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DETERIORATION OF SHELL COLLECTIONS
Causes, consequence and treatment

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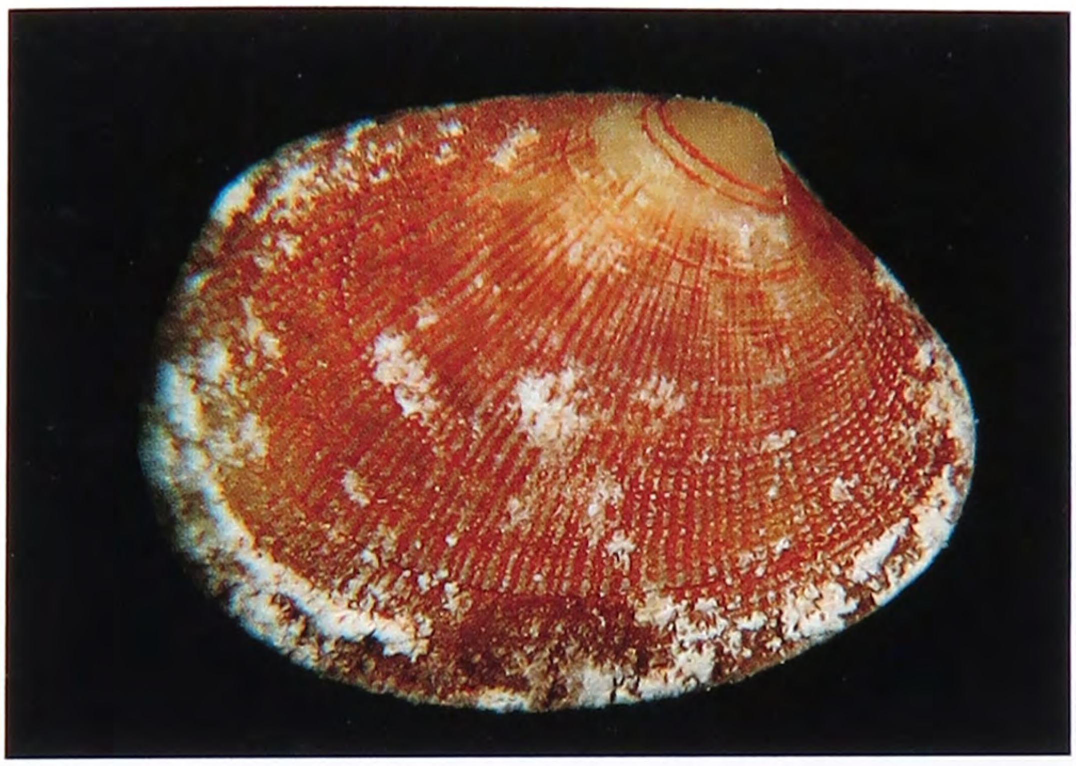

AANTASTING VAN SCHELPENCOLLECTIES.
Oorzaken, gevolg en behandeling

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FOREWORD

Even though we meticulously try not to mention and even though it seems that this item cannot be put in broad daylight, collectors, musea and others will sooner or later be faced with it: **"The deterioration of our shell collection"**.
I myself dare to state that in each and every collection around the world some items are slowly being destroyed by one or another kind of deterioration.
This paper results from my own investigations, tests and study, but above all from the necessity of preserving my own collection, which was suffering from numbers of known, but also less known forms of deterioration.
I do not claim to be exhaustive and some items may be food for thought and discussion and possible further investigations. Nevertheless, I think I can present a good overview of different kinds of deterioration and above all of what precautionary measures can be taken and how it can be treated.
I am convinced that many questions collectors ask themselves are answered in this paper.
All of this has made me realise that everything nature gives us is transitory and that everything will be taken back sooner or later.
We can only try to delay this process as much as possible so as to allow future generations to enjoy the forms, colours and beauty nature offers us.

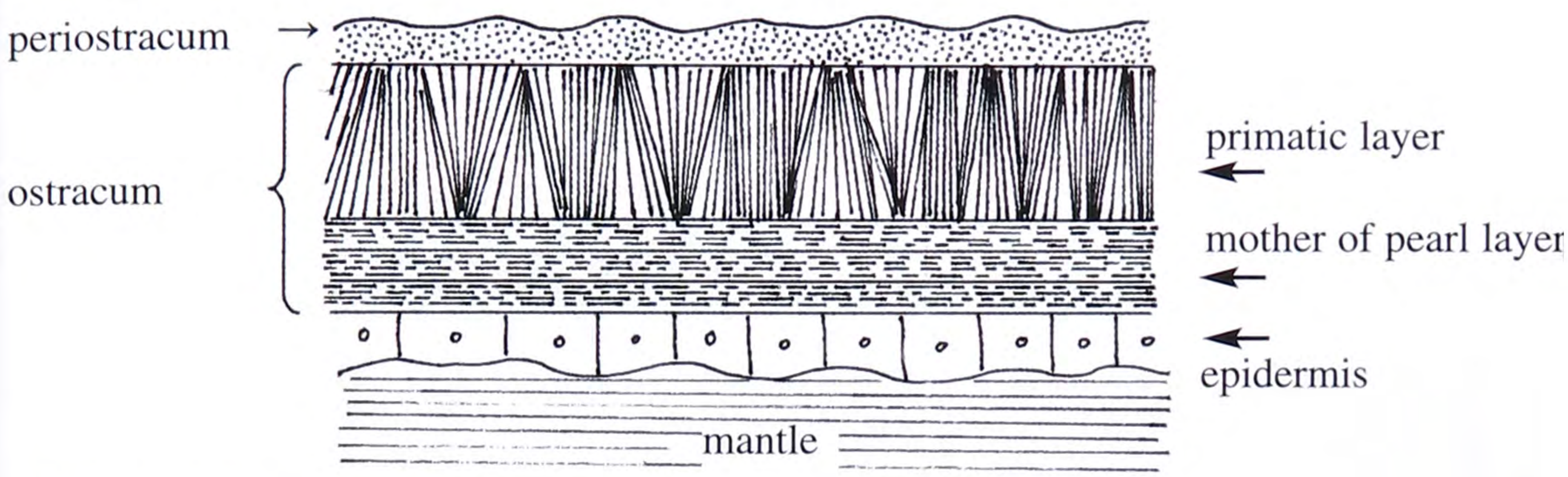
The author

1. CHEMICAL STRUCTURE AND MAKE-UP OF A SHELL

A shell consists of

*organic material 10%- (periostracum + possible bysus and operculum)
*anorganic material 90%+ ($CaCO_3$ and others: Si, Mg, Fe, Ba, ...)

General structure (majority of shells)



Periostracum (organic)

A kind of mucus is secreted near the edge of the mantle. This mucus is a combination of albumines that spreads along the outside of the shell and hardens into a horny substance, **conchiolin**. Conchilone is a substance close to chitin, which forms the exoskeleton of e.g. insects and lobsters.
Its function is to protect the shell from corrosion and other forms of deterioration in the water. However, not all shells have got a periostracum, e.g. Cypraeidae. They almost always surround their shell by two sideflaps of the mantle and thereby leave a layer of mother-of-pearl, which makes the shell shiny and smooth and which makes it more difficult for other organisms to attach to the shell.

Ostracum (anorganic)

The ostracum mainly consists of $CaCO_3$ and also contains small quantities of conchiolin. Calcification may occur through amino acids present in this conchiolin. The calcium elements, secreted by the epidermis are in this way enabled to crytallize.
The ostracum consists of two different layers, both characterized by the nature of their crystals, namely the primatic layer and the mother of pearl layer.

-**Primatic layer** (Calcite)

The outer layer of the ostracum, under the periostracum (if present) is called the primatic layer en consists of prismatic calcite crystals. This is the most stable form of $CaCO_3$. The crystals are in slanting to perpendicular position to the shell surface. This is the thickest layer in Bivalves a.o.
A prismatic layer is found in higher developped creatures.

-Mother of pearl layer (aragonite)

The mother of pearl layer consists of aragonite, which is the harder form of $CaCo_3$. It is a polymorph of calcite and consists of leaflike aragonite crystals. Its construction is parallel to the shell surface. The many fine layers cause the beautiful interference colours. Aragonite is not stable in atmospheric circumstances and then shows a tendency to turn into calcite, the most stable form of $CaCo_3$, after a while.

Note: Some families (e.g. Cypraeidae, Olividae, ...) only consist of aragonite. $CaCo_3$ is here mixed with a fibrous protein and builds fine needlelike crystals that form crossed layers. Every layer has got a different orientation, rendering a much stronger structure.

****Operculum – bysus – ligament*** **(resilium or tensilium)**

The operculum can either consist of conchiolin or be chalky (e.g. Turbo and Natica species). The chalky operculum originates from Ca salts that crystallize on a thin layer of periostracum that serves as a catalytic agent

2. CAUSES OF DETERIORATION

2.1. ACID ENVIRONMENT

The presence of an acid environment is one of the major causes of shell deterioration. This was first noticed by George Byne. He examined a museum collection that was affected by a white powder and drew some conclusions. Yet many of his statements turned out not to be correct! He for example claimed that the deterioration had been caused by a bacterium and that this bacterium spread from shell to shell like a kind of disease. Hence the name **"Byne's Disease"**, a name still used nowadays. Byne also stated that only marine shells had been affected and that land- and fresh water molluscs had been saved from affection. All these statement were later considered unfounded by Nicholls [1] and thoroughly examined by Tennent & Baird [2] in 1985. They concluded that the white powder consisted of calcium acetate, calcium formate or a mix of both, rendering a new double acid. The main cause of the deterioration could be found in the oak cabinets that had been used to store the shell collection. Oak and many other kinds of wood produce acids through the natural desintegration of cellulose. Once free in the air these acids can react with the calcium carbonate of the shell. The result of this reaction is the formation of a salt that can be noticed on the shell surface as a white powder or crystals.

The chemical reactions and formation of these salts is extensively discussed in section 2.1.2

coll. R. De Prins

[1] "Deterioration of shells when stored in oak cabinets" J. Soc. Chem. Ind.

[2] "The deterioration of mollusca collections: identification of shell efflorescense."

2.1.1 WOOD AND DERIVED WOOD PRODUCTS

We distinguish between natural wood, which is used in untreated conditions in the furniture industry and which at the most contains a thin layer of varnish or polishing wax (which provides no or only little protection against the acid) and derived wood products such as board material and other products made of woody leftovers and wood fibres.

Natural wood

This contains tannins in higher or lower quantities. Tannin plays an important role in protecting the wood from parasites. Tannins have the characteristic of tanning (= making unspoilable) the skin of animals by combining with the albumines and as a consequence turning the collagen into a water resistant dissolvent. These compounds contain many phenol groups, which makes them poisonous and corrosive.

Another important characteristic is that wood will slowly release acid vapours by the natural desintegration of cellulose, a process that keeps going on for centuries! One survey has even shown that an oak core in a leaden statue dating back from the 8th century BC still produced enough acid vapours to corrode the lead, even after almost 3000 years! [1] This shows that we can neglect the idea that wood stops releasing acid vapours when it is relatively old.
However, not all kinds of wood are harmful to the same extent: some kinds of wood only release tiny quantities of acid vapours and are therefore less harmful. It's in fact mainly the more lasting kinds that release most tannines.
A list with different kinds of wood and their degree of harmfulness can be found further on in this paper (section 2.1.3)

Derived wood products

Board material consists of woody leftovers or wood fibres which are kept together by resins. These resins are often made on a basis of formaldehyde, which is a very serious disadvantage for our shell collections as the released formaldehyde vapours oxidize into formic acid.

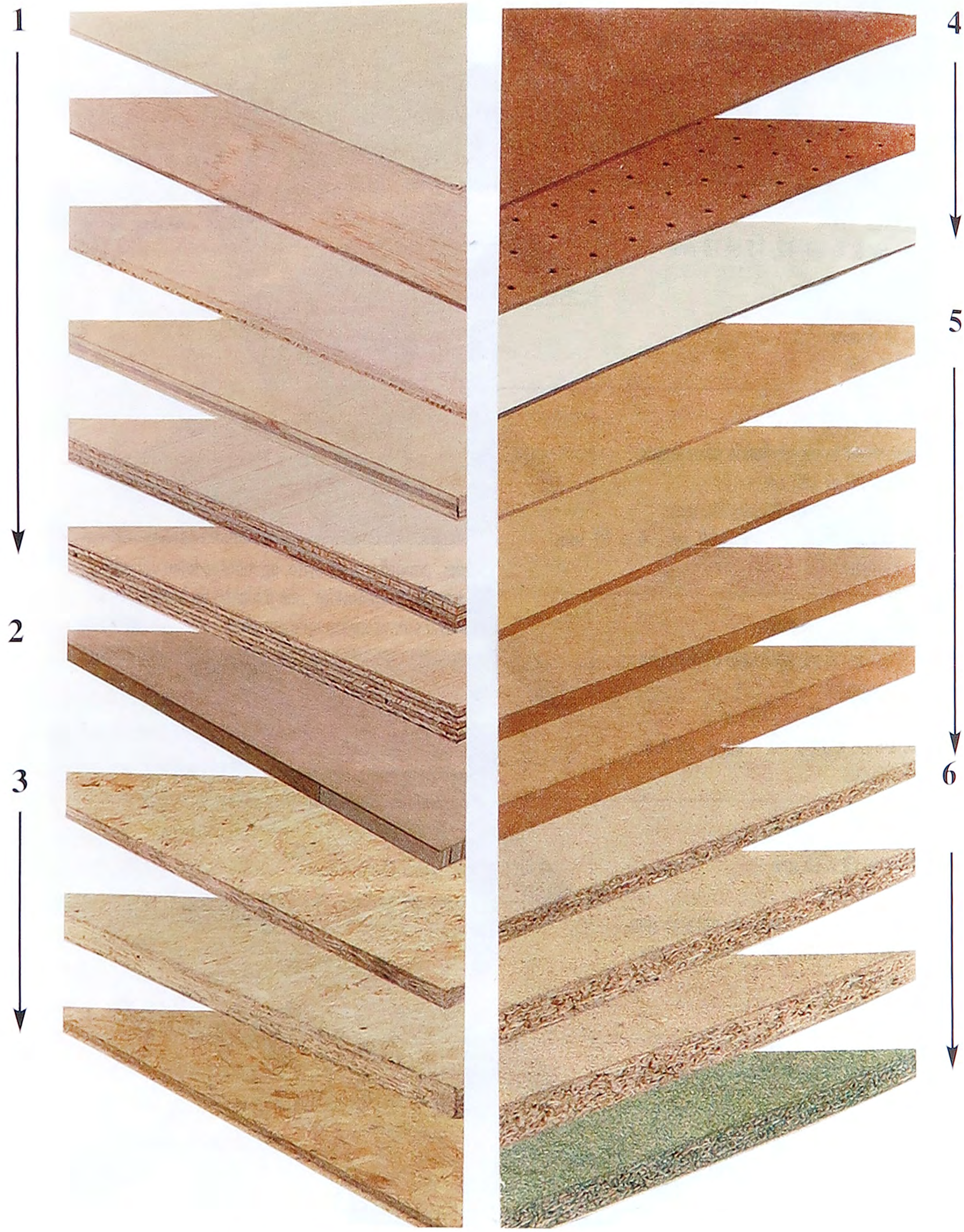
The quantities of released formaldehyde per kind of board are represented in the following overview.

Kind of board	resin type	formaldehyde release
Multiplex	PF/UF	+
OSB	PF	+
Shipboard	MF/UF	++
MDF	MF/UF	++
Hardboard	lignine	
Blockboard	UF	+

+ = low release
+ = aised release
++ = high release

OSB = oriented strand board
MDF = medium density fiberboard
(Consisting of dry wood fibres and resin)
PF = fenolformaldehyde
MF = melamineformaldehyde
UF = ureumformaldehyde

[1] **Tennant N.H. and Baird T., 1985**. "The deterioration of Mollusca collections: identification of shell efflorescence." Studies in conservation, Vol 30, pp 73-85



1 MULTIPLEX
2.BLOCKBOARD
3 OSB

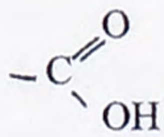
4 HARDBOARD
5 MDF
6 SHIPBOARD

2.1.2 CHEMICAL REACTIONS OF SHELLS IN AN ACID ENVIRONMENT

A) ACID VAPOURS RELEASED BY WOOD

The two most important acids that cause deterioration are formic acid and acetic acid. These two acids belong to the group of carbonic acids, which are characterized by the presence of a carboxylic group. If they react with a base the acid remains are salt, on our shells noticeable as a powder or as crystals.

ACID VAPOURS → CARBOXYLIC ACIDS



Carboxylic group = characterising atomic group

formula	*systematic name*	*trivial name*	*acid remains*
HCOOH	METHANOIC ACID	FORMIC ACID	FORMATE
CH_3COOH	ETHANOIC ACID	ACETIC ACID	ACETATE

In our kitchen as vinegar (= watery solution)

The acid present in ants a.o.

