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Book Reviews: Technical Books Section

OTHER REVIEWS IN THIS ISSUE
[Technical Books Section] Pages: |1| 2| 3| 4| 5| 6| 7|
[Popular Books Section] Pages: |1| 2| 3| 4| 5| 6|

REVIEWS IN THE PREVIOUS ISSUE | NEXT ISSUE

AN AUTHENTIC BOOK ON INVESTIGATION OF DROWNING DEATHS

Forensic Diatomology and Drowning, 1998 *by* Michael S. Pollanen
Elsevier Science B.V., P.O. Box 211, 1000 AE Amsterdam, The Netherlands, 170 pages, Hardbound, ISBN 0-444-82844-3. $149.00 (euro 147.93)

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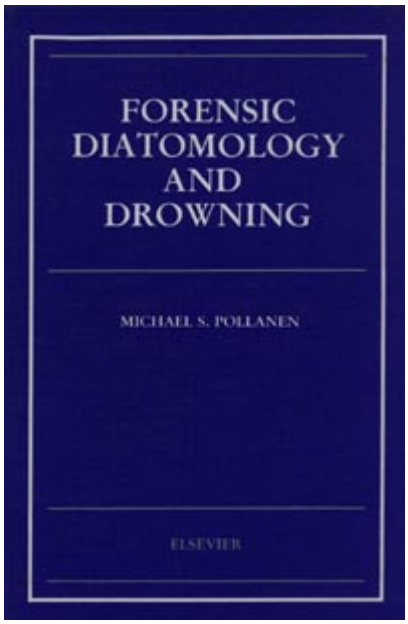
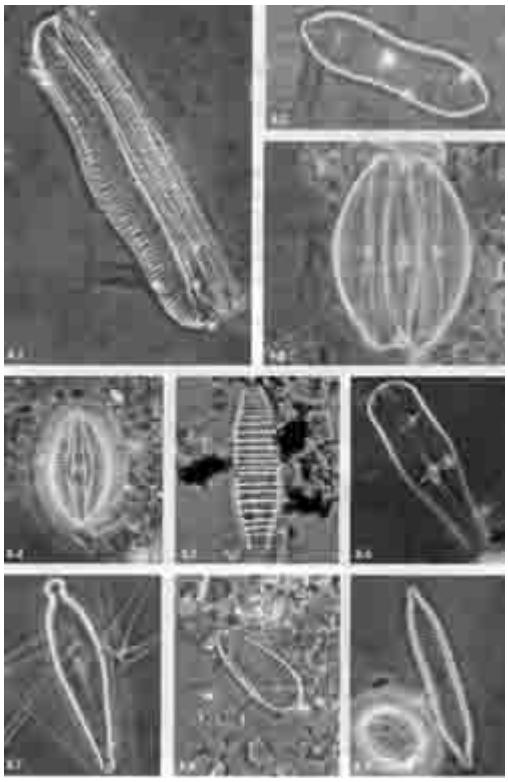


Ask any forensic pathologist to name three most controversial topics in his specialty and the chances are he would name diatoms as one of them. Spitz and Fischer[1] called them "War of Diatoms" and I personally prefer to see them as causing "The Great Divide" among forensic

pathologists of the world. Ask any Continental or British forensic pathologist about the value of diatoms in drowning and the chances are he would hold them in great esteem. This enthusiasm is generally not shared by American pathologists. Perhaps one of the reasons of this "Great Divide" is that the diatom test originated on the Continent (as we all know, it was Ravenstorf who first conceived the idea in 1904[2]). Nevertheless such "*Hegelian dialectic*" is often necessary in Forensic Pathology -as it is in any field of investigation - for it helps keep the specialty healthy, vibrant and growing.

I very vividly remember a time way back in 1980, when I was doing post-graduation in Forensic Medicine from the *All India Institute of Medical Sciences*, New Delhi. One fine day, our Head of the Department, Professor Jagdish Chandra gave me a fresh copy of *Medicine, Science and the Law* and asked me to go through a very interesting paper by Peabody. It was a review on diatoms[3]. I went through it in one go. So interesting and all encompassing was the paper, that I still remember it almost word by word, and often quote it in my lectures.

