine and putrescine) that act by inhibiting intestinal histamine-metabolizing enzymes. The enzyme inhibition increases the intestinal uptake of unmetabolized histamine (106–108). Histamine ingested by itself generally is much less toxic.

Scombroid poisoning is the most common form of ichthyosarcotoxism and occurs
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throughout the world wherever scombroid fish are eaten. Moreover, it is the only form of ichthyosarcotoxism in which bacteria play an active role in toxin production within the body of the fish.

Clinical Characteristics: The symptoms of acute scombroid poisoning resemble those of histamine intoxication. The symptoms are characteristic and appear with almost monotonous consistency. Toxic scombroid fish frequently can be detected immediately upon tasting the fish. Victims state that the fish has a sharp or peppery taste. Symptoms usually occur within a few minutes after ingestion of the toxin and consist of intense headaches, dizziness, throbbing of the carotid and temporal vessels, epigastric pain, burning of the throat, cardiac palpitation, rapid and weak pulse, dryness of the mouth, thirst, inability to swallow, nausea, vomiting, diarrhea, and abdominal pain. Within a short time a generalized erythema and an urticarial eruption may develop, covering the entire body and accompanied by a severe pruritus. The face of the individual becomes swollen and flushed, the eyes become injected, and coryza develops. In severe cases there may be bronchospasm, suffocation, and severe respiratory distress. Various other minor discomforts such as fever, chills, malaise, tremors, metallic taste, and cyanosis of the gums and tongue may occur. There is a danger of shock, and deaths have been reported. However, the acute symptoms generally are transient, lasting only 8–12 hours (48,108–111).

Treatment: The treatment of scombroid poisoning is largely directed toward relieving the symptoms of the histamine reaction. This form of poisoning is generally self-limiting and fatalities are rare. Minor intoxications can usually be treated with diphenhydramine (Benedryl). Scombroid poisoning may cause respiratory distress, in which case the victim should be taken immediately to an emergency treatment center. Epinephrine is the treatment of choice for respiratory problems in this instance, but it should be used with caution in older individuals with a history cardiac problems. See Refs.(27–29, 92,112–115).

Prevention: Scombroid fish and other related species believed to cause this form of ichthyosarcotoxism should be refrigerated promptly or eaten soon after capture. It has been shown that the histamine content in some of the scombroid fish increases from 0.09 mg/100 g of tissue to about 95 mg/100 g of tissue when kept at room temperature (20°C–25°C) for about 10 hours (116). Toxic scombroid fish cannot always be detected by appearance or odor. The histamine content in the flesh may be very high with little or no evidence of putrefaction. Scombroid or any other fish having a sharp or peppery taste should be discarded. Scombroid fish with histamine levels greater than 20 mg/100 g should be discarded.

G. Tetrodotoxic Fish

Tetrodotoxications constitute one of the most violent forms of marine biotoxications. This type of ichthyosarcotoxism commonly is designated as tetrodon or puffer poisoning. The causative trans vectors of the poison tetrodotoxin are members of the order Tetraodontiformes, formerly the Plectognathi, which includes the families Tetraodontidae, the puffers; Diodontidae, the porcupinefish; Canthigasteridae, the sharpnosed puffers; and Molidae, the molas or ocean sunfish. The order also includes such other fish families as the spikefish, filefish, trunkfish, three-toothed fish, and triggerfish, but these are not included in any degree of detail in this chapter. These same fish may also trans vect any or all of the ciguatera complex of poisons (e.g., ciguatoxin, maitotoxin, or possibly palytoxin). For
the most part, this section focuses on the fish families Tetraodontidae, Diodontidae, and Canthigasteridae.

Tetrodotoxications are the result of ingesting a poison known as tetrodotoxin, molecular formula $\text{C}_{11}\text{H}_{17}\text{N}_3\text{O}_8$, molecular weight 319, and $\text{LD}_{50}$ toxicity in mice is 10 $\mu$g/kg (117,118). Tetrodotoxin acts by preventing nerve conduction by an extremely specific and reversible blockage of the inward movement of sodium ions through the cell membrane of an activated neuron (48,119–121).