REACTION 1: FORMIC ACID + $CaCO_3$ (shell)

$$\underset{\text{(formic acid)}}{\mathbf{HCOOH}} \xrightarrow{+\ CaCO_3} \underset{\text{(calcium formate)}}{\mathbf{Ca(CHOO)_2}}$$

REACTION 2: ACETIC ACID + $CaCO_3$ (shell)

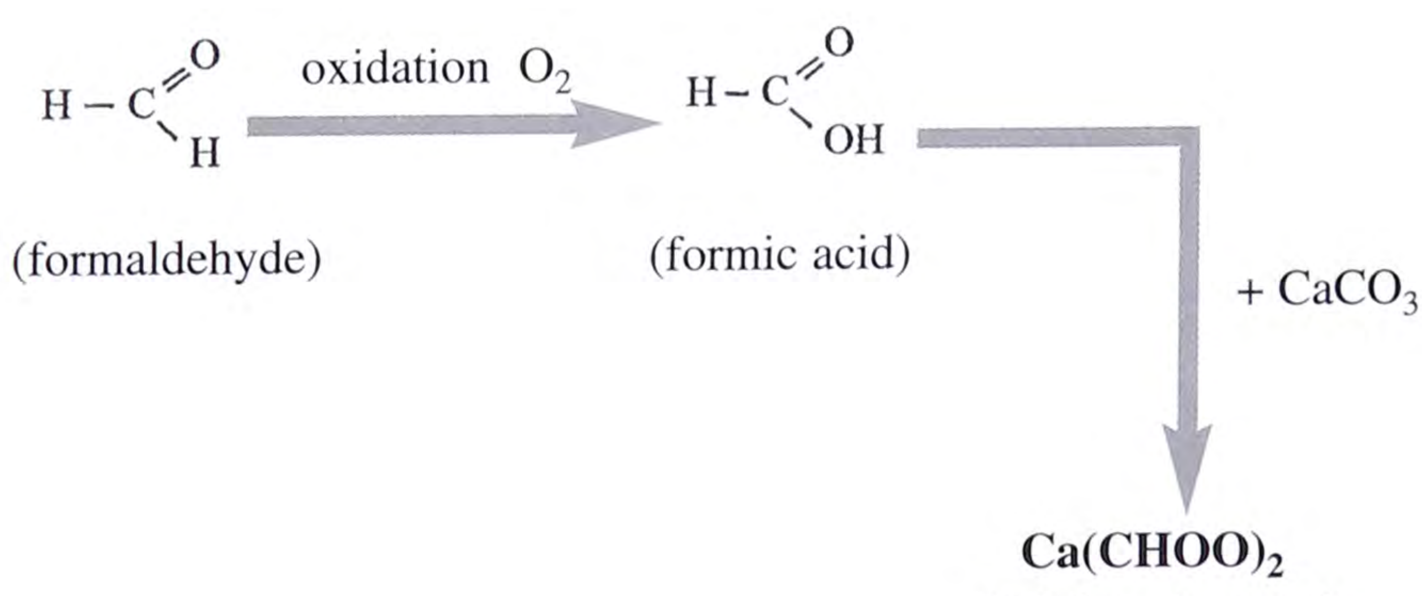
$$\underset{\text{(acetic acid)}}{\mathbf{CH_3COOH}} \xrightarrow{+\ CaCO_3} \underset{\text{(calcium acetate)}}{\mathbf{Ca(CH_3COO)_2}}$$

B) FORMALDEHYDE FROM BOARD MATERIAL

As mentioned before, board material consists of wood parts from different origins and a binding agent based on formaldehyde. From the scheme, one could derive that it is above all shipboard and MDF that are the culprits. I have had negative experiences with especially the latter.
I started changing my shell cabinets a few years ago as I needed expansion and a uniform system after 20 years of collecting. As ordering a big amount of cabinets divided into drawers is very expensive, I decided to do it all by myself. I already knew that oak was harmful to collections, but little or nothing did I know about all other kinds of wood. Most private collections I have seen during recent years are all in cabinets made of multiplex, shipboard, blockboard, etc. The reason is quite obvious as all these materials are rather inexpensive and easily processable. Moreover, we saw a big rise of MDF in those days as it was a cheap kind of board with many possibilities and very easily processable. Moreover, as opposed to other kinds of board, the structure and colour was uniform. All this made my choice very easy. With the benefit of hindsight, this was a bad choice with big consequences!
Not even 6 months later, parts of the collection were deteriorating very rapidly: every drawer contained at least a few shells covered with a kind of powder. *Cypraea* species became dull because the polish layer was being destroyed and tiny and fragile species were simply completely destroyed. I discoverd new cases of deterioration day by day until it became a real nightmare. I witnessed my life's work being destroyed and therefore quick measures were required. I first of all decided to identify the source of all this, and it all turned out to have a number of causes (see further). Yet, the most important cause was MDF: by processing the boards a very large amount of formadehyde was released and as the room with the cabinets was rather tight and full, the concentration of formaldehyde reached enormous volumes. I already knew from my chemistry studies that formaldehyde oxidizes into formic acid in combination with air and I was therefore able to identify the reason for the deterioration rather rapidly. It was most likely a combination of circumstances that caused the deterioration to manifest itself that aggressively.

Formaldehyde vapours from MDF are released everywhere in our daily environment. Realising that the uses for this product are very extensive (ranging from doors, cupboards, ceilings, floors, kitchens, etc.), I assume that the risks for our health is not neglectable. A small questionaire with suppliers confirmed that formaldehyde vapours originating from glues are indeed being released, but all within the ISO limits. Indeed, I can't imagine any problems if you have one MDF door in your house, but what if all your doors, cupboards, kitchen, furniture etc are made of MDF and your floors are covered with laminate? I really have some thoughts about this and I would especially like to know the concentration of formaldehyde in winter when most houses stay closed and only little aired. I also really hope the inhabitants do not have a shell collection!
The following scheme shows how the deteriorations works:

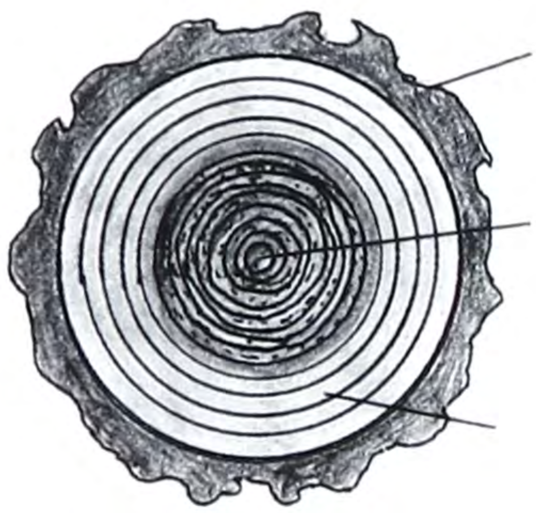
<u>REACTION 3: OXIDATION OF FORMALDEHYDE</u>



Another source of formaldehyde vapours can be found in fluid preparations that are not sealed properly. Even stuffed animals, crabs, starfish etc that have been injected with formaldehyde are wrongdoers. Quite some collectors also put cotton that has been drenched in formaldehyde in shells to make the animal remains dry out. By doing so, the shell can be deteriorated from the inside, without noticing it at first.

2.1.3 KINDS OF WOOD AND THEIR DEGREE OF HARMFULNESS

Natural wood that is used in the wood industry is divided into hardwood and sapwood. If you cut a tree-trunk, the most central and at the same time strongest part consists of hardwood. It contains the highest volumes of tannines and other chemical substances. The sapwood, which surrounds the hardwood and which is protected at the outside by the bark, has a much less dense structure and takes care of the transport of water and nutriments to the rest of the tree. It contains less chemical substances and is of lesser quality than the hardwood.



The wood industry divides hardwood into a number of categories of durability. This means that they are divided into 5 categories based on their natural resistance against fungi (see scheme). The most durable kinds of wood belong to category I, the least durable to category V. This durability is thus a consequence of the amounts of substances the wood contains as natural resistants. Sapwood, which contains much smaller quantities of these substances, always belongs to category V.

NATURAL DURABILITY OF HARDWOOD

CATEGORY	DURABILITY
I	VERY DURABLE
II	DURABLE
III	MODERATELY DURABLE
IV	LITTLE DURABLE
V	NOT DURABLE

Because durable wood contains much more chemical substances it will also release them after the wood has been processed, thus causing a higher risk for deterioration. There are most probably some exceptions to the rule, but generally speaking one can conclude that wood from category I is much more harmful than wood from category V. The category of durability is therefore a decisive element when it comes to the choice of wood if you decide to build your own shell cabinets or when you want to have them built.

CATEGORY ACID	VAPOUR DANGER
I	BIG – BIG
II	BIG
III	BIG-MODERATE
IV	MODERATE
V	MODERATE - LITTLE

The table below lists 34 different kinds of wood that are often used all over the world. For every kind of wood I have added the trivial name, the Latin name, its origin and its category of durability. This allows us to derive ourselves which kinds of wood produce a bigger danger for releasing acids and which ones are much less harmful. However, one should be aware that this table only counts for untreated wood, which means wood without any impregnation processes or layers of paint or polish.

TABLE OF KINDS OF WOOD

TRIVIAL NAME	LATIN NAME	ORIGIN	CATEGORY
Afrormosia	Pericopsis elata	W. Central Africa	I
Afzelia	Afzelia bipindensis	Cameroon, Gabon	I
Azobe	Lophira alata	W. Central Africa	I
Bangkirai	Shorea spp	South-east Asia	II
Beech	Fagus sylvatica	W. Central Europe	V
Cedar	Thuya plicata	W. Canada, USA	II
Oak (European)	Quercus robur, Q. petraea	Europe	II
Oak (American)	Quercus rubra	E. USA, SE Canada	IV
Maple	Acer spp	Canada, Europe, USA	V
Ash	Fraxinus excelsior	Middle-southern Europe	V
Eucalyptus	Eucalyptus delegatensis	Tasmania, Australia	III
Pine	Pinus sylvestris	Europe, northern Asia	III
Hemlock	Tsuga hetrophylla	W. Canada, USA	IV
Iroko	Chlorophora regia	Tropical Africa	I
Chestnut	Castanea sativa	Europe, Northern Africa…	II
Cherry	Prunus avium	Europe	III
Keruing / Yang	Dipterocarpus spp	Indonesia, Malaysia,Thailand	III
Larch	Larix decidua	Europe	III
Mahogany (African)	Khaya spp	Tropical Africa	III
Mahogany (American)	Swietenia macrophylla	S. & Central America	II
Meranti	Shorea spp	SE Asia	II
Merbau	Intsia spp	SE Asia	I
Walnut	Juglans spp	Europe	III
Oregon pine	Pseudotsuga menziesii	W. Canada & USA	III
Pin des landes	Pinus pinaster	S. Europe, N. Africa	IV
Poplar	Populus spp	Europe, Asia, N. America	V
Ramin	Gonystylus spp	SE Asia	V
Robinia	Robinia pseudoacacia	Europe (Hungary)	I
Sapele	Entandrophragma cylindricum	Central & W. Africa	III
Sipo	Entandrophragma utile	Central & W. Africa	II
Southern (yellow) pine	Pinus taeda, P. echinata	SE USA	III
Teakwood	Tectona grandis	Thailand, Indonesia	I
Deal-wood	Picea abies, P. excelsa	N Europe, N Asia	IV
Wengé	Millettia laurentii	Central & W. Africa	II

2.1.4 INFLUENCE OF OUR SKIN

A Belgian malacologist once asked me whether the fact that Cypraea specimens become dull might have to do with the constant touching by hands. As far as I know, no study has yet been carried out on this subject and I therefore only offer a theoretical explanation for the problem.
To understand this, it is necassary to give a brief explanation of what our skin does and what sweat exactly consists of.
The human skin has, next to its protective function against bacteria, viruses and radiation, also a number of other functions such as heat control, storage of fat and the production of vitamine D. One square centimetre of skin is host to 100 perspiratory glands, 10 hairs, 15 sebaceous glands, 1 metre of capillary, 3.5 metres of nerves and hundreds of tiny sensory organs.
All together, we have a total of 2 million perspiratory glands with a total length of 10 kilometres and we produce between 500 ml and 6 litres of sweat a day. The largest numbers of perspiratory glands can be found on the palms of the hand, the soles of the feet and the armpits. The evaporation of this sweat is necassary to allow our body to cool down. Warmth (from a.o. the burning of sugars) leaves our body for 75% through radiation and for 25% through sweat.
This sweat mainly contains water and salt, but also a few acids such as urinous acid, which is created by the desintegration of albumines, valerinic acid, caproic acid and butyric acid. The secretion of lactic acid is also possible. Certain perspiratory glands are namely able to absorb adrenaline. This adrenaline boosts the perspiratory glands, which causes an accelerated metabolism. This requires more energy and therefore cells will burn more glucose. However, through a lack of oxygen this conversion will not be profitable enough and therefore more lactic acid, which is a waste product, is created. The normal acid mantle, which also contains lactic acid, serves as a defence against harmful matter from the environment and protects us a.o. from skin moulds.

OVERVIEW OF MOST IMPORTANT ACIDS OUR SKIN RELEASES

Systematical name	*trivial name*	*formula*	*acid remains*
Butanoic acid	**Butyric acid**	$C_4H_8O_2$	Butyrate
Pentanoic acid	**Valerinic acid**	$C_5H_{10}O_2$	Valerate
Hexanoic acid	**Caproic acid**	$C_6H_{12}O_2$	Capronate
Hydroxypropion acid	**Lactic acid**	$C_3H_6O_3$	Lactate

These acids, together with acetic acid and formic acid, belong to the carboxilic acids. When they react with Ca^{++} they create salts such us calcium butyrate from the reaction of butyric acid with $CaCo_3$.

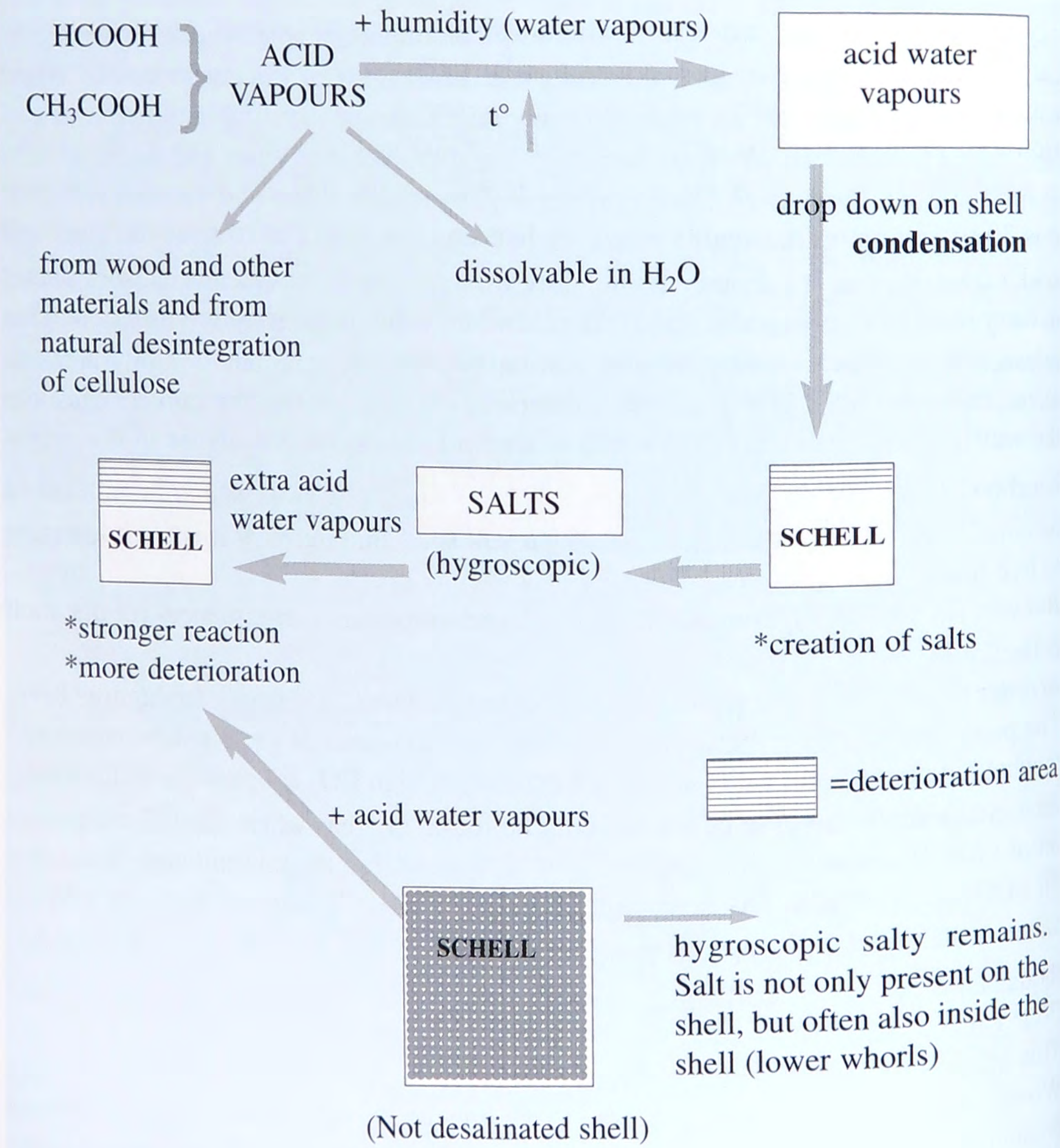
Thus, when sweat is left behind on shells, it is possible that the acids present in this sweat trigger off a chemical reaction and the creation of salts. The secretion and amount of sweat are of course different from person to person.

A more detailed survey is necessary and we might have to take up our shells with white velvet gloves in the future, as is already being done with objets d'art.

2.2 INFLUENCE OF HIGH HUMIDITY (in an acid environment)

Unless you are in a Turkish bath, a high humidity in an environment will always have a negative effect on its inhabitants or the material (of any kind) present in that environment. However, when it comes to shell collections, it is not the humidity itself that directly causes deterioration, although it plays an important role in some processes: it often accelerates and seriously increases the dimensions of the deterioration. When humidity co-incides with an acid environment, it functions as a solvent and means of transport. The acid vapours from wood a.o. are dissolvable in water and therefore also in environmental humidity. Upon cooling (e.g. by night), these acid vapours will condense and end up on the shell surface. Here they react with $CaCo_3$ from the shell and create salts. But, as we already know, salts are hygroscopic which makes them attract moisture and as a consequence also the acid water vapours from the environment. This means that a bigger amount of acid will be transported to the shell, which triggers extra reactions only causing a further deterioration of the shell. Even remaining salty remains (from insufficient desalination of the shell) cause an extra intake of acid water vapours. Even though we are talking about tiny quantities, this process will lead to serious consequences when it is able to repeat itself day after day.

The following scheme shows how a high humidity and remaining salty remains can have important and serious consequences for our collections.



