MARK BENECKE

TRACKING DOWN THE CULPRIT

Forensic Biology: Using Insects on Corpses and DNA to Capture a Killer

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About the Book

Blow fly maggots feast on moist, fresh cadaver tissue. Skin beetles prefer to feed on dried-out skin and hair. Cheese fly larvae graze on the corpse only when it turns to mush. Just what do these critters have to tell us about the carcasses they consume?

In sometimes gruesome but factual detail, forensic scientist Dr. Mark Benecke delves into the digestive tracts of bugs on dead bodies.

While forensic medicine focuses on determining cause of death; criminal biology seeks to locate the actual offender. DNA typing (genetic fingerprinting)—coupled with the analysis of insects on bodies, offender traces, and findings at the crime scene—make this scientific discipline key to uncovering clues not seen by the naked eye.

Benecke explains how forensic biology works and explores the question of why DNA typing is safer than any previous such identification method. But why does it unsettle so many people?

In an era when true crime tales such as "Serial" and "Making a Murderer" continue to fascinate audiences, Benecke weaves historical detail into today's conversation. Hitler's skewed perception of genetics. Nazis abuse of science as an excuse to murder. Benecke pulls back the curtain to reveal the uncomfortable side-effects of DNA research and the uncanny techniques

About the Author

Mark Benecke, Ph.D., is a sought-after expert in the field of forensic biology and forensic entomology (scientific study of insects to aid in forensic medicine). He is Germany's only "Officially Certified and Sworn-In Expert for Detection, Recovery, and Interpretation of Biological Stains." In the 1990s he was employed at the Chief Medical Examiner's Office in Manhattan. For 25 years he has worked on special cases around the world; for the last 20 years, he has been the German face of the documentary true crime series *Medical Detectives*. Among his most famous cases are the identification of the skull and teeth of Adolph Hitler, and his work on thousands of mummies in the Catacombs of Palermo.

Figure 1: Mark Benecke with NYPD officers
Photo: © Martin Schoeller

Readers can connect with Mark Benecke on various social media platforms:
Web: benecke.com
Facebook: facebook.com/markbenecke
YouTube: youtube.com/user/wwwsatankade

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Conor Dillon

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Natura non facit saltum.
(Nature does not make jumps.)

FOREWORD

When the first edition of this book – at that time, still a booklet – was published two decades ago, no one could predict how popular forensic biology would become within just a few years. The term itself had died out; the subject was no longer taught in a single university or police school in Germany. Today, our courses are overflowing with students, and the older German editions of *Kriminalbiologie* can be found on eBay at absurd prices.

Genetic fingerprints are now a standard criminal technique in many countries, just as photographs or common fingerprints (from fingers and feet) have been for more than a hundred years. In Europe (2002) and North America (2003), some very solid, active forensic entomology interest groups have sprung up. Many students, meanwhile, are conducting experiments with fly maggots, and I tip my hat to them. I wonder when the interest will recede? Hopefully never.

Perhaps it will, though, when the students notice that there are few comfortable jobs available to forensic biologists, and that classic biology (zoology and botany), the foundation of our field, has been cut at nearly every university. That’s why I’ve added a section in the third as well as the electronic edition of this book explaining what one needs to become a forensic biologist – namely, equanimity in the face of resistance and a relentless tenacity. And, as locals in my hometown of Cologne are prone to saying, you've got to "enjoy something just for the fun of it."

To better show that forensic entomology is not solely about a corpse's repository period (the post-mortem interval) or how long it has been lying on the ground, I've sought to include new and varied cases. All have something to do with investigations of death and articulate animals, but these cases should also demonstrate our wide-ranging biological approach.

New DNA profiling techniques of interest to the non-scientist have also been included. Due to its elegance, the RFLP analysis has also remained in the book – even if it is now rarely used inside forensic DNA laboratories in wealthier countries. Additionally, I work in developing countries where these analyses are sometimes the only possibility. They reveal most impressively how a major forensic change began: with a bathtub sponge and a plastic bucket to "blot" the DNA fragments from a gel to a nylon membrane.

Also newly added: a section on the so-called science of "Kriminalbiologie," or "criminal biology" previously focused on measuring and classifying individuals. This field died out after World War Two, as it had been politically abused, and many researchers had strayed from the scientific course. The majority of my colleagues are happy to erase this chapter of biological medicine. Botched "criminal biology" was, of course, rooted in greed, hatred, jealousy, and the desire for power-but, above all else, it was due to fundamental cognitive errors. And it's exactly this fact that scarcely anyone today wants to acknowledge – it's easier to blame Nazis than to blame a cognitive malfunction of scientists.