The tetraodontiform fish are characterized by the absence of parietal, nasal, or infraorbital bones, and usually have no lower ribs; the posttemporal region is present and is simple and fused with the pterotic of the skull; the hyomandibular and palatine are firmly attached to the skull. Gill openings are restricted. The maxilla is usually firmly united or fused with the premaxilla. Scales are usually modified as shields or plates. The lateral line may be present or absent, and sometimes is multiple. The swim bladder is present except in molids, and there are 16–30 vertebrae.

Tetraodontiformes can produce sounds by grinding the jaw teeth or the pharyngeal teeth or by vibrating the swim bladder. The stomach of some of these fish is highly modified to permit inflation to an enormous size. Fish with this ability are commonly called puffers. Inflation is caused by gulping large quantities of water into a ventral diverticulum of the stomach when the fish is frightened or annoyed. Deflation occurs by expelling the water. If the fish is removed from the water, inflation can occur with air (39,122). Puffers feed mainly on corals and mollusks, but tend to be omnivorous.

A wide range of phylogenetically unrelated aquatic organisms are now known to transvect tetrodotoxin, including starfish, gastropod mollusks, the Australian blue-ringed octopus, tropical reef crabs, goby fish, and a variety of freshwater amphibians. This subject has been reviewed in greater depth elsewhere (48).

**Representative Species**

There are a large number of fish species incriminated in transvectoring tetrodotoxin, but only a few representative fish are listed below.

Family: Canthigasteridae (sharp-nosed puffers)
Species: *Canthigaster rivulatus* (Temminck and Schlegel). Rivulated Goby. Length 3 in. (10 cm).
Distribution: Indo-Pacific, Japan.
Family: Diodontidae (porcupinefish)
Species: *Chilomycterus affinis* Günther. Porcupinefish. Length 6 in. (17 cm).
Distribution: Southern California, Galapagos Islands, Hawaii, Japan.
Species: *Diodon hystrix* Linnaeus. Porcupinefish. Length 35 in. (90 cm).
Distribution: All warm seas.
Family: Tetraodontidae (puffers, blowfish, fugu)
Species: *Arothron hispidus* (Linnaeus). White-spotted puffer. Length 21 in. (53 cm).
Distribution: Indo-Pacific, Panama, Japan, Australia, South Africa, Red Sea.
Distribution: West coast of Central America, Indo-Pacific.
Distribution: China, Japan.
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Distribution: Indo-Pacific, Red Sea, China, Japan, eastern coast of Africa.
Distribution: California to Peru, Galapagos Islands.
Distribution: Atlantic coast of the United States south to Guiana.
Distribution: Rivers of northern and western Africa.

Tetrodon (Puffer) Poisoning

**Method of Intoxication:** Puffer poisoning or tetrodon poisoning is caused by ingesting the flesh, viscera, or skin of toxic tetraodontiform fishes (i.e., sharp-nosed puffers, puffers, porcupinefish, and other related fish). Certain goby fish, gastropod mollusks, and tropical reef crabs are also capable of transvectoring tetrodotoxin and causing a biotoxication. Puffer fish are more dangerous to eat immediately prior to and during the reproductive season, during which time the poison content in the body of the fish increases with the gonadal activity. The skin, liver, ovaries, and intestines are the most toxic portions of the fish. The musculature of the fish usually is safer to eat than other parts of the fish, but at times it also may be toxic. The toxicity of the fish cannot be determined by its appearance, freshness, or size since even small puffers may contain sufficient poison to be lethal.

Puffer and fugu poisoning continues to be the major cause of fatal food intoxications in Japan, where puffer meat is looked upon as a gourmet delicacy. The sale of toxic puffers is carefully regulated by public health authorities in Japan, but this has not prevented periodic outbreaks of fatal food poisoning. The U.S. Food and Drug Administration (FDA) recently has permitted the importation of Japanese puffers for sale in fugu restaurants in the United States (25,87), but this does not guarantee the safety of puffer products. All puffers are potentially toxic unless they have been cultivated artificially (123–125). There is evidence that several different strains of marine bacteria may play an important role in the biosynthesis of tetrodotoxin in the body of the fish (5,7).