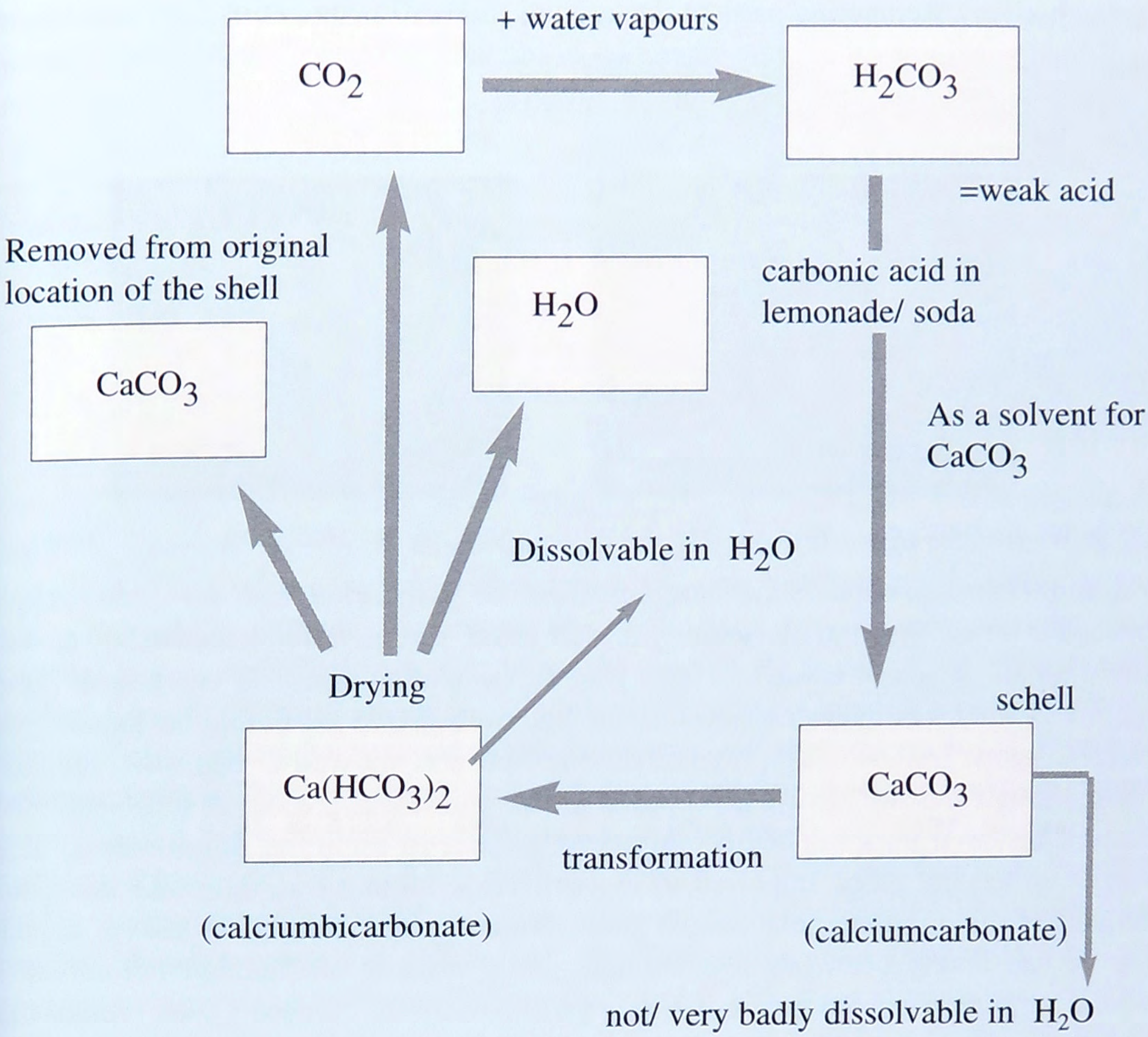
Conclusion: the higher the humidity (and temperature), the faster the reaction.

2.3 RELATIONSHIP BETWEEN ATMOSPHERIC HUMIDITY AND CO_2

Carbon dioxide (CO_2), for 0,3% present in the air, is one of the most important gases for human life. Because green plants are able to get carbon out of CO_2 and release oxygen through photosynthesis, we can inhale this oxygen. Through a combination of carbon with hydrogen, oxygen from the water and minerals from the soil, plants form a number of vegetable substances that can be eaten by both humans and animals.
However, CO_2 can also be formed through burning materials that contain carbon such as wood, charcoal and tobacco. It is characteristic of CO_2 that it is heavier than air and it is 30 times more dissolvable in water than O_2. When it dissolves in water, a weak acid, carbonic acid, is formed. We all know what this acid tastes like, because it is used in fizzy mineral water (soda) and soft drinks. The bubbles are simply CO_2 that's being released. Rain also contains a certain amount of carbonic acid, but in highly industrialized and polluted regions, its concentration can be so high that the rain changes into the well-known "acid rain". CO_2 concentrations are also much higher in the neighbourhood of a cement factory because a lot of CO_2 is released during the process of heating limestone in order to get lime. You will soon find out why it is not interesting to live in the vicinity of such a factory as a shell collector.
But why do raised CO_2 concentrations have such important consequences for our shell collections?
In order to get the picture right, I would like to take you to a stalactite/stalagmite cave. The processes that have been going on there for thousands of years can be compared to what happens to our shells if they are exposed to high CO_2 concentrations for a long time. Stalactite/stalagmite caves can only be found in areas where the soil contains a lot of lime. Rainwater containing carbonic acid seeps through this soil and dissolves a bit of $CaCO_3$. When it has reached the cave and a drop is hanging from the ceiling, water and CO_2 will disappear because of drying and $CaCO_3$ will stay behind. After thousands of years, the ceiling of the cave will be ornamented with stalactites and the floor with stalacmites.
This process is also called the carbonate-bicarbonate cycle.
When a shell collection is situated in a room where a lot of carbon dioxide is already present or is being created through a.o. smoking, burning candles, wood-burning stoves, etc. and where atmospheric humidity plays an important role, this process will also happen here. The scheme below shows us how CO_2, created through the warming up during the day, is absorbed by the moisture present in the environment, condensed at night through cooling down and ends up on the shell as acid water of condensation. The acid water then functions as a solvent for $CaCO_3$. Because $CaCO_3$ does not or only very badly dissolves in water, a transformation into calcium bicarbonate

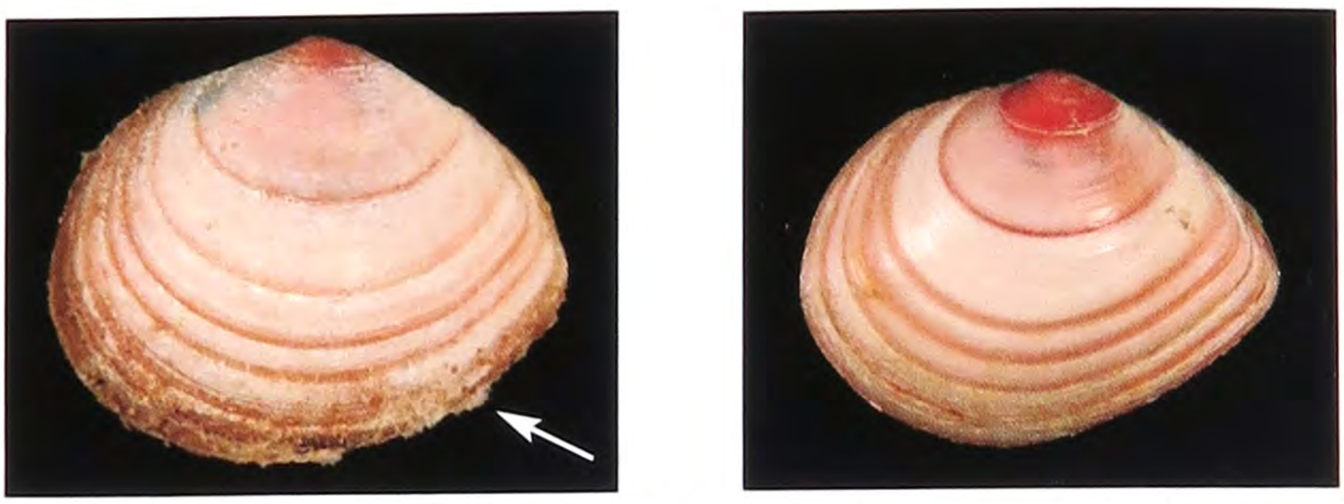
$Ca(HCO_3)_2$, which does dissolve, takes place. When the environment warms up again (e.g. by daytime), the water of condensation will dry up and carbon dioxide and water will once again be released and return to the cycle. A very tiny amount of calcium carbonate, removed from its original location, thus remains on the shell. Even though this is a slow process and the quantities of removed calcium carbonate from the shell are small, it can have serious consequences when it is repeated day by day, year by year. Everything of course depends on the concentration of carbon dioxide and the atmospheric humidity. The latter is rather low in Europe compared to more tropical and subtropical regions with a typically much higher atmospheric humidity and where the temperature at daytime and nighttime differs a lot.

CARBONATE – BICARBONATE CYCLUS



2.4 DETERIORATION CAUSED BY FUNGI

Deteriotration by fungi mainly occurs on the organic part of the shell (periostracum, operculum, ...). Remaining parts of the animal, shells still containing the dried animal and dried specimens that were drenched in alcohol (such as Chitons) are of course much more sensitive to damage done by fungi.



Macoma balthica (Linné, 1758): L: with fungi   R: normal (coll. R. De Prins)

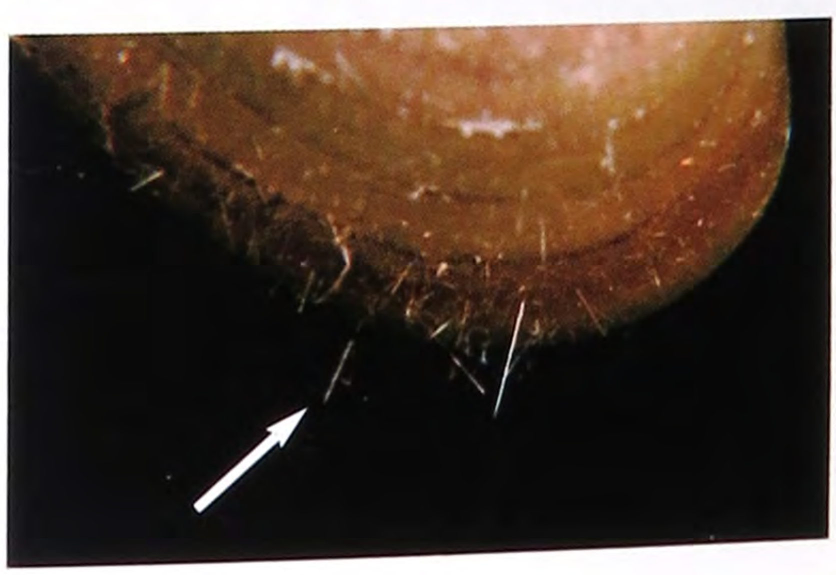
Yet, fungi can also damage the anorganic material en therefore also our shells. I experienced this new given to malacology myself. As if the deterioration caused by an acid envorinment was not enough, I was also faced with fungi! The creation of fungi requires ideal circumstances: humidity and warmth give a good impulse to allow the fungi to grow. In those days, my collection room was not well-aired so that moisture (even though it is not always perceptible at first sight) was present in sufficient quantities. The environmental temperature was normal to high.The fungi(traces) themselves turned out to be imported in my collection room by an old collection I had acquired from a retired malacologist a few months before. During 40 years of collecting he had barely been faced with fungi, partly because of the dry environment in which he kept his collection, but enough traces were still present, even though they had remained inactive for all those years. Once they reach an ideal environment, you get a real 'explosion'. It was at first shells from his collection that caused the rise of fungi.
Especially operculum and periostracum are fungi's favourites and air currents and handling the shells allow for a rapid spread of the traces and a rapid increase in the deterioration.
Because I was investigating deterioration through acids, I had a closer look at the fungi: after taking a number of samples and grafting them on breeding grounds, I was able to to isolate a number of fungi with the help of a friendly clinical biologist. Even thought identifying fungi is very difficult and food for specialists, we managed to trace certain characteristics, which allowed us to identify their family and genus.
The most important we found was **Aspergillus** sp., along with **Trichophyton** and **Penicillium**. The last one can however also be present as a contaminant.

Trychophyton seems to be a fungi that is also active with humans, especially on horny layers such as nails and hair (see photo). This can explain the presence on periostracum and operculum.

Deterioration of toe nails by Tricophyton sp.

Throughout the survey, I also noticed that the shells themselves had been attacked. At first I thought I was dealing with powder and crystals from the acid emmisions of the wood, but after a microscopic survey, I could only conclude that mildew threads and needle-shaped crystals were present on the shells. Most needles were at right angle with the shell surface. Some were visible to the eye and the most impressive ones even reached a length of 7mm! (see photo). While studying the fungi, I also came across a very interesting given that showed certain fungi produce an acid (oxalic acid) through their metabolism. They can create sharp needles of calcium oxalate crystals by transforming sugars, but it is almost needless to say that the oxalic acid will also react with the calcium from our shells and that the fungi itself will extract calcium from the shell surface. Both Aspergillus and Penicillum sp seem to be such fungi: lab surveys on oxalates of the needles was affirmative. Needless to say that further surveys are required and that an exact identification needs to be done by a mycological identification lab. The costs are however so high that this is impossible for private purposes.

needle-shaped crystals of calcium oxalate on *Donax trunculus* Linné, 1758 caused by the presence of Aspergillus sp. (coll. R. De Prins)

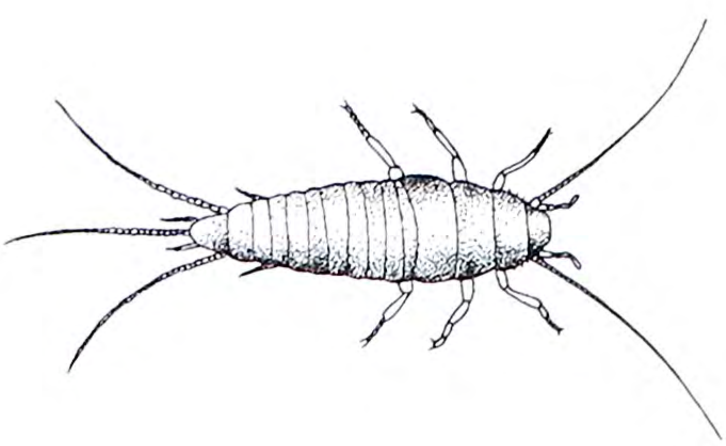


2.5 DETERIORATION CAUSED BY INSECTS

Deterioration by insects can have positive as well as negative consequences!
The deterioration is usually limited to the organic material of the shell (periostracum, operculum), but insects can also cause serious damage to labels, cardboard boxes, wood, books, etc. The scientific value of a collection can be lost when data on labels are destroyed by the gluttony of tiny insects (see photo).
The ones responsible for this deterioration are mainly hide beetles, book lice, mites, silverfish, ...
The only positive side to the presence of certain insects is that they will start removing the remaining soft parts of the animal in the shell. However, this does not outweigh the other damage they can do.
These insects occur in every collection and even in every environment. They only get dangerous when their number seriously increases, which enables them to cause serious damage. You still do not have to worry when you find a single individual (adult or larva) of the following insects. A real plague is often linked to circumstances of the environment and trouble will remain small when risk factors such as humidity, high temperatures and leftovers of food are kept to a minimum. Bought collections and newly acquired material can often bring along unwelcome animals. You sometimes do not know in what conditions the collection was formerly kept, so keeping it in quarantine and thoroughly inspecting it are not superfluous!

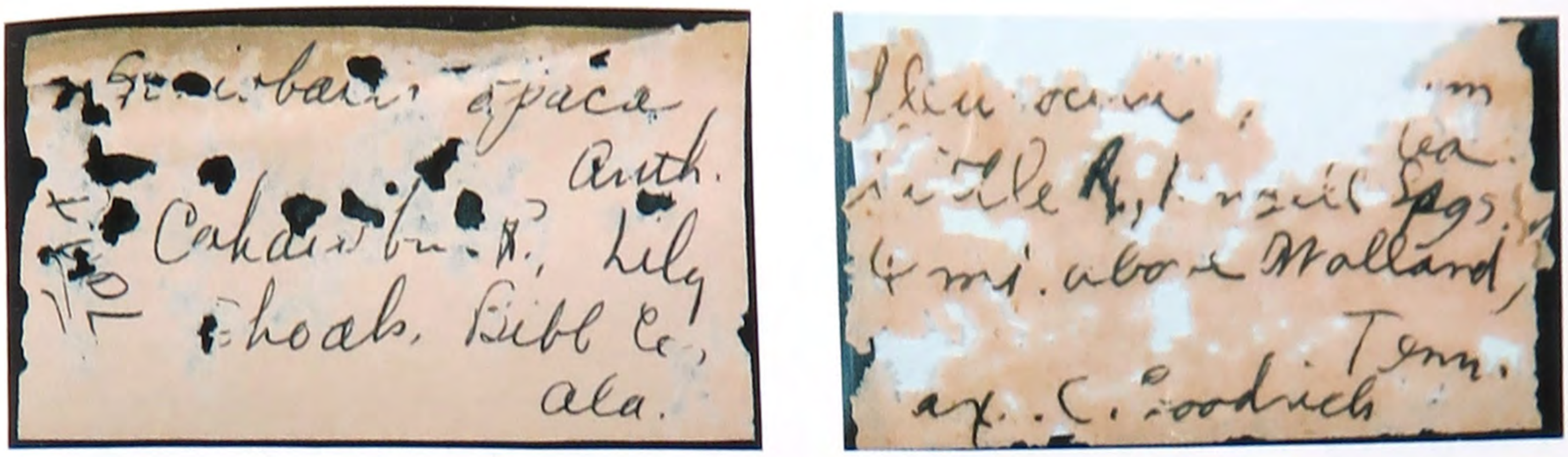
SOME EXAMPLES OF FREQUENTLY FOUND ATTACKERS

Silverfish (Lepisma saccharina)



M. Leclercq © KBIN

Silverfish can be found in every house: they are tiny, flat, silverish white insects that are active at nighttime. They can above all be found in more humid places such as bathrooms and kitchens. You can often see them run away when you suddenly swith on the lights. They make nightly searches for leftovers of food and products contain-



Labels from an old collection that have been visited by silverfish (coll. K. Fraussen)

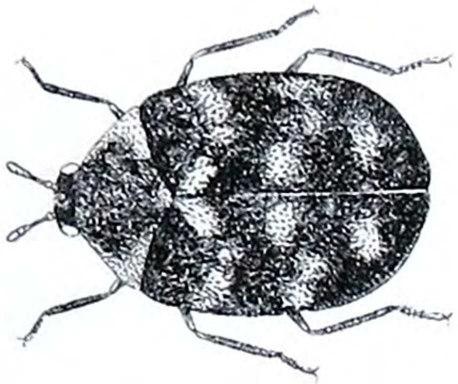
ing starch. Their most harmful characteristic, however, is that they are able to digest cellulose. They therefore enjoy gnawing our labels and books.
Stamp collectors have to be very anxious about these animals because the gum on the stamps seems to have an enormous appeal..