Beyond that, we all make cognitive errors, mostly by overestimating our own knowledge. I experience it time and time again in the courtroom when the defense says: “I believe every word you’ve said. All of your measurements are comprehensible. Your testimony, however, rests on a false foundation. What you have deduced, here, is accurate – but it has nothing to do with this case.” There are four simple tricks to lower the risk of such inaccurate outcomes:

1. Trust no one, especially not your own assumptions.
2. If a ten-year-old doesn’t understand your explanation, then perhaps it is incorrect.
3. Always conduct experiments that sensibly test your assumptions.
4. After eliminating all factually false possibilities, the rationale left standing is correct – regardless of how unlikely it sounds.

You actually don’t need to know anything else in terms of factual evidence-specifically evidence not guided by feelings and assumptions – in order to crack cases.

Have fun with this book, which is meant to be understood by all, but at the same time should hopefully whet your appetite for deeper, more specialized lectures. And please remember: Believe nothing, trust no one, and, in an emergency, ask your small nephew or niece whether he or she both believes and understands what is allegedly the *only* correct solution. Perhaps there is another, much simpler one.

Berlin, 2018
Mark Benecke

P.S.: The beetle on the cover was chosen by the layouter. She loved it, so we kept it!

INTRODUCTION
Forensic Medicine, Forensic Pathology, and Forensic Biology

Reality is far more exhilarating than any fictional concoction. This much is known by fans of true crime stories, but also by all of the silent assistants who help solve crimes worldwide, employing equal parts of great meticulousness and patience to investigate the traces left at a crime science and on a corpse. Beyond police, special investigators and, depending on the culture, forensic medical experts, or coroners, are also involved. Long ago, they often worked without gloves – but wearing ties – while dealing with a corpse. Some of them were lawyers, priests, village elders, or even professional investigators. The requirement today is often an advanced medical degree to become a forensic medical expert, which is a specialization in the same vein as those for ear, nose and throat doctors, opthamologists, neurosurgeons, or pathologists.

When forensic medical experts are at times called pathologists, that's often wrong. Pathologists are primarily concerned with illness-induced changes in cells. They can distinguish, for example, healthy cells from those afflicted with malignant cancer, doing so by examining thin layers of tissue; these are the clinical pathologists. Rare, however, is the pathologist who works with unnatural causes of death and the effects of violent acts, like hangings, drownings, stranglings, or drug overdoses. Such pathologists are called forensic pathologists.

This confusion of terms arrives from the US. North American forensic medical experts undergo a different education than, let's say, their German colleagues and are therefore labeled as forensic pathologists. Initially, they learn – just like German forensic medical experts – how to recognize sick tissue. But they are then additionally taught how to differentiate between natural and unnatural causes of death. Beyond that, they're taught autopsy methods, as well as criminal investigation techniques (bloodstain pattern analysis, for example, or analysis of traffic accidents).

In central Europe, the hands-on work of crime scene analysis traditionally falls, first and foremost, under the purview of the police. It's for that reason that the North Americans are real forensic pathologists, while their counterparts in other countries are sometimes consultants in medical jurisprudence. These consultants can determine whether a person was shot from long or short range, whether he or she was hanged before or after death, and whether separated body parts once belonged together or not. They determine the cause(s) of death for those dumped in mass graves and how long they have been lying there. Since this work is often carried out in relation to a judicial criminal or civil case, forensic medical experts in Europe were previously called "court doctors." This inaccurate term, however, has died out in the past 30 years.

Forensic work (from "in foro," which means before the judge or public) is, as always, not only exciting and multifaceted, but also strongly intertwined with other areas of research. In many investigations of deaths, there is also something scientifically novel to discover, and forensic medical experts often work closely with other scientists when dealing with things such as clothing fibers, a bitemark, a piece of lacquer, or an old invertebrate bone that was discovered in the forest (see fig. 2).

This leads us to forensic biology – a small area of research into death investigations. It resembles the American "forensics" in that it combines criminal/police work, the natural sciences, and the criteria of medical-forensic (or "medico-legal") thinking. This natural science of criminalistics is not conducted by doctors, but rather by biologists with differing areas of expertise. These biologists could include geneticists, previously called "blood group experts" or serologists; insect experts, or entomologists; and botanists, or plant morphologists; chemists, or toxicologists; and physicists.

Figure 2: With the prevalence of plague deaths, general knowledge about corpse appearances (the decomposition stages therein) were good. From: E.H. Langlois, 1852.

Currently, the best-known forensic biological techniques are the investigation of corpse insects (forensic entomology), the investigation of blood traces (bloodstain pattern analysis, blood spatter analysis), and the creation and analysis of genetic fingerprints (DNA profiling). All three methods have garnered much public attention and have made it possible to solve cases previously considered difficult or impossible to crack. This book clarifies why this is so, and how it got to be that way.