**Clinical Characteristics:** The onset and symptomatology in puffer poisoning varies greatly depending upon the person and the amount of poison ingested. Initial symptoms usually consist of paresthesias of the lips and tongue, malaise, pallor, dizziness, and ataxia that develop within 10–45 minutes after ingestion of the fish, but may occur as much as 3 hours or more after ingestion. The paresthesias are described as a tingling or a prickly sensation that may subsequently spread to the fingers and toes, and gradually develops into numbness. In severe cases, the numbness may involve the entire body, which has been described by victims as a floating sensation. Hypersalivation, profuse sweating, extreme weakness, precordial pain, headache, subnormal temperatures, hypotension, and a rapid, weak pulse usually appear early in the succession of symptoms. Nausea, vomiting, diarrhea, and epigastric pain frequently are present. The pupils are constricted during the early part of the intoxication, but later become dilated. As the disorder progresses, the pupillary and corneal reflexes are lost.

Shortly after the development of the paresthesias, respiratory symptoms become a prominent part of the clinical picture. Respiratory distress, as noted by an increased rate of respiration, movements of the nostrils, and shallow respiration, generally is observed. Respiratory distress later becomes very pronounced, and the lips, extremities, and body become intensely cyanotic, Petechial hemorrhages involving extensive areas of the body, blistering, and subsequent desquamation may occur. Muscular twitching, tremor, and loss
of motor coordination become progressively worse and finally terminate in extensive muscular paralysis. The first areas to be involved are usually the throat and larynx, resulting in aphonia, dysphagia, and, later, complete aphagia. The muscles of the extremities become paralyzed and the patient is unable to move. As the end approaches, the eyes of the patient become fixed and glassy, and convulsions may occur. The victim may become comatose, but in most instances the patient remains conscious and the mental faculties remain acute until shortly before death. The fatality rate of puffer poisoning is about 59% in untreated cases. There are no accurate mortality statistics worldwide.

**Treatment:** Early treatment seeks to remove the gastric stable toxin, which is partially inactivated by alkaline solutions. If the victim is seen within 3 hours of ingestion, gastric lavage should be performed with at least 1 L 2% sodium bicarbonate. This is followed with activated charcoal in sorbitol solution. If the victim has difficulty swallowing or breathing, or is not alert, intragastric manipulation should be preceded by endotracheal intubation.

Supplemental oxygen and ventilatory assistance should be promptly instituted as respiratory paralysis progresses. The physician should remember that the paralyzed victim may be fully conscious and should offer the victim frequent verbal reassurances.

Hypotension induced by tetrodotoxin may require the intravenous (IV) administration of crystalloid fluid augmentation. Bradyarrhythmias generally respond to atropine (0.5 mg IV up to 2.0 mg). Severe heart block may require the placement of a temporary transvenous pacemaker.

While a minor intoxication may be limited to paresthesias, all victims should be observed for at least 8 hours to detect deterioration, particularly respiratory failure. Under no circumstances should anyone with dysphagia be given liquids by mouth.

The fruit of the nono tree (*Morinda citrifola* Linnaeus) has been used for centuries by South Pacific islanders to treat the symptoms of ciguatera fish poisoning (2) and may be helpful in the treatment of tetrodon poisoning. The juice of the fruit is now sold in the United States and elsewhere throughout the world under the trade name “Noni.” The usual dosage is 3–4 ounces of the juice per day, or four capsules of the concentrate. The product is nontoxic and should be tried. See Refs. 27–29.

**Prevention:** If one follows the old Mosaic sanitary laws in Deuteronomy 14:9–10—eliminate all scaleless fish from the diet—then puffer poisoning will never be a problem. If one is living in Japan and has a desire to eat fugu, he should purchase the fish from a first-class, authorized restaurant with a licensed puffer cook. However, even following this procedure will not absolutely guarantee food safety. Eating puffers, at best, is a game of Russian roulette. In any event, the skin and viscera of the fish should never be eaten. No cooking or drying procedure destroys the poison.