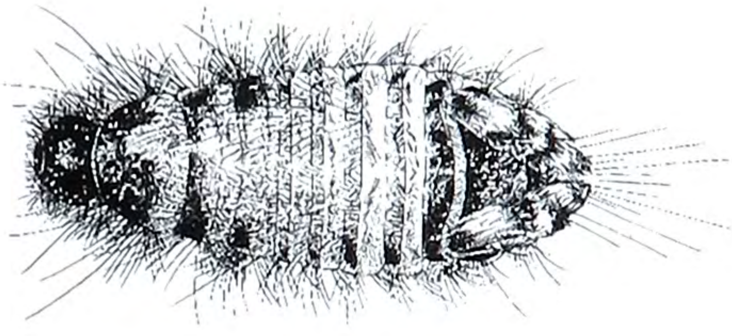
Hide beetles (fam. Dermestidae)

© KBIN

© KBIN

They are small beetles that mainly feed on dried dead parts of plants and animals. Some are able to digest horny layers and therefore also chitin and conchiolin.
The most well-known in our regions are the **carpet beetle** (Anthrenus scrophulariae) and the **museum beetle** (Anthrenus verbasci). However, it is the larvae of these beetles that cause most of the deterioration in our collections. They all look rather hairy and sloughings of these larvae can often be found in the aperture of shells.
Especially the museum beetle (Anthrenus verbasci) can cause a lot of damage when it is able to enter an insect collection (see photo), but also the operculum and periostracum of shells can completely be destroyed within a short time. It can also gnaw its way through cardbaoard, so cardboard boxes do not provide any protection.





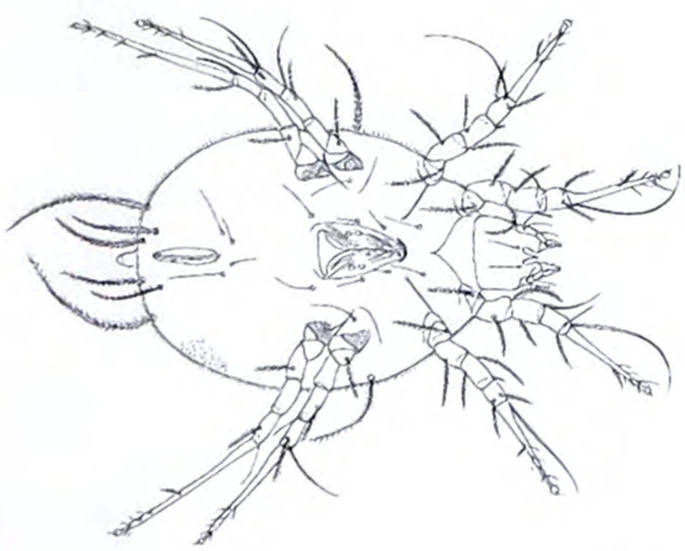
M. Leclercq © KBIN M. Leclercq © KBIN

Anthrenus verbasci l: adult beetleR: sloughing of a larva that can be found in cabinets

coll. R. De Prins

Evidence of the museum beetle's gluttony in a butterfly collection

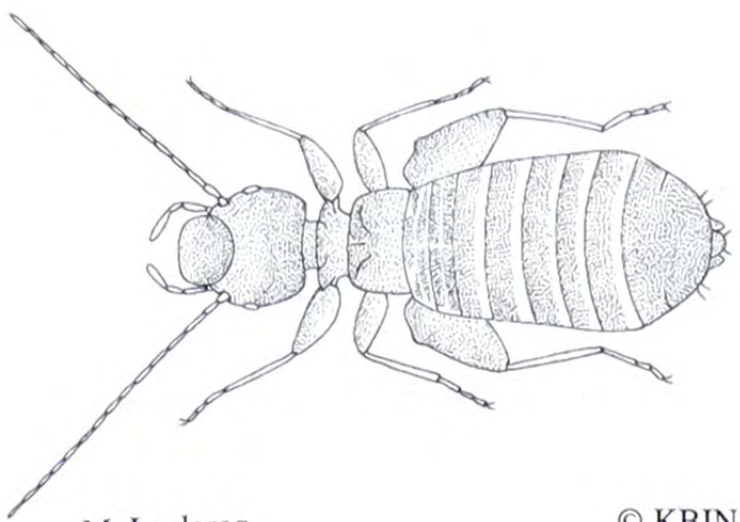
Book lice



M. Leclercq © KBIN

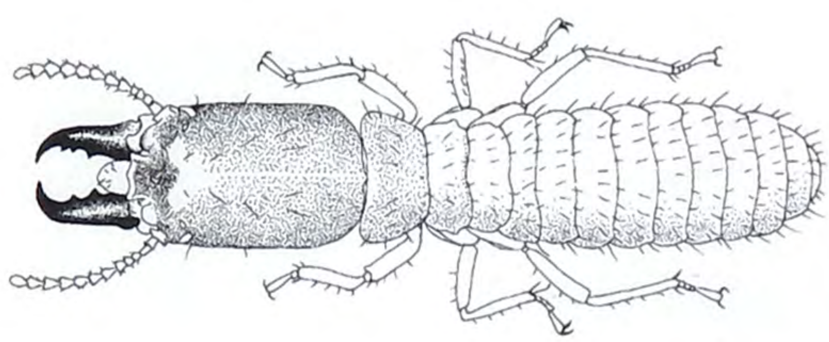
Dust mites such as the **common mite** (Glycyphagus domesticus) are in fact no insects, but form a separate Order within the Arthropoda. Like spiders, they have got 4 pairs of legs. They occur abundantly in every house where mattresses and carpets are their favourite hiding places. Yet, I have once upon a time found them in the velvet coating that is used as a bottom in plastic boxes in order to create a background that is in contrast with the shell (often black velvet).

Book lice



M. Leclercq © KBIN

Book lice are non-flying animals chunning the light and favouring a higher atmospheric humidity. They can often be found between papers and books. They do not damage the paper itself, but feed on the gum which means that books can fall apart after a certain time. Their main food, however, are mildew threads and the presence of these animals in a collection therefore indicates that the atmospheric humidity is too high in certain parts of the collection room.



M. Leclercq © KBIN

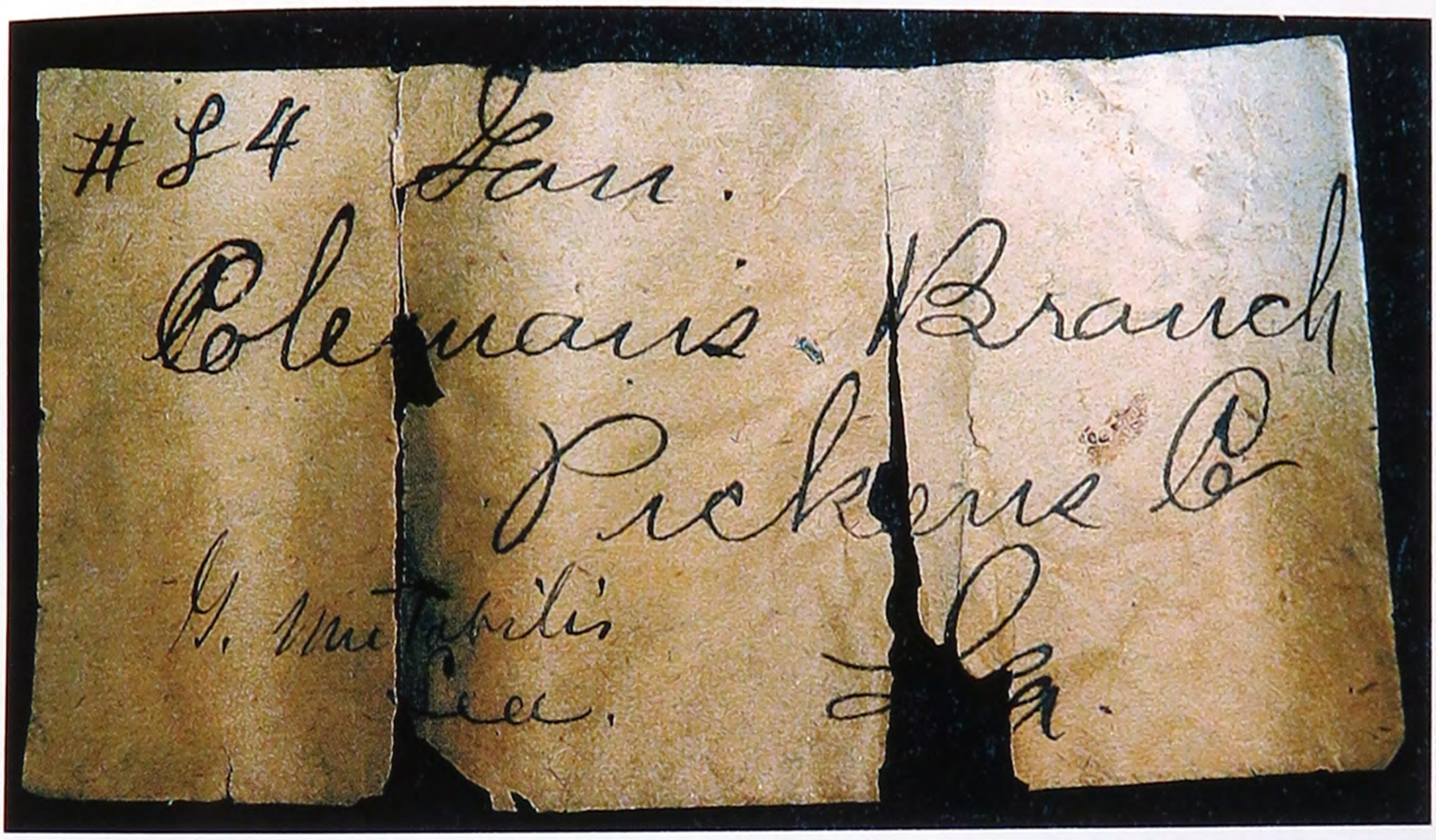
Termites

Termites are insects that mainly occur in tropical regions. Like ants and bees they live in colonies with a queen. They are by far the most harmful attackers for wood, but they can also deteriorate other materials consisting of cellulose such as books and labels. Next to warmth they also need moisture. Their presence therefore indicates a too humid environment. Only two species occur in (southern) Europe.

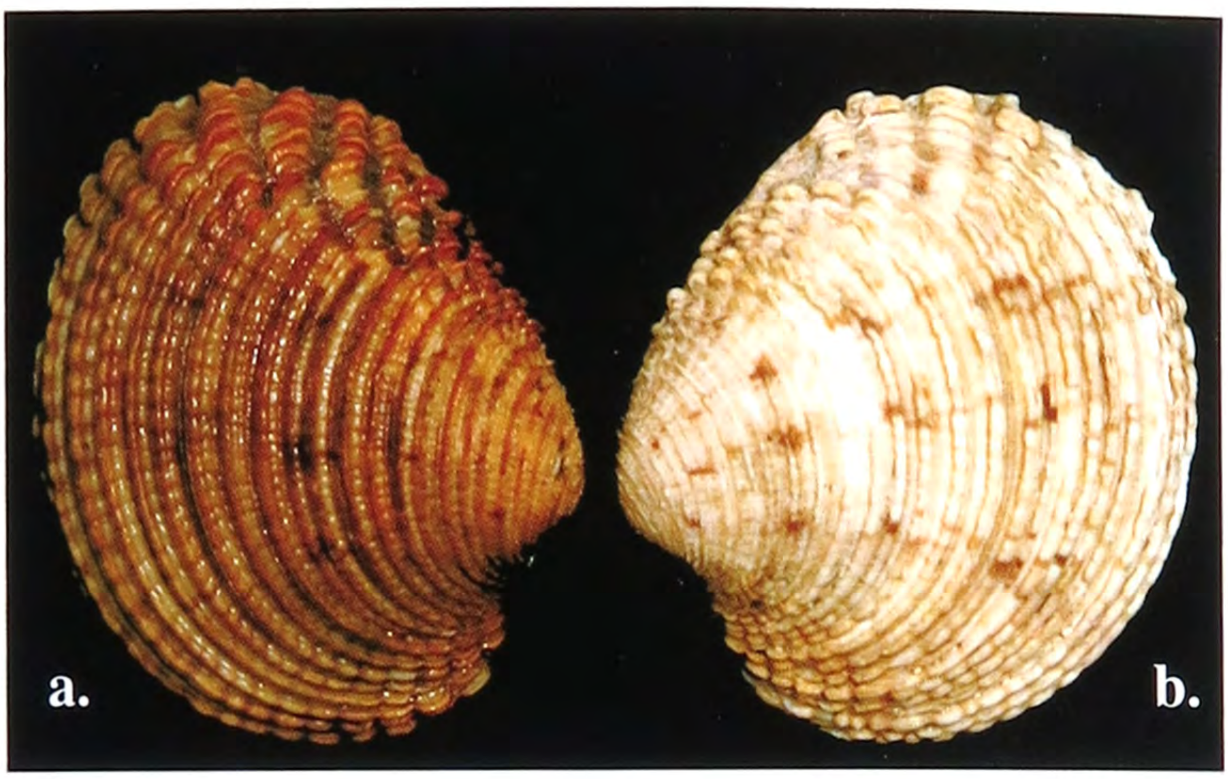
2.6 DETERIORATION CAUSED BY LIGHT

The influence of light on our shells and the related loss of colours is a factor which should not be underestimated for our collections. Both the normal, visible light and the invisible ultraviolet light (UV) can cause discolouring or even the total loss of colours. The unit of visible light is represented in lux. The normal values are about 5000 lux for a cloudy day and about 100 000 lux for a sunny day.
Artificial light has a value between 100 and 1000 lux. One can accept as a rule that the higher the luminous intensity, the more harmful for the collection.
UV-light is divived into 4 groups (UVA, UVB, UVC and VUV), depending on their wavelength. The shorter the wavelength, the higher the energy. The unit is nanometre and is 315 to 400 nm for UVA, whereas VUV has a wavelength of 40 to 200nm.
Direct sunlight falling into the collection room or museum room is of course very bad and should be avoided, but artificial light is not harmless either. When visible light and UV-light shine on an object, energy is transmitted and as a result a number of chemical reactions can be triggered. These are called photochemical reactions. The photochemical reaction will even continue after the exposure to light has been stopped, which only means a bigger damage being done.
The ideal environment is a dark room without windows that is only illuminated when necessary. Covering showcases with dark cloth is an option.
If the collection room has got a lot of windows, it is best to blind them or cover them with a filter in order to decrease the strength of the light considerably. If showcases are illuminated by artificial light, it is best to use lamps that are not stronger than 50 lux and contain at most 75 microwatt per lumen UV light. Hang artificial lighting at a sufficient distance from the shells: the closer to the shells, the higher the intensity and the higher the energy and temperature, which can lead to the drying or flaking of the periostracum and the bursting of thin or fragile species (e.g. Pinna sp.).
Everyone can check whether too much light is coming into the room at home. One can exaclty measure this with a luxmeter, but sometimes this can be derived from small facts: books are also sensitive to light and one often sees the library and the collection of a private collector stored in one room. If the back of a recently acquired book has already somewhat faded, too much light is coming into the room and measures should be taken.

In order to prove that light indeed has an effect on colours, I decided to do a small experiment with a bivalved shell (*Venus verrucosa* Linné, 1758). I have exposed one valve to the light of a mercury vapour lamp (HQL 125W Osram) for 8 hours a day during 5 months and kept the other valved in a closed drawer of my desk. I deliberately decided not to use a very colourful shell but a very common brownish hue. The photograph clearly shows the consequences after those 5 months and one can easily draw conclusions about what the shell will look like within 20 years. If no reference material is available, one will of course not notice this process, unless dealing with very colourful specimens. One only notices this when comparing shells from an old collection to recently collected material. You can do the test yourself by taking e.g. a (*Cypraecassis rufa* Linné, 1758) or a (*Strombus gigas* Linné, 1758) that has been lying on the cupboard in the living room for 10 years and comparing it to a more recent or dark stored specimen and you will soon realise what I mean.



Label from an old collection that has been exposed to sunlight for a long time. (Coll. K. Fraussen)



***Venus verrucosa* Linné,** *1758*
Fig a) right valve, normal colour
Fig b) left valve, exposed to HQL light for 5 months

Salle Vayssière (Oiseaux et coquillage). Museum D'Histoire Naturelle Marseille. Mid 19th century. Big windows on the right hand side allow sunlight to fall freely on shells and bird collection.

3. HOW DO I RECOGNISE DETERIORATION IN MY COLLECTION?

Tracing and recognising the different kinds of deterioration is very important if you want to protect a collection from numerous problems later on. A regular spot check or even a thorough inspection once in a while can save you from a lot of trouble. It is especially important to trace fungi in time because such a deterioration can have serious consequences in a short time. If the deterioration is caused by acids, the process is much slower and the consequences are often only visible after months or even years, unless the acid concentration is unusally high.
Not everything that looks like deterioration of one kind or another really is deterioration. White crystals are often only salty remains and white powder can be caused by the natural scale from the water or it is remains of overgrowth of all kinds of sea animals. The degree of deterioration and the deterioration area can strongly differ within a collection. It is therefore possible that some specimens in a drawer with only one species show deterioration whereas others are completely unaffected. The reason why is not always clear, but whether a shell has been boiled or not, desalinated, collected dead or alive or oiled all plays an important role. Moisture is an important factor of influence, but is not always noticeably present: the humidity in certain parts of a room can be 20% higher than in the rest of the same room through condensation and accumulation, which of course means a higher chance to find deterioration caused by fungi and acids.
The following identification tool for each kind of deterioration should enable you to recognise the majority of all problems. (also see photo plates)

3.1 DETERIORATION CAUSED BY AN ACID ENVIRONMENT

A consequence of acid releases from wood, derived wood products, chemical substances, ...

- **White powder or white crystals** are visible on the shell surface and above all on the sutures in Gastropoda and in between the ribs of Bivalvia. The spire, which is the oldest part and at the same time the most damaged part through natural erosion, often shows deterioration, too. This can especially be noticed in species that live in the tidal zone such as Trochidae and Patellidae.

coll. R. De Prins

- When touching the shell, the **white powder sticks on your fingers**.

- Look carefully and use a magnifying glass or zoom lens.
  The very beginning is often not visible to the naked eye.

- Taste the powder with the tip of your tongue. If you are faced with deterioration, there will often be a **clear sour taste**. (Natural scale does not taste sour).