PART 1
ARTHROPODS AND CORPSES

There's a good reason that every vertebrate must one day die: Each generation of vertebrates has to procreate so that its genetic attributes can be newly combined. Thus, a species – including humankind – can preemptively adapt to potential and unforeseeable changes to the natural environment. As the environment changes – for example, in the amount of ultraviolet light in the earth's atmosphere – there could be some offspring who have already, by chance, genetically adapted to exactly those conditions. In order to provide living space for their offspring, the older generation needs to age and die. Hence, the programming of our "blueprints," the genetic material DNA.

Just as important as the new combinations of genetic material is the fact that the bodies of those who have died return to the circle of life for those who are living. For this to happen, the components of the body must initially be broken down (see chapter: Corpse appearances and incorruptible saints). Large, complicated, entangled proteins, such as those in the skin or intestines, will break apart into ever-smaller building blocks (molecules) during the decomposition of the body, so that another entity can ingest and utilize them. In this smaller form, they can be reused and repurposed more easily by new life forms.

The decomposition of a body is a complex process that has yet to be replicated by a technical apparatus. For every stage of decomposition, there is a specially adapted organism. The most important recyclers of bodies, but also the least beloved, are, with the exception of single-cell organisms and multiple-cell fungi, highly-developed insects (see fig. 3). Blow fly maggots (Calliphorids, Sarcophagids and others) obtain nutrition, for example, from moist, relatively fresh corpse tissue, while skin beetles and the common carpet beetle (like Dermestids), are specialized to be able to consume dried-out skin and hair.

Figure 3: Insects on a cadaver
Insects help to return dead animals to the cycle of life. Here, some important cadaver settlers of the medieval period: on the clover, the Lucilia caesar blow fly

(Calliphoridae); on the mouse, two red-banded burying beetles, Nicrophorus (Silphidae); two dung beetles (Histeridae) and a real burying beetle, Phosphuga atrata; on the ground, a large Nicrophorus germanicus burying beetle. Drawing © Jürgen Ritter, Haar.

Figure 4: Burying beetle on a human corpse
A burying beetle eats the ear of a partially mummified corpse. Photo: © Mark Benecke

Cheese fly larvae (Piophilidae) settle upon a corpse when it reduces to a paste-like texture, and large burying beetles (like Silphidae) can use tools in their mouths to gnaw down tough, mummified skin (see figs. 4 and 5). The animal-driven recirculation of biological substances is not a pleasant sight, but without the process of putrefaction and consumption by maggots and other insects, the circle of life would come to a halt, since there would be no more "construction" materials available (see fig. 6).