V. **ICHTHYOOTOXIC FISH**

Ichthyootoxism is one of the lesser-known forms of fish poisoning. Ichthyootoxic fish constitute a group of fish that produce a poison generally restricted to the gonads. This group of toxic fish does not include the ichthyosarcotoxic puffers because the poison in puffers is distributed widely throughout the body. The musculature and other parts of the body in ichthyootoxic fish generally are safe to eat. Some of these fish are found only in freshwater. There does not appear to be any particular phylogenetic affinity other than the fact that the fish involved are all members of the class Osteichthyes, the true bony
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Fish (see Sec. IV.C for a description of the class Osteichthyes). Most of the intoxications resulting from the ingestion of ichthyootoxic fish occur during the reproductive season, during which the gonadal activity of the fish is at its peak.

**Representative Species**

Family: Acipenseridae (sturgeons)
Species: *Huso huso* (Linnaeus). Sturgeon. Length 6 ft (1.8 m).
Distribution: Black Sea, Sea of Azov, Caspian Sea, Mediterranean Sea, and rivers that drain into these seas.

Family: Lepisosteidae (gars)
Distribution: Rivers of Cuba, bays and coastal waters of the Gulf of Mexico.

Family: Esocidae (pikes)
Distribution: Freshwaters of Europe, northern Asia, and North America.

Family: Cyprinidae (minnows)
Species: *Barbus barbus* (Linnaeus). Barbel. Length 35 in. (89 cm).
Distribution: Freshwaters of northern and central Europe.
Distribution: Freshwaters of central Asia.
Species: *Tinca tinca* (Linnaeus). Tench. Length 24 in. (64 cm).
Distribution: Freshwaters of Europe.

Family: Stichaeidae (pricklebacks)
Distribution: Freshwaters of Japan and Korea.
Family: Cottidae (sculpins, cabezon)
Distribution: Pacific coast of North America.

**Ichthyootoxism (Fish Roe Poisoning)**

*Mechanism of Intoxication:* Ichthyootoxism, or fish roe poisoning, results from ingestion of various salt- and freshwater fish of Europe, Asia, and North America, and to a lesser extent, the tropics. The roe of many freshwater and estuarine fish of eastern Europe and Asia are dangerous to eat during their reproductive period, usually March–June. Most ichthyootoxic fish are members of the freshwater Cyprinidae minnow genera *Barbus*, *Schizothorax*, and *Tinca*, found in Europe and Asia, and the genus *Stichaeus* of the family Stichaeidae, found in Japan and Korea. These fish have caused innumerable intoxications in Europe and Asia. A Pacific North American species of the Cottid genus, *Scorpaenichthys*, also has produced intoxications.

Although cooking is said to destroy most ichthyootoxins, it cannot be relied upon as a completely safe procedure since the poison in some fish appears to be resistant to heat. The musculature and other parts of ichthyootoxic fish generally are safe to eat during the reproductive season. The chemical nature of ichthyootoxins is unknown. For a more comprehensive review of this topic, see Refs. 25 and 48.

*Clinical Characteristics:* Symptoms develop soon after ingestion of the roe and
consist of abdominal pain, nausea, vomiting, diarrhea, headache, fever, bitter taste in the mouth, dryness of the mouth, intense thirst, a sensation of constriction of the chest, cold sweats, irregular pulse, low blood pressure, cyanosis, pupillary dilation, syncope, chills, dysphagia, and tinnitus. In severe cases there may be muscle cramps, paralysis, coma, and death. Barbus roe usually does not cause death, but fatalities have resulted from eating Schizothorax roe (53).

Treatment: Treatment is symptomatic. There are no known antidotes.

Prevention: Avoid eating the roe of any fish during the reproductive season unless you have positive knowledge that the roe is safe to eat. This preventive advice is particularly pertinent to the freshwater and brackish water fish of Europe and Asia and all tropical marine species. Cooking fish roe cannot be relied upon to inactivate ichthyotoxins.