Heteropolar Diatoms. These appear on page 141, and constitute one of the eleven plates depicting various types of diatoms

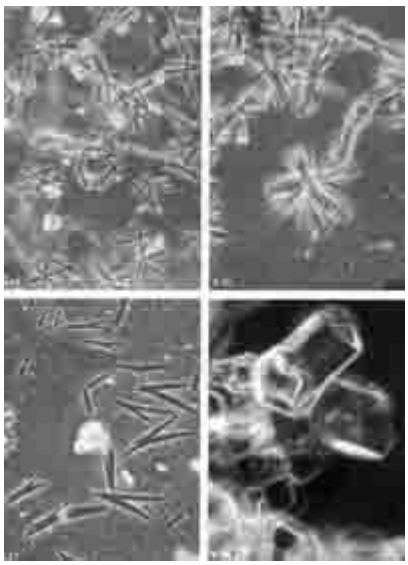


The book under review explores this subject further, quite deeply and authoritatively. I saw it on my table one fine Sunday morning just after getting up, and I asked my wife who brought it. She told me that she had found it in the mail, and had kept it in on my desk, so I could check it on waking up. I asked her to prepare the morning breakfast, and by the time she came, I had hurriedly gone through the first chapter. I would spend the rest of that Sunday - and most of the subsequent week - reading this extremely interesting and informative book.

Why do I call it extremely interesting? Because it does not take sides - it examines the issue objectively from both angles. And I like this approach. And why do I call it extremely informative? Because I saw so many things in this book for the first time in my life. For instance the mini-atlas of

diatoms at the end of the book is the first of its kind I have seen. This atlas gives a total of 11 plates, each with pictures of about ten different diatoms. Thus we get to see more than 100 different diatoms which are important for forensic pathologists. The plates are in black and white and depict such diatoms as Centric diatoms, Naviculoid diatoms, dorsiventral diatoms, heteropolar diatoms and so on. One interesting plate on heteropolar diatoms is reproduced on the right for the benefit of the readers, so they can know what I am talking about. On page 95 is yet another interesting plate. I would have thought they were diatoms, but I was amazed to read in the caption that they were not. They were acid-insoluble material in bone-marrow "that co-purify with diatom frustules", but so remarkably do they "ape" diatoms that any expert could get stumped. Of course the author helpfully tells three pages later (on page 98) how we can differentiate between the two. Among the four points that the author gives us, one is that the crystals have no fine structure such as raphe, pits and striae (like diatoms). If you go back to the plate, you indeed appreciate this feature! This remarkable plate is reproduced below and to the left.

Are these diatoms? Stumped?? These are acid-insoluble material in bone marrow that co-purify with diatom frustules, and can often confuse the inexperienced!

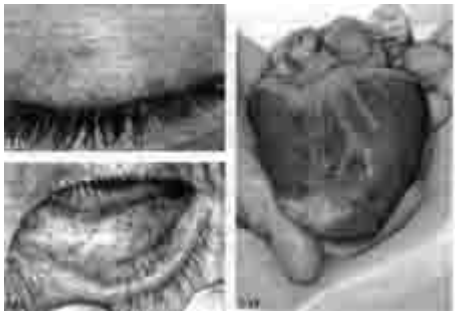


The book has eight chapters of which seventh is the mini-atlas we have already talked about. Chapter eight is nothing, but a compilation of 93 best references on the subject of diatomology. This leaves us with six descriptive chapters. Chapter one is introductory in nature and tells us about diatoms in general. Things like what are diatoms, how many species of diatoms are known, that there are different species living in freshwater and salt water and so on. Some basic facts are figures are given (for instance 5% of all drownings are homicidal). Among the famous cases described in this chapter is the classic *Brides in the Bath* case, in which one John Smith successively (and successfully) drowned his three wives, before being finally caught. The author tells us that all "bath drownings" can be divided into four general categories: (i) Accidental drowning complicating natural disease such as epilepsy or coronary artery disease (ii) Accidental drowning complicating drug intoxication (iii) Homicidal drowning (as in *Brides in the Bath* case just mentioned) and (iv) Suicidal drowning. Ways to distinguish between these are described.