Hexaplex trunculus (Linné, 1758)

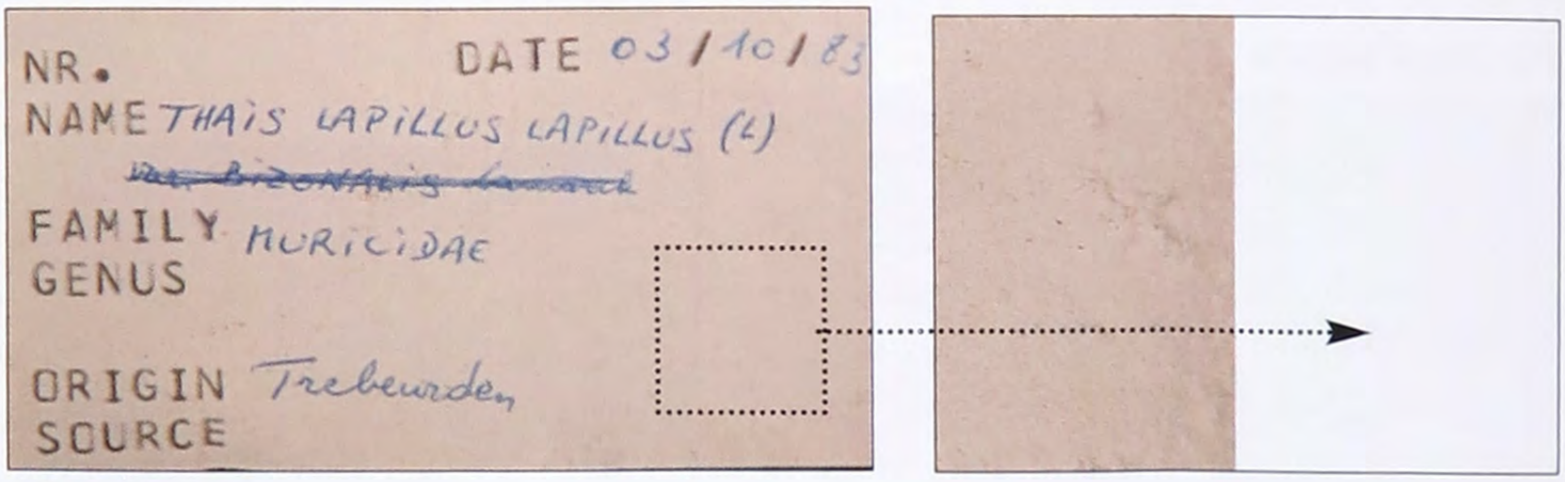
This photo shows a natural scale covering the entire shell.

- Some shells **pulverize or fall apart into flakes** when you try and lift them. It is often the prismatic layer that flakes off, thus revealing the mother of pearl layer from the outside. The periostracum, too, can flake off, but this is possibly only the result of dryness, which makes the periostracum shrink and break away from the shell. I have mainly noticed this pulverizing and flaking off in smaller and more fragile species that often only consist of one or two shell layers. Trochidae, too, seem to be sensible to these processes.

- **Smelling an acid smell when opening a drawer or cupboard** is the consequence of the accumulated acid concentratrions from the wood.

- Glossy shells can look **dull**. Families such as Cypreaidae and Olividae are sensible to this. However, the deterioration can also come from the inside. The glossy layer is still present, but one can clearly notice the deterioration of the lower layers.

- When labels get deteriorated, this is caused by the reaction of the acid vapours with the $CaCO_3$ in the paper. The createds salts will push the fibres upwards, causing the **paper to look granular or with bubbles**. Discoloration is also possible, but also has other causes.



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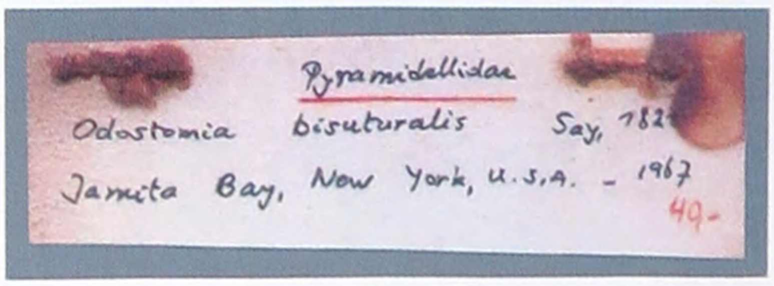
- **Metal objects and staples** often show **signs of corrosions sooner** than the shells themselves and can therefore be good indicators for a too acid and too humid environment.

Volatile organic acids have deteriorated both label and staples.



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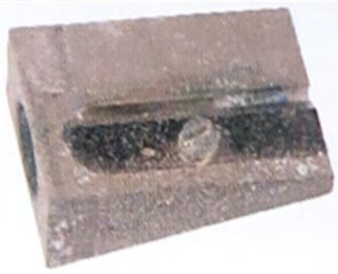
This metal pencil sharpener has been in an MDF drawer for a couple of months. Clear traces of deterioration can be noticed.



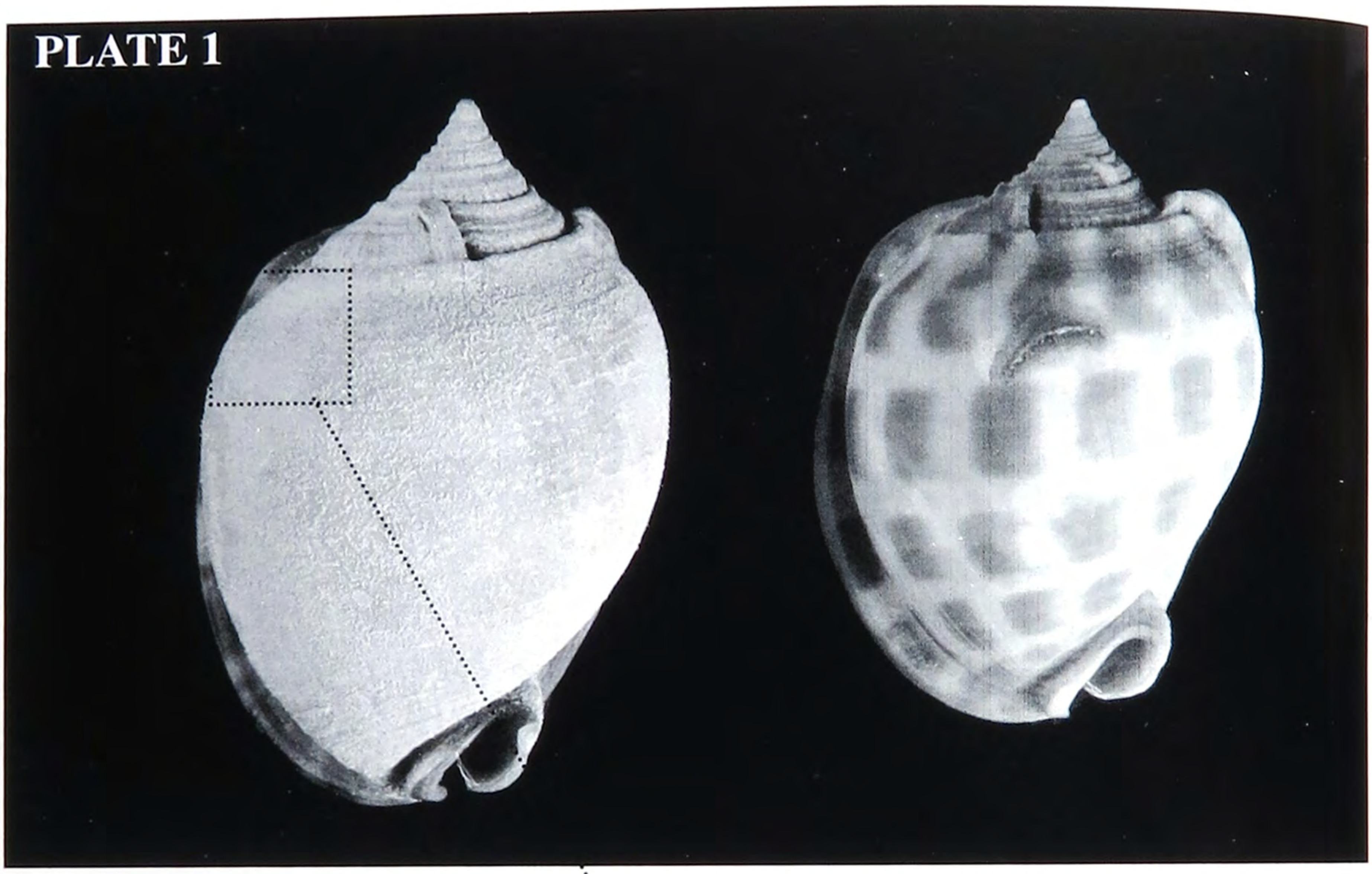
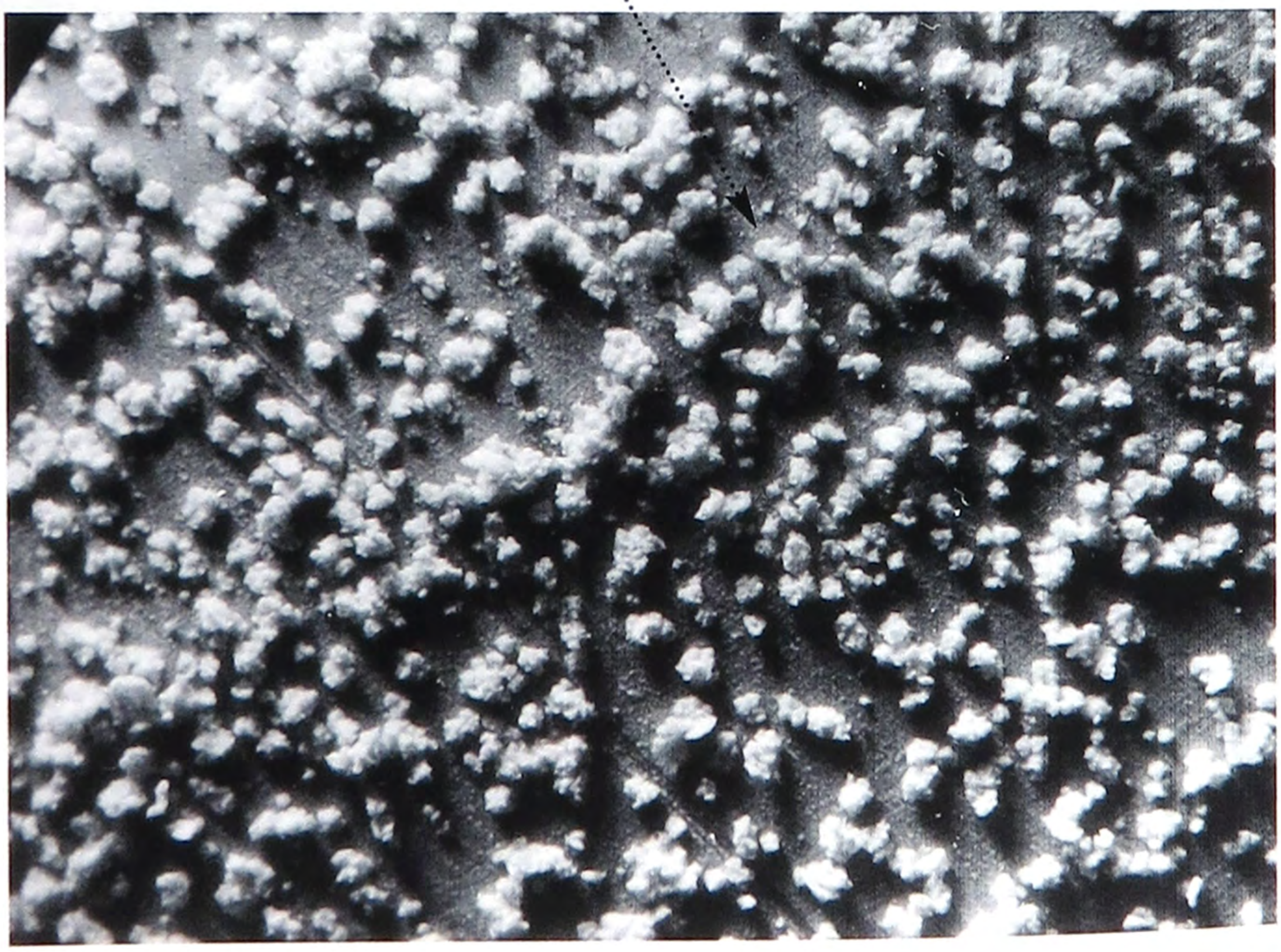
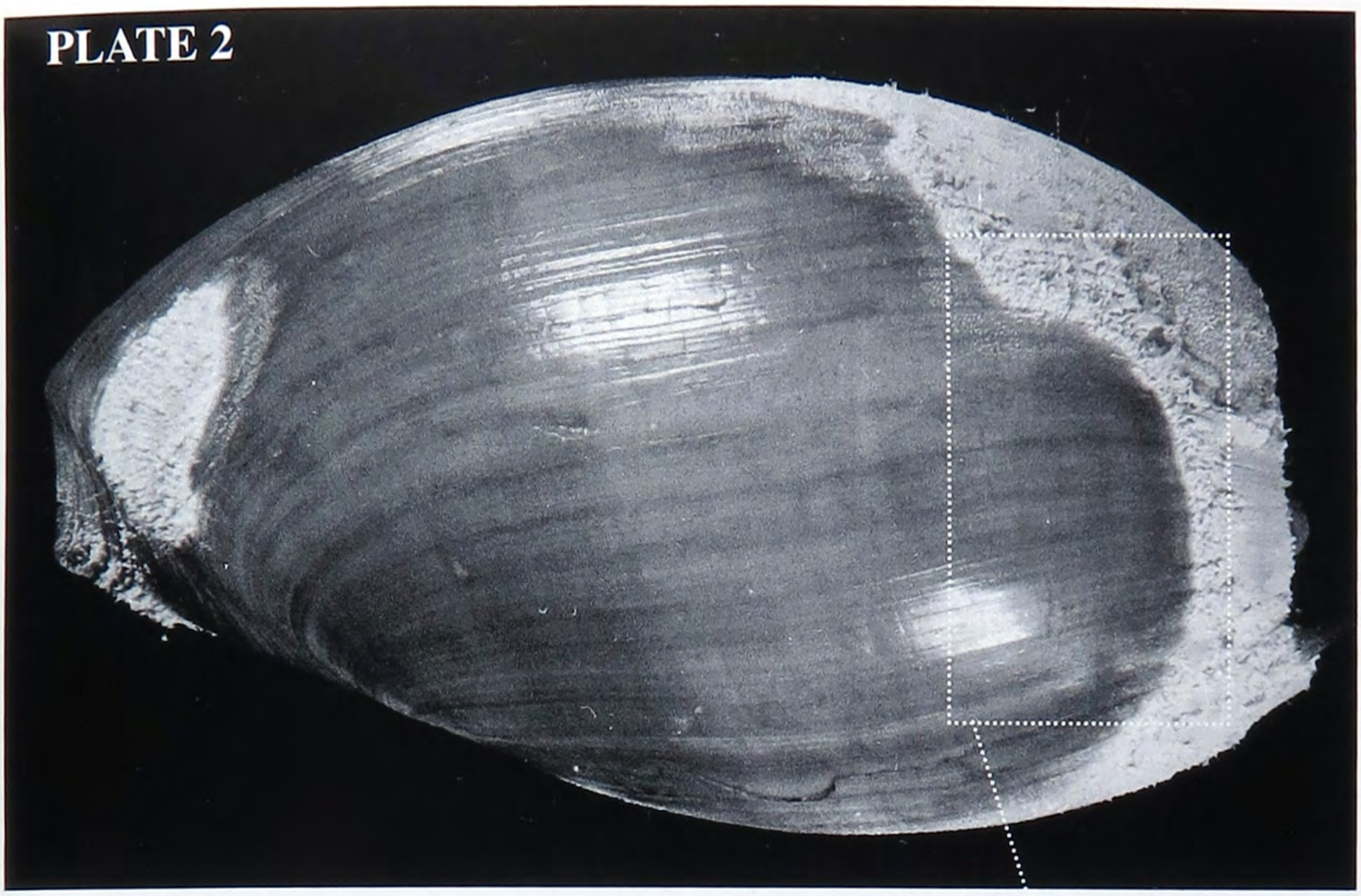


Foto W. Adam 1946

Phalium areola (Linné, 1758)



Detail of the deteriorated area (x15)

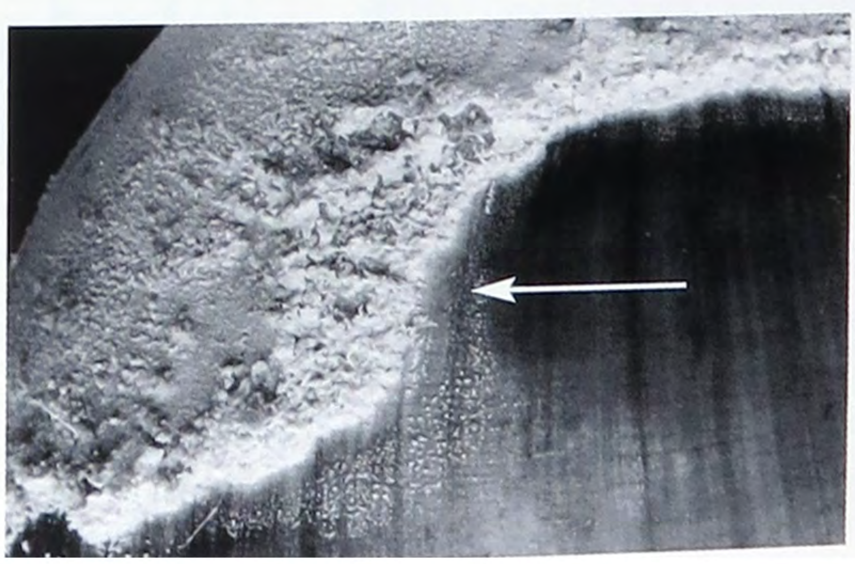


Melo (Melocorona) amphora **(Lightfoot, 1786)** Foto W. Adam 1946 ©KBIN

Detail of the deteriorated area (3/4)

This photo clearly shows the presence of needle-shaped crystals.

Foto W. Adam 1946 ©KBIN



Detail of the deteriorated area (3/4)

The accumulation of ca^{++}salts, caused by acid vapours, renders a strongly thickened white layer on the shell surface.