VI. ICHTHYOHEMOTOXIC FISH

Ichthyohemotoxic fish consist of a variety of different species of eels. All of the fish of this group are members of the order Anguilliformes (Apodes). The members of this group are characterized by an eel-like body, abdominal pelvic fins (when present), and an air bladder connected with the intestine by a duct. Gill openings are narrow or slitlike. The scales, if present, are cycloid. The dorsal and anal fins are very long and usually confluent (126).

The research on ichthyohemotoxic fish, or fish having toxic blood, reveals that there is very little clinical information involving humans. Hemotoxins are largely parenteral poisons and seldom toxic when taken by mouth. Very little is known concerning the chemical nature of these poisons.

Representative Species

Family: Anguillidae (freshwater eels)
Species: Anguilla anguilla (Linnaeus). Common European eel. Length 39 in. (1 m).
Distribution: Europe, fresh- and saltwater rivers.
Family: Congridae (conger eels)
Species: Conger conger (Linnaeus). Conger eel. Length 79 in. (2 m).
Distribution: Atlantic Ocean, Mediterranean Sea.
Family: Muraenidae (moray eels)
Species: Muraena helena (Linnaeus). Moray eel. Length 59 in. (1.5 m).
Distribution: Eastern Atlantic and Mediterranean Sea.

Ichthyohemotoxicism

Mechanism of Intoxication: Ichthyohemotoxins are largely parenteral poisons, although there are a few instances on record in which individuals have become intoxicated due to ingestion of large quantities of the poison by mouth. Most of the ichthyohemotoxic fish generally are recognized as good food fish. However, ingestion of fresh blood or serum from these fish may cause food poisoning. This is a rare form of marine food poisoning.

Clinical Characteristics: Very little is known concerning the symptomatology of ichthyohemotoxicism in humans. Fish serum intoxications may be of two types: systemic, a form that results from drinking fresh, uncooked fish blood, and topical. The symptoms of the systemic form consist of diarrhea, bloody stools, nausea, vomiting, hypersalivation,
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skin eruptions, cyanosis, apathy, irregular pulse, weakness, paresthesias, paralysis, respiratory distress, and possibly death. For the topical form, there is a severe inflammatory response when raw eel serum accidentally comes in contact with the eye or the tongue. Oral symptoms consist of burning, redness of the mucosa, and hypersalivation. Ocular contact invokes a severe burning sensation and redness of the conjunctivae, lacrimation, and swelling of the eyelids. Eye irritation may persist for several days. Usually recovery is spontaneous. For a more comprehensive discussion of this subject, see Ref. 48.

Treatment: Treatment is symptomatic. There are no known specific antidotes.

Prevention: Care should be taken in the handling of eel blood. Raw eel blood should not be ingested. Cooking is said to destroy the toxic properties of eel blood.

VII. ICHTHYOHEPATOTOXIC FISH

The livers of certain edible species of fish are sometimes found to be toxic to eat. Most of the outbreaks of ichthyohepatotoxicism have occurred in Japan. Nothing is known concerning the chemical nature of the poisons involved. It is believed that in some instances the intoxications are due to hypervitaminosis A. The fish involved are members of the class Osteichthyes.

Representative Species

Family: Scombridae (tunas, mackerels, albacore)
Species: Scomberomorus niphonius (Cuvier and Valenciennes). Japanese mackerel.
Length 39 in. (1 m).
Distribution: Japan, Korea, China.
Family: Serranidae (Sea bass, grouper)
Species: Stereolepis ischinagi (Hilgendorf). Sea bass. Length 78 in. (2 m).
Distribution: Japan, Korea.