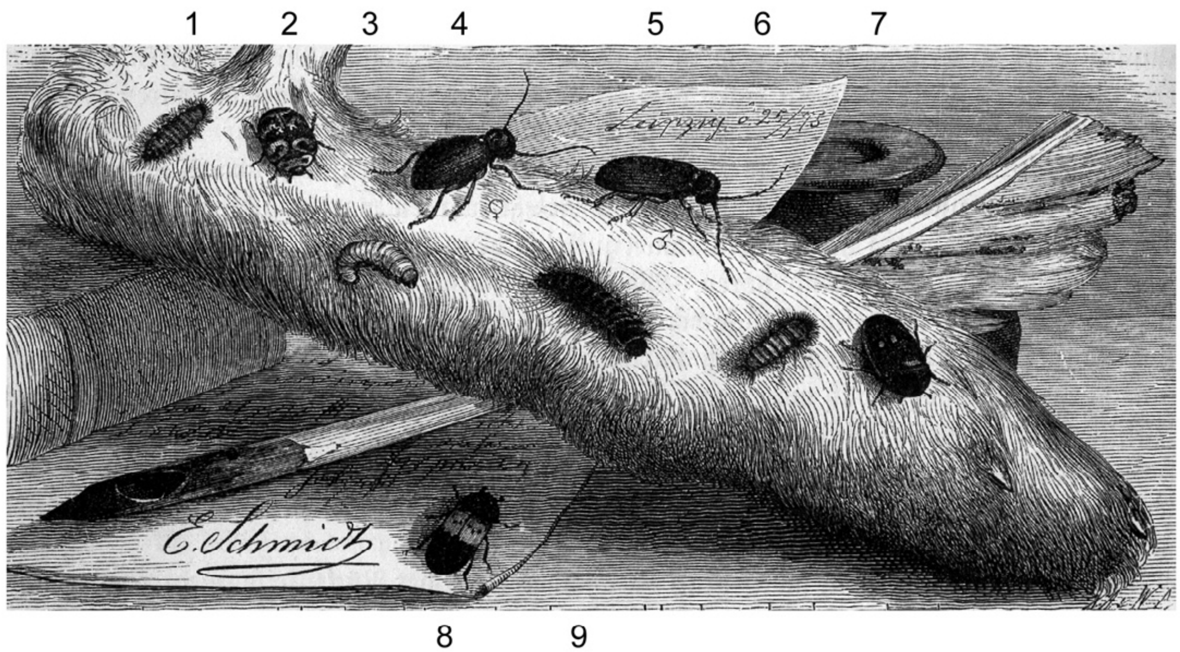

Figure 5: The "hour hand" of a post-mortal clock
Not all corpse insects are attracted by soft tissues. These beetles prefer hard materials like hair and dried-out skin. An estimation of a corpse's repository period, whether in days or weeks, is not possible with these animals alone. However, they often indicate a minimum or maximum repository period. If maggots, then, are a clock's "second hand," beetles are its "hour hand." 1, 2: Museum beetle (Anthrenus) with larva; 3-5: Spider beetle (Ptininae) and its larva; 6, 7: fur beetle (Attagenus pellio) with larva; 8, 9: skin beetles (Dermestes lardarius) and its larva. (Drawings by Emil Schmidt in: Ernst Ludwig Taschenberg's Brehm's Life of Animals (Brehms Thierleben), volume nine, third edition, 1892).

Of the many forms of life that nourish themselves through cadavers, forensic biologists are interested most in particular flies and beetles. These so-called corpse insects, of which there are hundreds of kinds, not only nourish themselves primarily through rotting tissues, but seek out these tissues as a breeding grounds for their offspring. Blow fly females can, for example, detect a freshly deceased corpse from significant distances, flying there quickly. They then lay their eggs in wounds or, absent any bodily injuries, into bodily cavities, such as the nose, mouth, or ears, or in soft parts of the body, like the eyes. If the eyes are closed, the blow fly females lay their egg packets (patches) precisely upon the crack between the lids in the corner of a person’s eye.

Figure 6: Circle of life
Flies are not the end of the recycling chain. When they die, they're consumed by fungi or disassembled by ants – like here at the "Body Farm, the University of Tennessee's Anthropological Research Center Facility. Photo: © Mark Benecke

Because insect eggs and larvae constitute ideal prey for beetles and birds, flies lay numerous eggs as a precaution (see fig. 7). The metallic blue or green iridescent species of the blow fly Lucilia and Calliphora, respectively, generate small egg packets. Flesh flies, in contrast, which are easily recognizable with their beautiful stripes and checkerboard-like patterns (see fig. 8), distribute their eggs across the surface; at times they even lay tiny, living maggots.

Hatching from the eggs are tiny, whitish maggots that immediately begin using their hooked mouthparts to scrape off tissue that they often pre-digest via their own bodily excretions.

Figure 7: Egg deposit from blow flies
A shiny, yellowish-green Lucilia caesar fly lays an egg mass on bedsheets bound around a corpse. The corpse cannot be reached by the fly, but can be reached by the maggots that hatch from the eggs. Photo: © Mark Benecke

Figure 8: Flesh fly
A flesh fly, Sarcophagid, from a domestic corpse in Cologne, Germany after record-breaking summer heat. Female flesh flies do not lay egg masses, but instead casually distribute living larvae on decomposing tissue. The insects are easy to recognize through their elegant bodily patterns: Silver and black stripes up front (thorax), with a checkered abdomen. Photo: © Mark Benecke

Figure 9: Larvae inside a blister.
Young larvae avoid light and dry air. Here, blow fly maggots in the first larvae stage inhabit a putrefactive blister between two layers of skin in which fluids from decomposition have collected. Photo: © Mark Benecke

Maggots avoid light, wind, cold, and dry air. As young larvae, they're very sensitive to dehydration. In addition, they require a minimum temperature to be able to further develop. Unlike humans, insects cannot generate body heat. That's why more insects are found in summer than in winter; either the cold kills them or their development is stunted until it's warm once more. At a cold crime scene, that means there's sometimes not a single insect to be found, even though many are alive and well on the corpse. Should a forensic flashlight scan across the corpse or beam of sunlight fall upon it, the animals will hide under or inside the corpse. In the worst case, they abandon the corpse entirely, as during storage in a chilled room. A particularly hostile condition for maggots exist in institutes of forensic (legal) medicine: There, it's bright and cold.

Figure 10: Corpse at the place of discovery
It's always worth examining a corpse directly on site. Weather, off-putting odors, or "work hours" should be of no relevance, since only at the scene can the living environment that's dismantling the body truly be measured and understood. In the lab, a biologically satisfactory investigation is therefore only possible with difficulty. Additionally, many insects flee during the transportation of the corpse. Photo: © Mark Benecke