Foto W. Adam 1946 ©KBIN

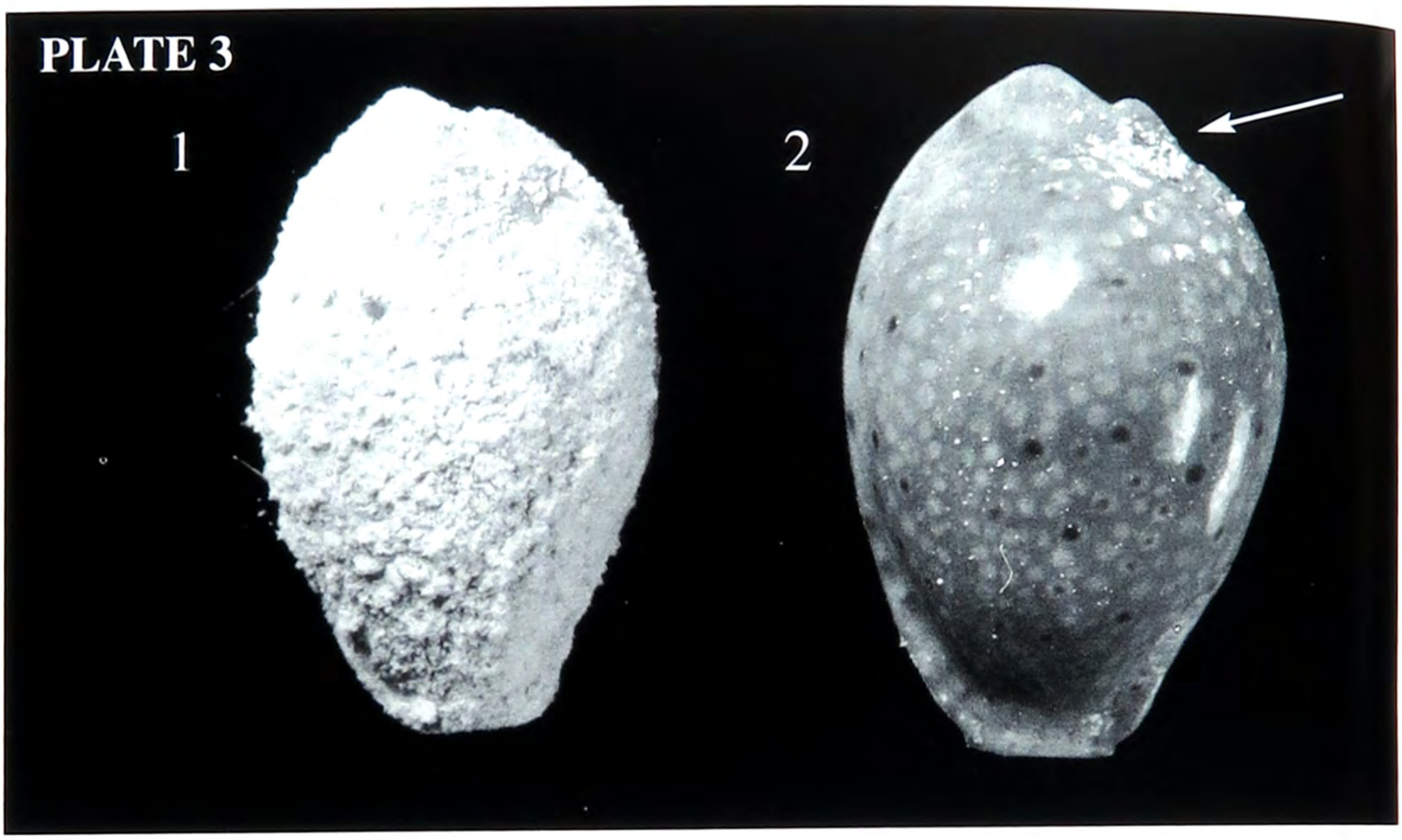


Foto W. Adam 1946 ©KBIN

Cypraea ocellata (Linné, 1758)

-Fig 1 clearly shows deterioration covering the entire shell which will completely destroy the glossy layer.
-Fig 2 only shows a minor form of deterioration.

Foto W. Adam 1946 ©KBIN

Detail of the deteriorated area (x15)
This detail clearly shows a granular kind of deterioration on the shell surface.

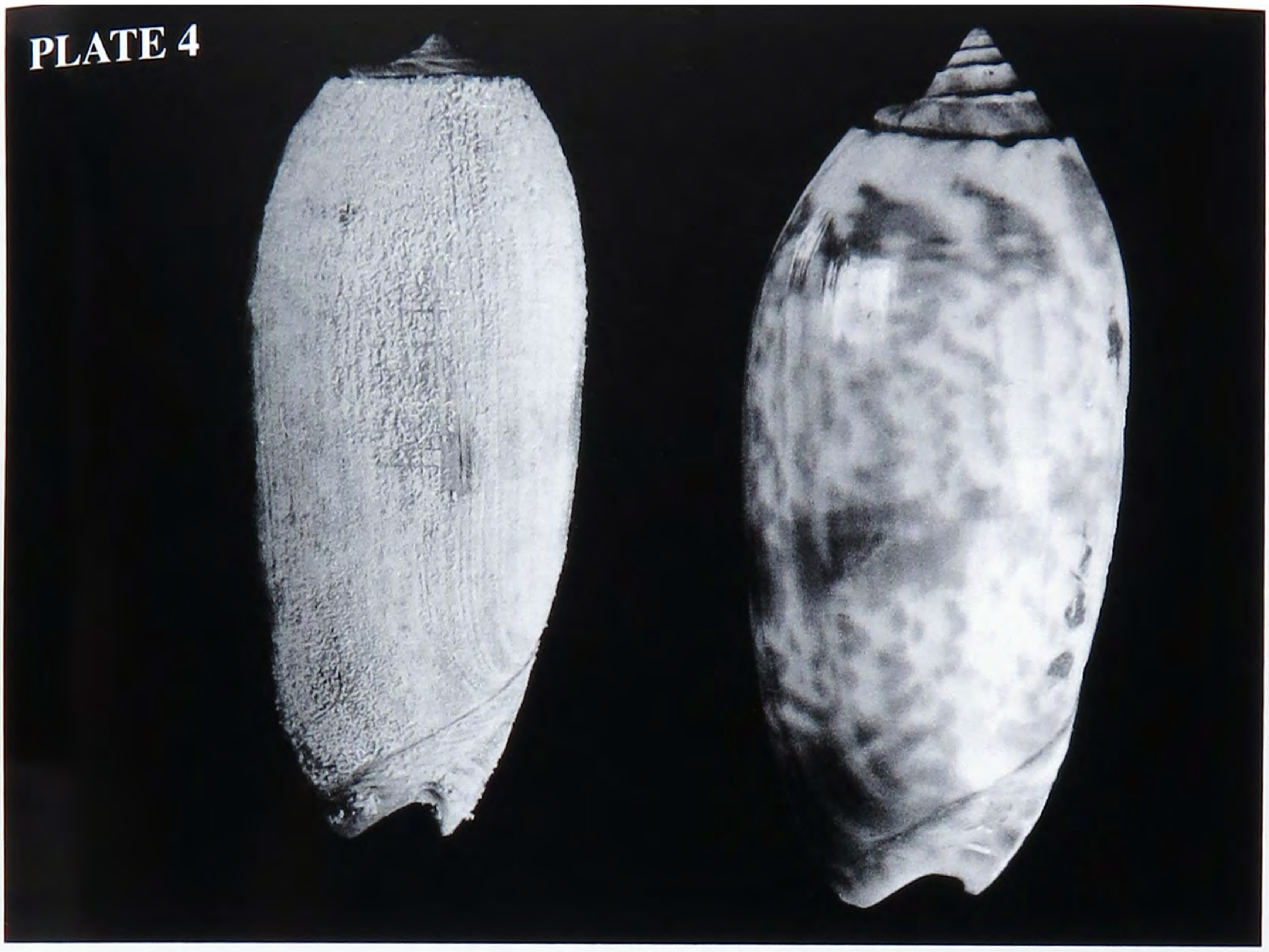
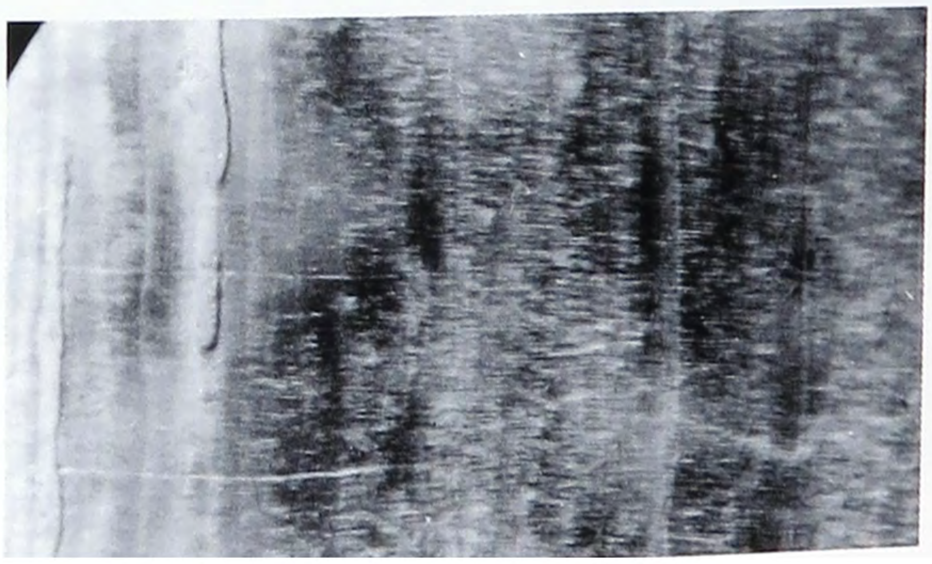


Foto W. Adam 1946 ©KBIN

Oliva miniacea **(Röding, 1798)**

Detail of the deteriorated area with clearly visible granular salt crystals (x15)

Foto W. Adam 1946 ©KBIN



Same area, but after cleaning and removal of the deterioration. The glossy shell surface now shows permanent signs of damage. (x15)

Foto W. Adam 1946 ©KBIN

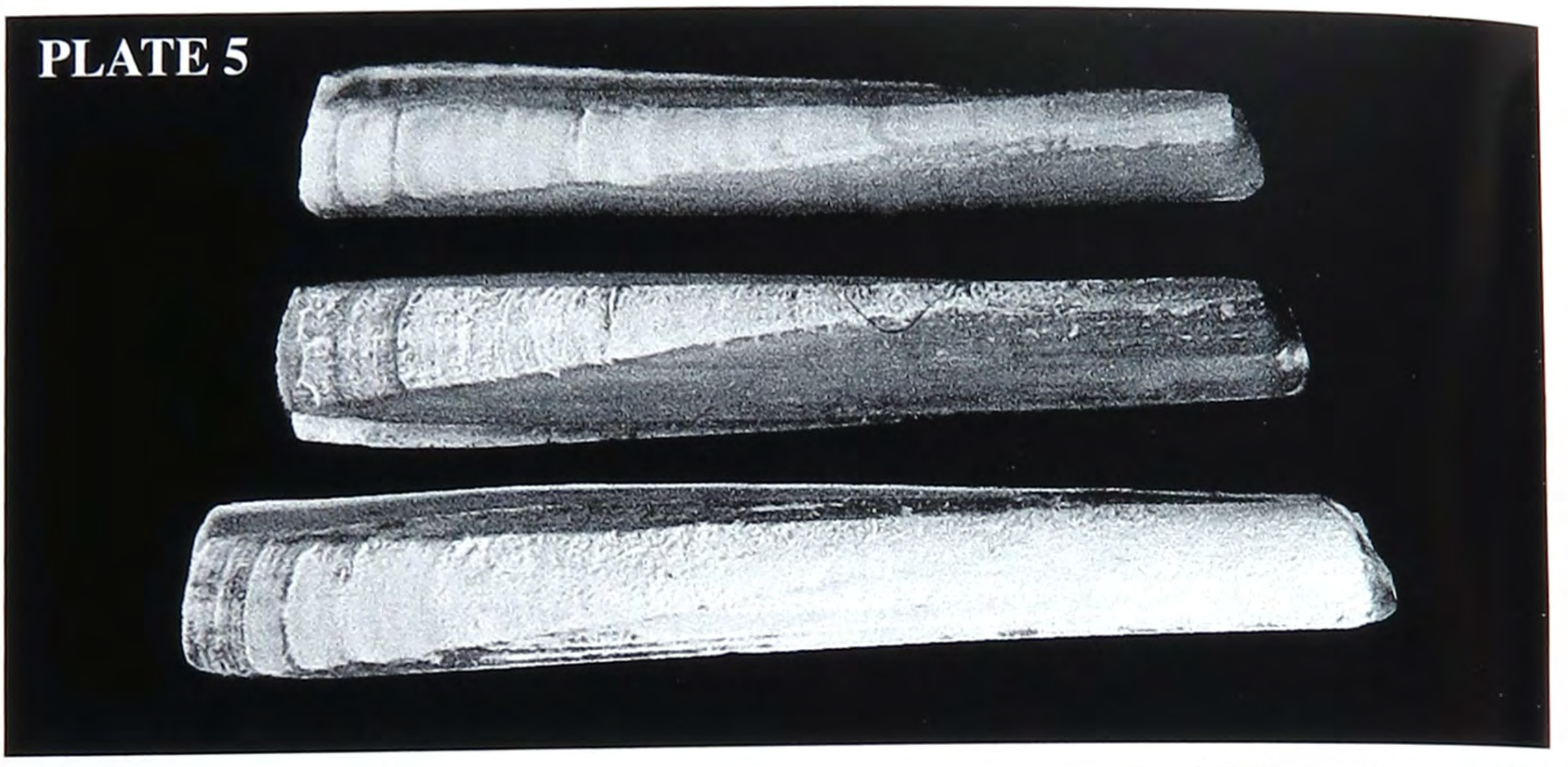


Foto W. Adam 1946 ©KBIN

***Ensis* sp.**

Above: normal specimen without any deterioration

Middle: deterioration of spots that were not covered by the periostracum

Below: completely deteriorated shell

Foto W. Adam 1946 ©KBIN

***Cypraea caputserpentis* (Linné, 1758)**

The specimen on the left shows an abundant white deposit at the edge of the shell and some isolated granules on the dorsum.

***Epialtus dentatus* (Chili)** Foto W. Adam 1946 ©KBIN

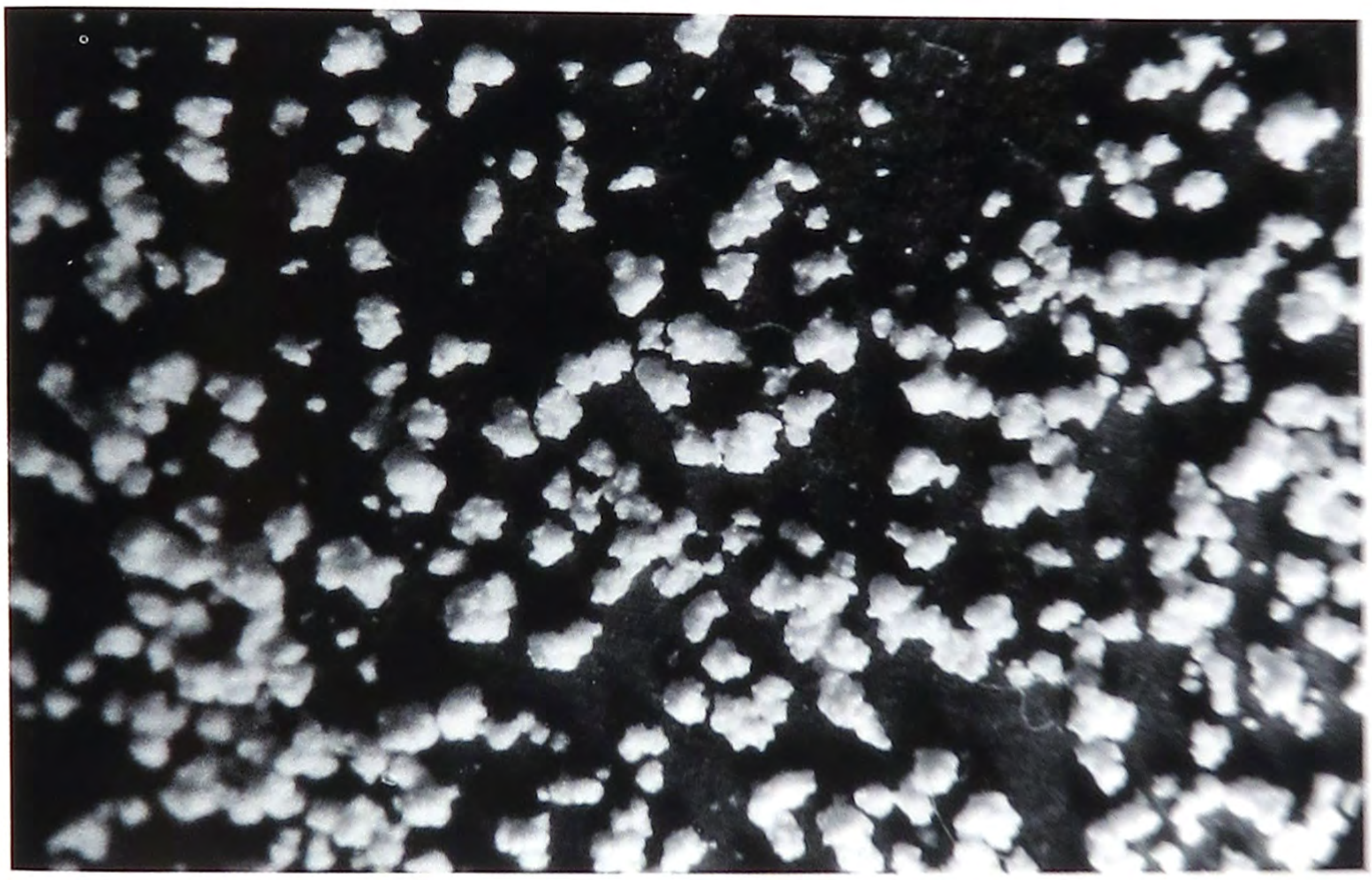


Foto W. Adam 1946 ©KBIN

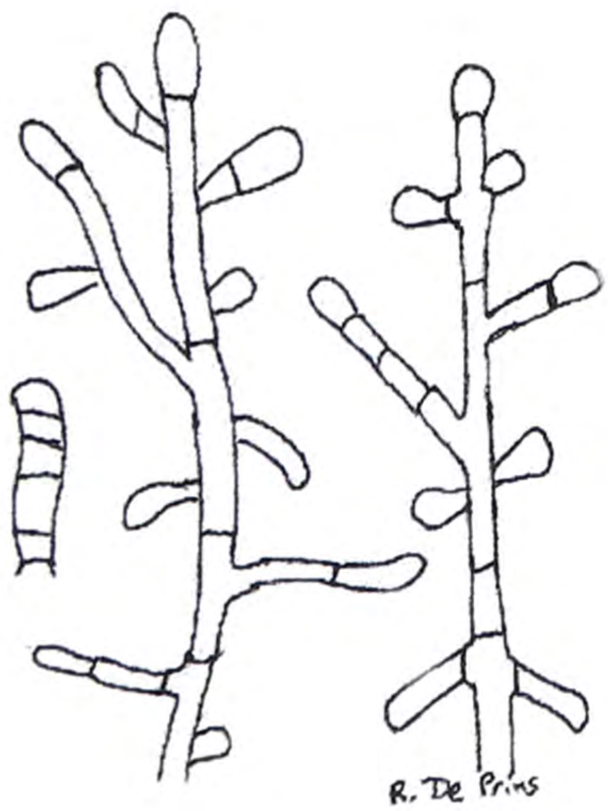
Detail of the deteriorated area (x15)