Ichthyohepatotoxicism (Fish Liver Poisoning)

Symptoms of ichthyohepatotoxicism appear within 30 minutes–12 hours after ingesting the fish liver. The initial symptoms consist of nausea, vomiting, fever, and headache. The headache may be very severe and is said to be intensely aggravated by the slightest movement of the body, head, or eyes. A mild diarrhea may be present, but abdominal pain generally is absent. The face of the victim usually becomes flushed and edematous, and a macular rash having large patchy erythematosus areas develops. Within 3–6 days, desquamation appears. Large areas of skin may peel off around the nose, mouth, head, neck, and upper extremities, and gradually extends over the entire body. Epilation may result. Desquamation may continue for about 30 days. Vesicular formation of the oral mucosa and bleeding from the lips may occur. Orbital pain, joint aches, and cardiac palpitation with a rapid pulse may be present. Victims have complained of a slippery sensation on the tip of the tongue. Most of the more acute symptoms disappear in about 3–4 days. Residual symptoms consist of chapping of the lips, stomatitis, and mild hepatic dysfunction. Recovery usually is uneventful. No fatalities have been reported. The liver may be enlarged, but no jaundice has been observed.

Treatment: Treatment is symptomatic. There are no specific antidotes.

Prevention: Care should be taken in eating fish livers. In general, the liver is one of the most dangerous parts of a fish to eat. If a fish is poisonous, a greater concentration
of the poison is likely to be found in the liver than almost any other part of the fish. Cooking does not destroy the poison. Most outbreaks of ichthyohapatotoxism have resulted from eating fish livers that have been sautéed or in soup. The toxicity of fish liver cannot be determined by its appearance. It is recommended that fish livers be eliminated from the diet unless there is reliable information that it is safe to eat.

VIII. **ICHTHYALLYEINOTOXIC (HALLUCINOGENIC) FISH**

Ichthyalleyeinotoxism, or hallucinogenic fish poisoning, is caused by ingesting certain types of reef fish known to occur in the tropical Pacific and Indian Oceans. This biotoxication may result from eating either the head or flesh of the fish. The source and chemical nature of the poison is unknown. Most of the fish species incriminated in ichthyalleyeinotoxism also are involved in ciguatera fish poisoning. Whether there is a relationship between these two types of intoxications is not known. All of the hallucinogenic fish are members of the class Osteichthyes.

**Representative Species**

- **Family**: Kyphosidae (sea chubs)
  - **Species**: *Kyphosus cinerascens* (Forskål). Sea chub. Length 20 in. (50 cm).
  - **Distribution**: Indo-Pacific.
- **Family**: Mugilidae (mullets)
  - **Species**: *Mugil cephalus* (Linnaeus). Common mullet. Length 12 in. (30 cm).
  - **Distribution**: Cosmopolitan.
- **Family**: Mullidae (Goatfish, surmulletss)
  - **Species**: *Upeneus arge* Jordan and Evermann. Goatfish. Length 12 in. (30 cm).
  - **Distribution**: Indo-Pacific.

**Ichthyalleyeinotoxism (Hallucinogenic Fish Poisoning)**

**Mechanism of Intoxication:** Ichthyalleyeinotoxism, or hallucinogenic fish poisoning, is caused by eating the flesh or head of certain species of toxic reef fish, producing hallucinations. The poison reputedly is concentrated in the head of the fish, which is said to be the most dangerous part of the fish to eat. The nature of the poison is unknown. This type of biotoxication is sporadic, uncommon, and completely unpredictable. You cannot detect a hallucinogenic fish by its appearance. The poison is not destroyed by cooking.

**Clinical Characteristics:** The poison affects primarily the central nervous system. The symptoms may develop within minutes to 2 hours after ingestion of the fish, continue for about 24 hours, and then gradually subside. Symptoms consist of dizziness, loss of equilibrium, lack of motor coordination, hallucinations, and mental depression. A common complaint of the victim is that it feels as though "someone is sitting on my chest," or there is a sensation of a tight constriction around the chest. The conviction that they are going to die or other frightening nightmares are characteristic aspects of the clinical picture. Other complaints consist of itching, burning of the throat, muscular weakness, and, rarely, abdominal distress. No fatalities have been reported. This form of poisoning is generally mild.

**Treatment:** Treatment is symptomatic. No specific antidote is available.

**Prevention:** Caution should be exercised in eating those species of reef fish that
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have been incriminated in ichthyoallyeintoxism. When possible, natives should be consulted before eating the fish in tropical areas. Hallucinogenic fish cannot be detected by their appearance.

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REFERENCES

Halstead