Chapter two in on pathology and pathophysiology of drowning, which is more of a recapitulatory nature. Pathology of asphyxia is dealt with in general. Phenomena like petechial haemorrhages (*please see below and to the right for one illustrative diagram from the book*)

occurring in asphyxial deaths are described. There are separate sections on such controversial issues as fluidity of the blood and pink teeth. Knight in his excellent *Forensic Pathology*[4] exclaims at page 350, "Descriptions of an abnormal fluidity of blood seen at autopsy in asphyxial deaths are part of forensic mythology and can be dismissed with little discussion." But Pollanen seems to differ with him. On page 26, not only does he affirm his belief in fluidity of the blood, but cites reasons for this too: "Persistent fluidity of the blood likely relates to inhibition of the coagulation process due to some unknown mechanism". Both these antithetical statements from contemporary books tell us that this controversy is far from over!

Petechial haemorrhages in asphyxia. These are however classically not seen in drowning deaths





Chapter 3 is entitled "The Medico legal value of the diatom test for drowning". The chapter describes chemical tests for drowning such as the classic Gettler test and why this test failed. Gettler[5] reasoned that if the person entered the body of water while still alive, the water must cross the alveolar bed and reach the left heart, thereby causing haemodilution there (if the drowning occurred in freshwater. Of course the reverse would happen if it occurred in salt water). He measured chloride ion in both chambers, and his formula for determination of these differences was simply put as follows:

$(S_R-S_L)/S_R$

Where S_R is the solute concentration in the *R*ight heart and S_L the concentration in the *L*eft heart. This looks very logical and impressive, but unfortunately does not work in actual practice, as chloride undergoes radical changes after death. This is one ion which decreases after death as a function of time (due to intracellular shift) and indeed has been utilized for the determination of time since death[6]! Coe found that plasma chloride falls almost by 1 mEq per Liter per hour after death[7]. In such a situation - which of course was not known in Gettler's time - it was disastrous even to attempt to measure chloride as a function of drowning. Attempts have been made to overcome this situation by measuring such exotic ions as Strontium[8], and the book discusses these attempts in great depth.

Classical sign of wet drowning. Copious, thick froth at the mouth



Besides the chemical tests, there are the so-called "Micro-organism tests" for drowning. Any collection of water does not just have diatoms but a host of other microscopic organisms. In fact filtered water (as the one which flow in our taps) may not have as many diatoms, but it still has a number of microorganisms. Why, then, are these microorganisms not employed as indicators of ante mortem drowning? This has indeed been done. Protozoans such as *Tetrahymena* have been recovered from left heart and cultured, indicating that the organism entered the body during the drowning process. Other important organisms such as Daphnia, chlorophyta and dinoflagellate have been tried in a similar manner. In fact anything present in water, which is small enough to enter lung capillaries would serve as well as diatoms. One can find a beautiful Science Fiction story on the web, in which the central character attempts to diagnose drowning by detecting petroleum in the victim's blood, because the body of water where he drowned was contaminated with spilt petroleum!

But despite all these alternatives, diatoms still rule the roost. Why? Because firstly they are too numerous and more importantly these are the only microorganisms with acid resistant frustules, making them easier to extract from post-mortem tissues. Any attempt to extract other perishable microorganisms from the blood is likely to end in failure.

On page 56, the author introduces us to the *Criterion of Concordance*. According to this criterion, the diatoms found in the blood and organs of the victim (such as femur), must be the same. This is to refute the objections of many pathologists who assert that diatoms are ubiquitous in human tissues. Researchers have found diatom like particles in hepatoportal circulation indicating thereby that they might have entered through ingested food or water. It is implied that they would then get distributed among the tissues of the body during the life of the person. The author of course doubts this assertion, reminding us that such a process would entail completion of a very hazardous journey by these tiny particles, which is not likely. They have to dodge Kupffer cells in the liver and phagocytes in the blood (which are live and active) in order to find a safe

haven in the terminal organs. Yet the application of the *Criterion of Concordance* would be sufficient to silence most critics in a court of law.