Not only shells, but also other natural objects containing calcium carbonate $CaCO_3$ can become deteriorated (e.g. Crustaceans, corals, eggs)

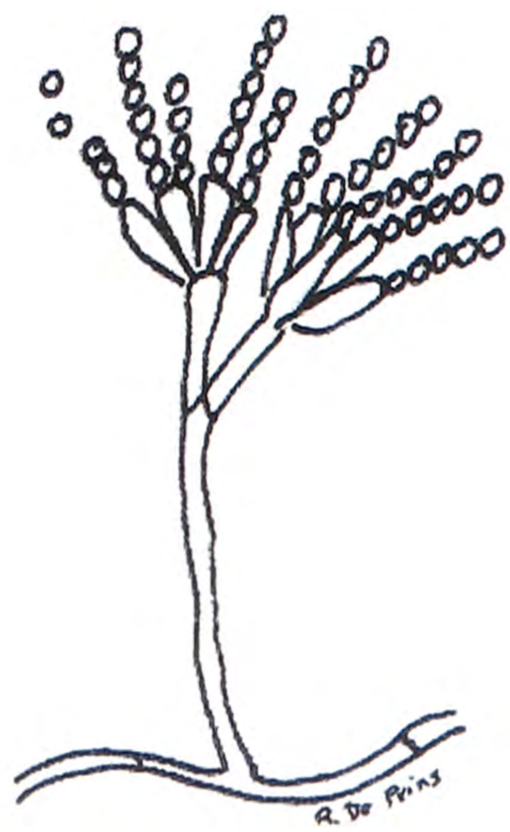
3.2 DETERIORATION CAUSED BY FUNGI

- The morphological characters of fungi are dependent on the species. They are mostly **threadlike** and often recognisable as a **greyish white fuzzy layer**. The **tracekeepers** are often visible to the naked eye as **black dots**. They can survive in an inactive state for years.

Left: microscopic photo of an Aspergillus, clearly showing the conidia (black dots).
Right: schematic representation



schematic representation of a Trichiphyton, a fungus that can be found on the shell surface.



schematic representation of a Penicillium, a fungus that is often present.as a contaminant on the organic parts of the shell

- They can **most often be found on the organic part** of the shell such as the **operculum and periostracum**, but can just as well be present on the shell itself.

- The presence of **needle-shaped crystals** (calcium oxalate) on the shell itself is possibly a sign of deterioration by species of fungi that produce oxalic acid, but checking the crystals for oxalates is necesarry. However, this requires some chemical know-how.

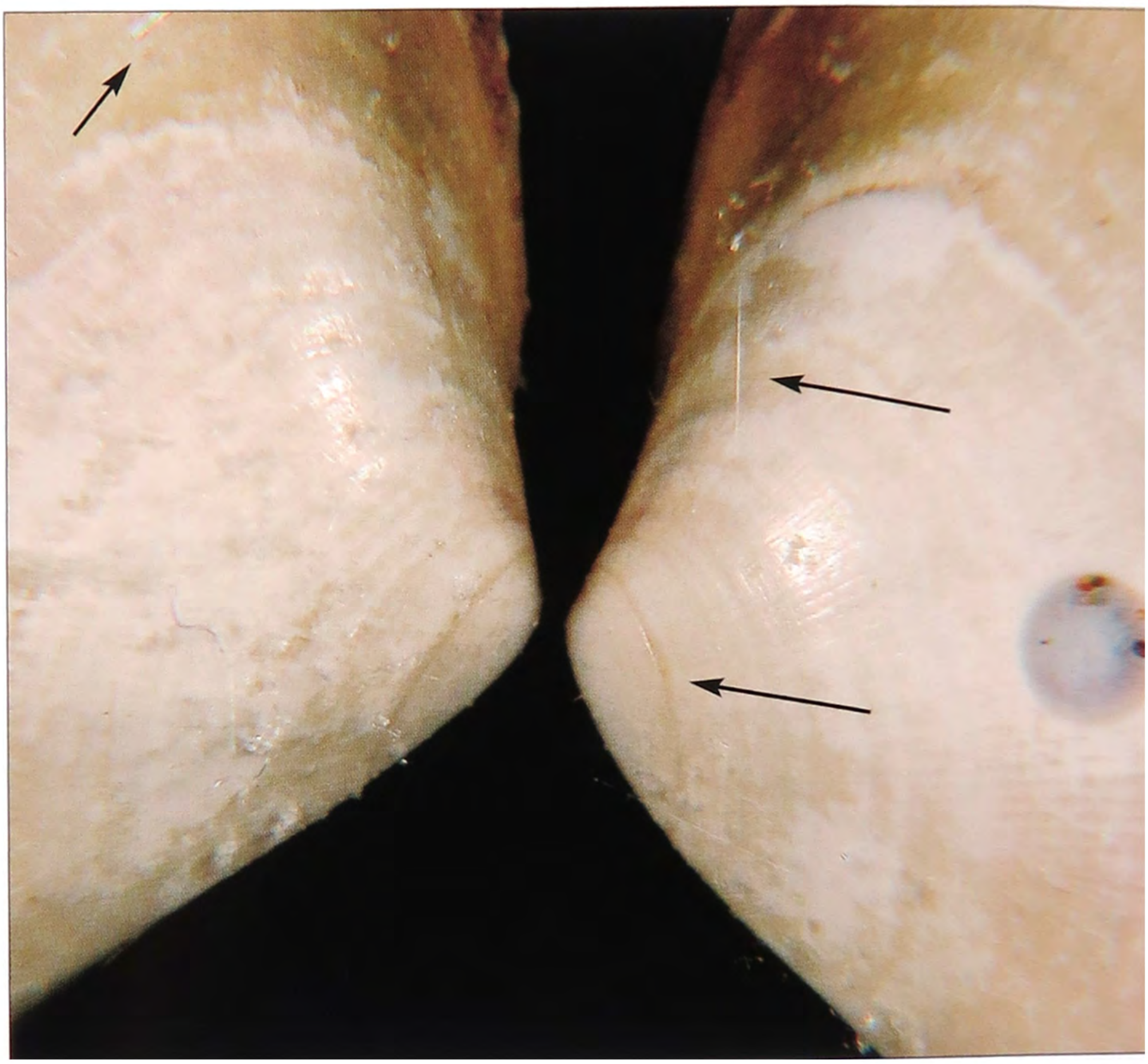


Foto W. Adam 1946 ©KBIN

Zonites algirus **(Vellefranch, 1934)**

Most of the shell surface is covered with needle-shaped crystals. I suppose we are faced with a deterioration caused by fungi and that the needles consist of calcium-oxalate. Unfortunately, further surveys on this specimen are no longer possible as the deterioration dates back from the mid-20th century.

Foto W. Adam 1946 ©KBIN

Detail of the crystal's structure

This photo clearly shows the rising needles, which are of considerable size.

3.3 DETERIORATION CAUSED BY INSECTS

- **Small holes and traces of devouring** are clearly visible on the operculum and periostracum.

- **Brown powder in and around the aperture** indicates the activity and presence of the larvae of small beetles such as the museum beetle. The brown powder is only the desintegration of animal remains that remained in the higher whorls because of uncareful cleaning.

coll. R. De Prins

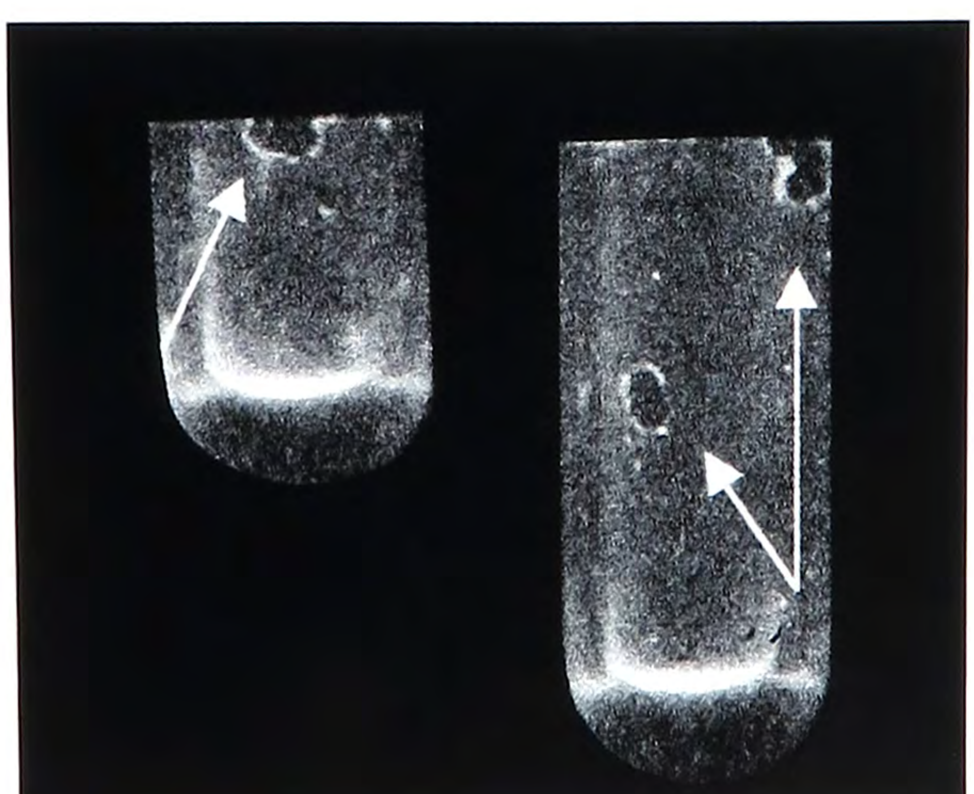
The larvae of Dermestidae have been feasting on the animal remains in the shell.

- **Dead beetles and sloughings of larvae** in the neighbourhood of the shell.

coll. R. De Prins

- Damage done to labels, cardboard boxes etc. can be recognised through all kinds of **traces of devouring.**

- Deterioration of capsules is also possible.



coll. R. De Prins

Larvae of the carpet beetle have chewed through the wall of the capsule. However, it is not clear whether the larvae was already present in the capsule (introduced together with the shell) or that it managed to intrude the capsule from the outside.

4. HOW DO I TREAT MY DETERIORATED SHELLS?

It is not because a collection shows traces of deterioration that there is a reason to panic! A few treatments are often sufficient to give the shells their fresh appearance back and most shells can be returned to the collection without any noticeable damage to the specimen. Yet, when the deterioration has persistently been present, been present for a long time or the glossy layer has disappeared and the shell has turned dull, it might regrettably be lost forever. As a matter of fact, it happens quite some times that shells in big collections or in musea stay untouched in cabinets and cellars for a long time and therefore regrettably do not stand the test of time.

4.1 DETERIORATION CAUSED BY AN ACID ENVIRONMENT

1. Deteriorated shells can simply be washed in lukewarm fresh water which dissolves the salts. Persistent cases can best be left in the water for 24 hours in order to allow a sufficient desintegration of the crystals.

2. Allow enough time for the rinsed shells to dry before re-entering them in the collection (also internally!)

3. The carefully cleaned and dried shell can be oiled to return its fresh appearance. Be careful that you use the correct kind of oil (see additional iformation 7.1 oils)

4. Very seriously damaged specimens can best be removed from the collection. They have usually become both esthetically and scientifically useless.

4.2 DETERIORATION CAUSED BY FUNGI

1. **With very limited and local moulds**, touching with alcohol is often sufficient. This can best be done with a soft brush.

2. **With larger deteriorations**, it is best to wash the shells in lukewarm water to which an non-corrosive antiseptic product has been added.

3 **With very serious deteriorations**, an emergency measure is necessary! This can be done by fumigating the entire room with a broad-spectred antimycoticum, such as the "Clinafarm smoke Candle". This is a candle that has to be placed on a fireproof surface (e.g. stone). After lighting the candle, it only burns for some 20 seconds, but it causes an enormous smoke production that spreads throughout the entire room. Keep in mind that cupboards and drawers must be opened! It is important to seal both doors and windows hermitically and to warn the neighbours as you otherwise risk an unexpected and unwanted visit by the fire brigade. The working in takes about 6 hours and the only disadvantage is the fine layer of dust that is left behind. This can easily be removed from the cupboards, but asks a lot of work for the shells. The collection is now free of all fungi!

4.3 DETERIORATION CAUSED BY INSECTS

- The brown powder in the aperture can simply be shaken out or wiped away.

- When not faced with a real plague of insects, it is best to take no action at all. A single beetle larva can of course cause some damage, but it can also eat some remaining soft parts of the molluscs in places we can hardly reach and therefore prove to be somewhat 'useful'. As it is only a single representant, there will be no further generations and the problem will solve itself.

- If bigger damage to periostracum, operculum and neighbourhood arises, one can take action by using insecticides, e.g. dichloorvos. You had better not use mothballs (paradichloorbenzene), phenol, and other benzene compounds as they are all carcinogenic and thus not good for our health!

- When faced with plagues of silverfish, book lice and dust mites, it is no use fighting the animals, but better to solve the humidity problem. When the humidity is sufficiently low, these animals will automically be destroyed or reduced to normal amounts. Find comfort in the thought that every normal house is host to thousands of small insects that live together with you in the living room, the kitchen, the bathroom and even in your bed day by day!

5. PRECAUTIONARY MEASURES

In order to limit the risks of deterioration, it is useful to take certain precautionary measures. A few small, cheap adjustments are often sufficient to save a collection from all kinds of trouble. If you take the items mentioned below into account, you will surely be saved from a lot of problems.

- **Remove all animal remains. Do not put any cottons in the shell that have been drenched in formaldehyde** in order to harden the remaining soft parts. You can possibly use a self-created mini high-pressure water spray to remove the remains with some power. One can also cook species that are suitable for this process (no Cypraeidae!). Freezing also renders good results. With live-collected microshells it is often impossible to remove the animal without damaging the shell and it is therefore best to put them in alcohol 70% for a few days and leave them to dry sufficiently afterwards

- Allow the shells to **desalinate for a sufficient time** in order to remove salty remains. One can leave the shells in fresh water for a few days, but should not forget to change the water regularly in order to remove the salts that have been dissolved. Do not forget to rinse and desalinate grit: microshells are very sensitive to salty remains because of their fragile structure.

- **Rinse, wash and clean the shells thorouhgly** in order to remove loose animal and vegetable remains. If one wishes to keep shells in their natural condition with overgrowth etc., it is best to put them in alcohol 70% first and store them in separate boxes or bags after drying them. If a problem should pop up later on (e.g. mildew), it will be easier to isolate them and prevent contamination with the rest of the collection.

- Make sure that all cleaned shells are **completely dry** before entering them in the collection, also internally! Bivalved shells are often completely dry on the outside, while it still contains water inside. Higher whorls of gastropods are also a place where water often stays behind and in combination with remaining soft animal parts this creates a possibility for the arisal of fungi.

- **Keep shell collections you have bought in quarantine** and thoroughly inspect it. Especially mind fungi.

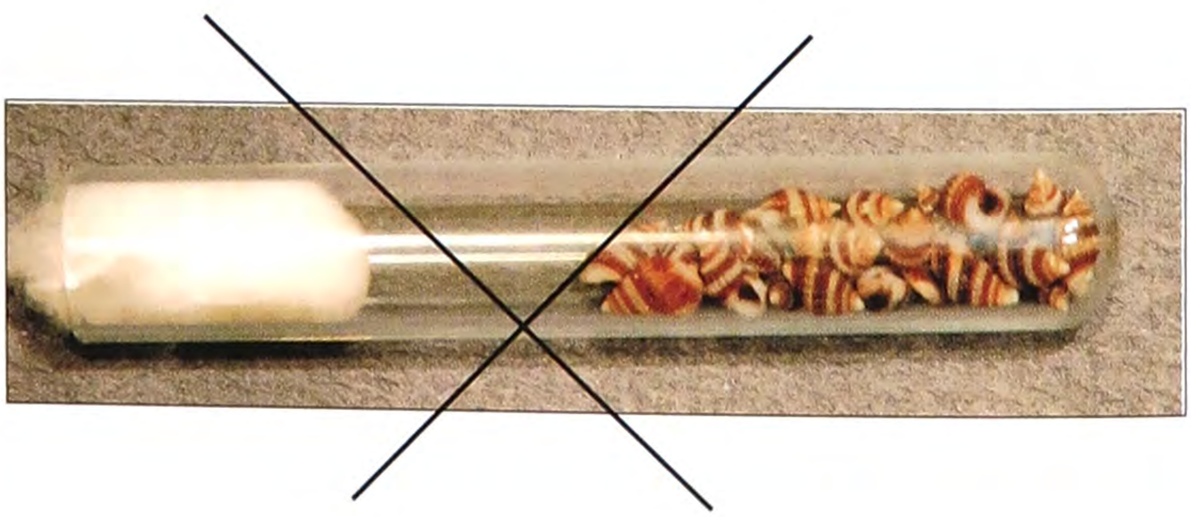
- **Oiling shells** is a possible protection.
  Attention: too much oil attracts dust and bacteria.
  (What kind of oil should be used? See section 7.1)

- **Store shells in closed metal or synthetic cupboards**. Separate packing in **ziplock bags, plastic boxes**, etc is another possibility. (see section 7.3 for plastic)

- **Try to avoid acid kinds of wood and board material with a high formaldehyde release**! Whenever these are present, treat the wood with a suitable varnish (see section 7.4).