What are the methods employed to extract the frustules from the bones? We all know about the nitric acid digestion method, but the author tells us many more. Ultrasonic radiation can be used to solubilize tissue; enzymatic digestion with proteases -such as proteinase K- can be done; strong anionic detergents such as sodium dodecyl sulphate and non-specific tissue solubilizers can be used; and finally physical methods such as simple centrifugation, membrane filtration and gradient centrifugation have all been tried. The book discusses these methods and gives us important references to explore these exotic methods in further detail.

Personally I found chapter 4, the most gripping of all, mainly because the contents of this chapter were so new to me. Entitled "Validity and utility of the diatom test using bone marrow", it introduces such concepts as sensitivity and specificity. To understand these terms, let us first understand that the diatom test indeed is not a foolproof test (even the author, who is a great advocate of this test admits this at several places). There can be false positives and false negatives. The following table (devised by this reviewer) sums up this situation rather neatly:

Outcome of the test	Drowning	Diatoms
a = true positive	+	+
b = false positive	-	+
c = False negative	+	-
d = True negative	-	-

Table showing the concept of false positive and false negative tests

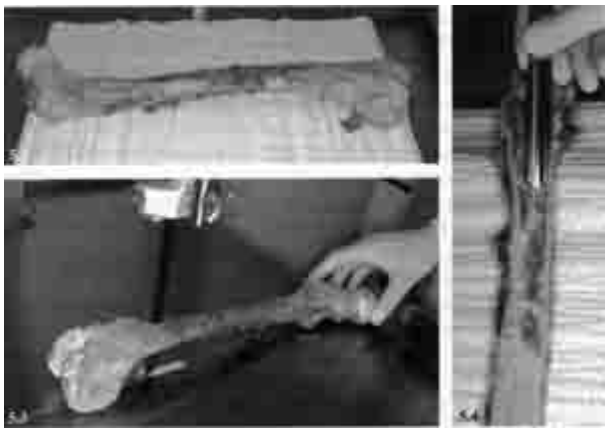
Murder in the Hudson river which was solved with the help of diatoms. Readers may want to refer to the book for details of this interesting case



Sensitivity of a test defines the ability of a test to *rule-out* a disease - in this case drowning. Thus sensitivity of the test would be determined by the number of all true drowning cases from which diatoms can be recovered. In our case sensitivity would be "a/(a+c)". A test with high sensitivity can

be employed as a useful screening test. Specificity on the other hand defines the ability of a test to *rule-in* a disease. A test with a high specificity can be very useful in individual cases.

Extraction of diatoms. Details are provided in the book



What does this mean? If one could devise a test for drowning with a sensitivity of 1.00 (the maximum possible), it would mean that it could be used as a perfect screening test. There can be no *false negatives*. If on the other hand, one could devise a test with a specificity of 1.00, it would be extremely useful in individual cases, for there would be no *false positives*. In other words specificity+false positive rate always equals 1.00; and so does the sum of sensitivity and false negative rate. The sensitivity of the diatom test is given in the book as 0.26 (quite low), and specificity as 0.85 (quite high). Because of this, although diatoms can not be used as a useful screening test, they are quite useful in individual cases. Of course one can now calculate the false positive and false negative rates (0.15 and 0.74 respectively). And this is not where the author stops! He goes on to introduce such concepts as *positive predictive value* and *negative predictive value*, but I would let the reader explore these terms himself from the book.

Chapter 5 details the laboratory procedure for the diatom test and chapter 6 gives some investigative applications of this test. These are also quite useful and well written.

For whom would the book be most useful? Of course this book would be most useful to forensic pathologists, especially those who have to face drowning deaths on a routine basis. The book should also be useful to researchers in the field of drowning, as it so effectively summarizes all the current knowledge on drowning. The book is well illustrated with black and white photographs. This has perhaps been done to keep the cost of the book down. One only hopes that the author would replace some of the photographs - especially those of the diatoms in the mini-atlas at the end - with colored ones. All in all, a very useful book which should find a place on the shelves of all forensic pathologists.

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