- **Do not use acid or chlorous paper** for your labels. Most kinds of print papers are safe, as well as most ink cartridges. (Aksing your dealer might be useful.)

- **Do not use natural cottons** in the shell or to close glass tubes.
  (see section 7.2)



IBoth musea and private collectors often use glass tubes sealed with cotton to store microshells..

coll. R. De Prins

Some self-made boxes from an old shell collection (early 20th century). The boxes were made of compressed wood remains (a kind of cardboard) and covered with a glass lid. All materials used may be the cause of deteriorations!

- **Do not use cork plugs** to seal glass tubes. Cork is made of the bark of the cork-oak (Querqus suber) and releases volatile organic acids..

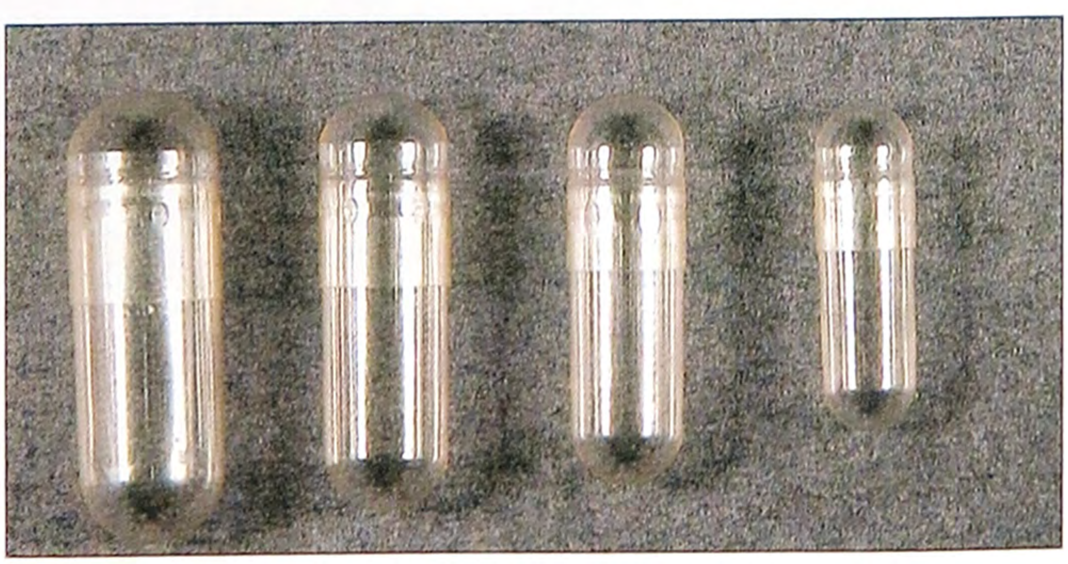
coll. F. Swinnen

All shell that were stored in the tubes and boxes in this picture have been deteriorated. Both cottons and cork are the culprits, but the fungi associated with the cork oak have rendered entire labels illegible.

● **Microshells** can best be put in unused transparent capsules and then stored in small plastic boxes

coll. R. De Prins

coll. R. De Prins



coll. R. De Prins

INFO!

Capsules are made of gelatine and glycerine. The size of capsules is indicated with a number ranging from 5 to 000, 5 being the smallest and 000 the biggest. They are composed in such a way that they dissolve in digestive fluids and thus release the drug they contain. In water with a temperature of 37°C, they should release their content within 2 hours.

To check their reliability when it comes to storing small shells, I decided to do a number of experiments. The first one was a heat test to find out about the highest temperature the capsules could stand. The experiment showed that they are easily able to survive a **dry temperature of 100°C for one hour** without structural changes. Very low temperatures (-20°C) were not a problem, either. A high, low or changing environmental temperature (as often is the case in tropical areas) does not have an immediate negative effect on capsules.

The second experiment focused on the capsules' stability when brought into contact with different fluids.
The results allow for the following conclusions:
Capsules are: **-not dissolvable in cold water**,
yet they swell and become weaker
-dissolvable in hot water
-not dissolvable in alcohol,
yet they become softer without becoming sticky
-**dissolvable in acetic acid.**

These results allow for the conclusion that **cold water is harmless**, but that **volatile acid vapours can have an effect on the capsules**. However, when they are stored in plastic bags or boxes, this risk will be about zero.

As capsules are not dissolvable in alcohol, they might offer the possibility of storing both shell and animal in alcohol. However, it is necessary to make a tiny hole in the capsule and to fill it with alcohol to keep it from floating at the surface. Long-lasting test results are not available yet and maybe it is still too early to consider this way of storage efficient.

Capsules that are kept in a very dry environment for a long time can become fragile. Capsules that are exposed to too much light, will turn yellowish after a certain time.

- **Use copying paper or KOH impregnated filter paper** for the bottom in the drawers as a barrier between the wood and the shells, thus as a protection against acid vapours (see section 7.5)

- **Regularly air drawers and cupboards** to allow the accumulated acid vapours to get out..

- **Cover the floor with a carpet** and protect falling shells from breaking or damage.

- **Protect** the collection room **from direct sunlight** or hang cloths over show-cases (see section 2.6)

- Try to keep the **level of carbon dioxide as low as possible** by airing the collection room regularly, by not smoking and not burning candles in this room. Tobacco smoke contains benzene and folrmaldehyde. It is also best to avoid the presence of an incinerator such as a stove.

- **Ban food and drinks from the collection room.** Especially drinks containing carbonic acid and nutrients with vinegar such as pickles, gherkins, etc. respectively increase the level of carbon dioxide and acetic acid in the environment. Food remains that have been left behind attract a number of harmful insects and increase the possibilities for the arisal of fungi.

- **Keep a wet collection apart from a dry collection.** Leaking organisms preserved in fluid and releases of certain chemical substances such as formalin are always possible. If alcohol is used as a preserving fluid and the number of preparations takes quite an amount, security also plays an important role as explosions are possible when large concentrations of alcohol can be released in the room. Using a cool, dark, secured room with adapted explosion resistant switches and lighting, possibly with an additional smoke detector is no luxury!

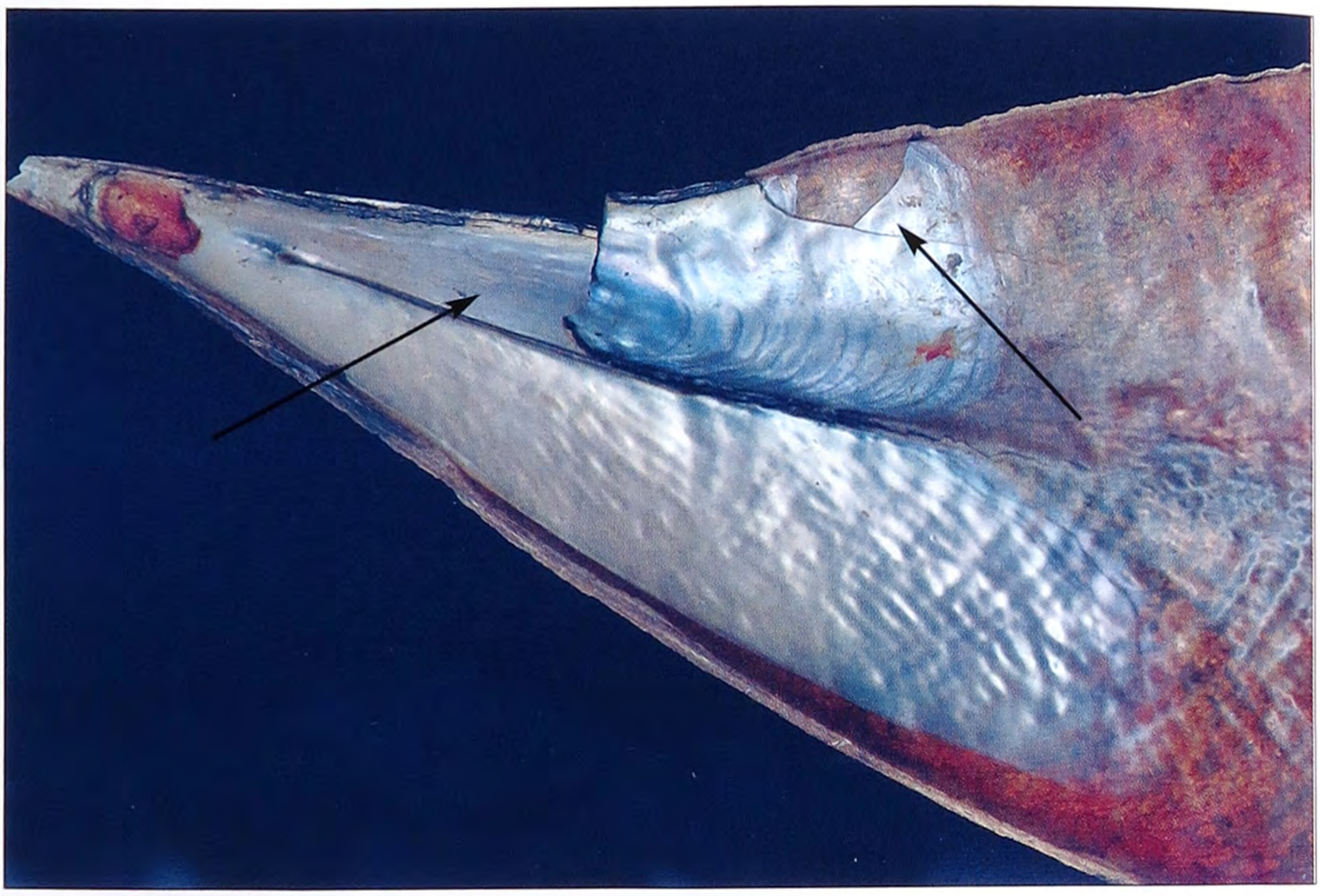
- **Stuffed animals and dried marine invertebrates** such as crabs, starfish, sea urchins, etc. can best be kept in another room as they have often been treated with formalin.

- **Regularly check the atmospheric humidity.** Placing a hygrometer is a possibility to trace increases sooner. This need not be expensive: even the kind you can buy in the nearby garden centre will do.

6. THE IDEAL CIRCUMSTANCES

Creating an ideal room to store our collection is of course easier when the house or building around it still has to be built. The collection room or museum room can then be chosen and organized as we please. It is possible to take the choice of construction materials for the room, showcases and cupboard as well as the lighting, ventilation, and other precautionary measures fully into account. An existing building usually does not offer an ideally situated room and alterations are often necessary to reach the ideal circumstances to store the collection optimally.

A problem that often pops up is moisture. Bad insulation, single glazing and a single wall only add to the problem. **Thoroughly airing is the only solution! One can also install a ventilator in the window which sucks the air out of the room. The advantage is that acid vapours are likewise being removed**, thus not allowing for high concentrations to accumulate. This ventilator can be controlled by a timer, which makes manual control superfluous and which also allows for airing during your holidays. **Airing too often** also has **negative effects** because it allows dust to come into the room and dust also has disadvantages.
Humidity problems in corners or cupboards can easily be **solved with an absorbent**. These can be purchased in every DIY-centre. I myself use platic pots filled with calcium chloride grains (the substance used in absorbents) that I put in every cupboard. The calcium chloride is very hygroscopic and when the grains have done their job, one can simply throw away the absorbed fluid and fill the pot with new grains. One can also use silica gel, but the costs are considerably higher.
The ideal relative humidity is 55 to 65%. Higher than 65% creates an increased risk for the creation of fungi. A constant **temperature of 19°C to 21°C** all year long is ideal, but often not maintainable, especially in tropical and subtrapical regions. **Big temperature changes** can be **disastrous** for certain shells. Dryness can even cause certain shells to burst or even fall apart. When it is too dry, the natural amount of humidity present in the shell will disappear, causing the shell to become duller. Oiling refills the pores and brings the shell back to its fresh appearance.



coll. R. De Prins

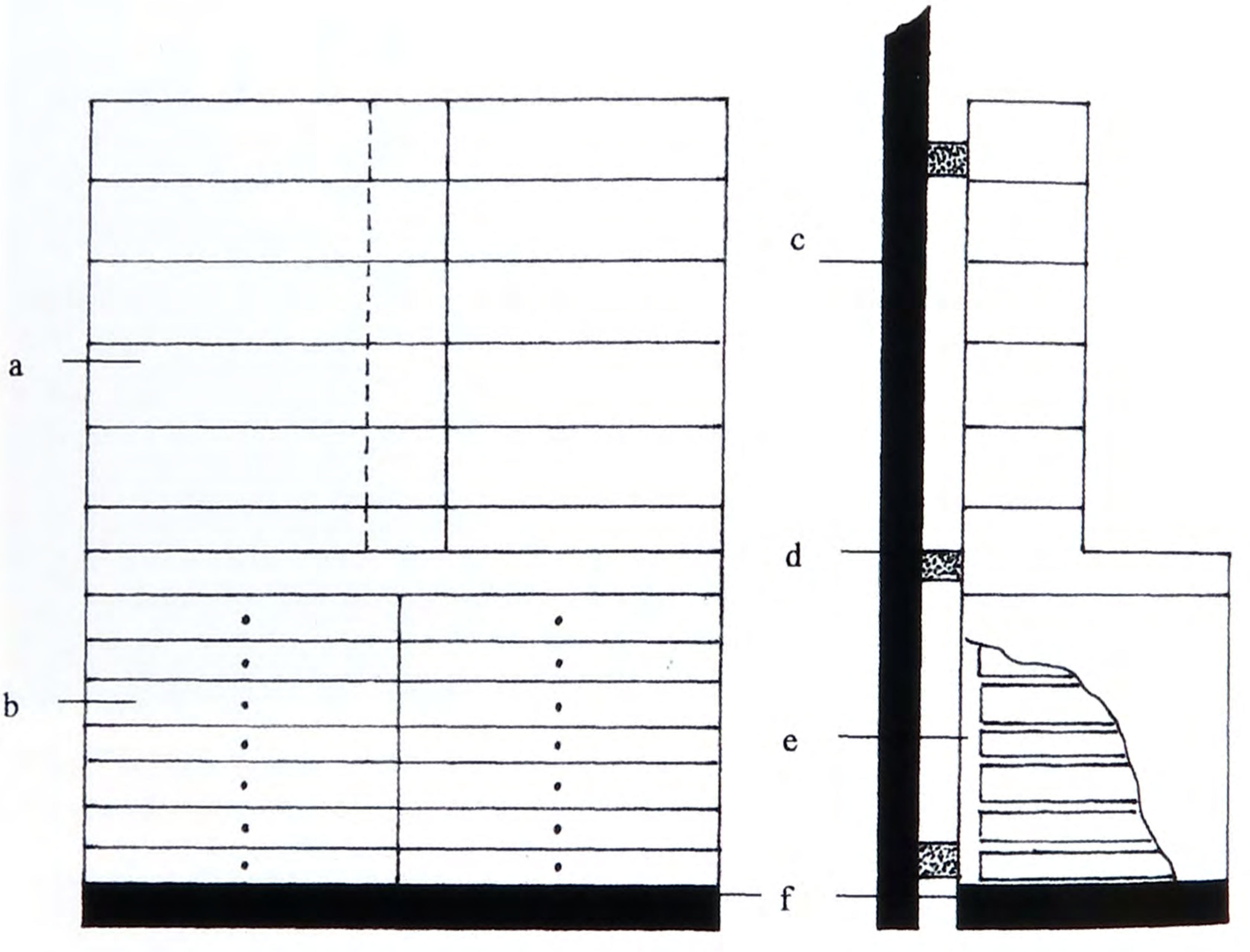
Pinna nobilis Linné, 1758
This shell shows bursts caused by a very dry environment.

coll. R. De Prins

Remains of the prismatic layer of a Pinna nobilis Linné, 1758 that had been so strongly distended, that it literally exploded..

If you have your cupboards made or make them yourself, keep in mind that you have to choose **kinds of wood that release as few acid vapours as possible** (see section 2.1.3). **Treat** the wood **with a proper varnish** (see section 7.4) and keep in mind that **air circulation in and behind the cupboard** must be possible. **Put cupboards** therefore never completely against a wall and definitely **not against an outer wall** because the outer- and inner temperature can differ considerably. In the following drawing, one can see an example of a traditional shell cabinet with showcase (a) and drawers (b) below. By putting slats (d) on the back, one avoids the cupboard being completely put against the wall (c). This allows for air circulation behind the cupboard and as a consequence avoids the accumulation of moisture. The drawers themselves better do not take the full length of the cupboard. This leaves space for air circulation in the cupboard itself (e). One can also add an extra grid in the upper or lower board of the chest of drawers and perforate the back board. It is best to use iron or synthetic conductor. Wooden conductors quickly wear off the varnish layer, which causes the release of acid vapours on those spots. Also provide a small pedestal for the cupboard (f), so as to form a barrier between the colder floor and the bottom of the cupboard. If the collection room is on the goundfloor, it also provides a protection against floods.

Scheme of a classical shell cabinet with drawers and showcase



Make sure that cupboards and drawers are closed when you are not working in the room. This prevents direct sunlight and dust falling in the drawers.

Make sure there is no way for direct sunlight to come in. Blinding or putting filters in front of the windows and over bulbs is recommended. Furthermore, covering the floor (especially in private collections and workrooms) with a non-poisonous synthetic carpet as a protection in case shells should fall is useful.

7. ADDITIONAL INFORMATION

This part is meant to provide the reader with extra information about materials and products that have been mentioned in previous sections. Literature often refers to chemical products and other materials, but the reader is often unaware of what the author is referring to. For instance, one can find almost everywhere that mineral oil shoud be used to oil shells, but what in fact is mineral oil? I advised not to use natural cottons in the chapter “precautionary measures”, but how can they be recognised and distinguished from other synthetic or mixed cottons? Moreover, what you read on the packing is not always what you are buying! To give but one example: a friendly malacologist had already been using expensive ‘genuine black sheep’s wool’ imported from England for years. He used this wool as a contrastive bottom in plastic boxes and glass tubes with microshells. After a thorough survey, I found that it was no sheep’s wool at all, but that he had been buying dyed cotton wool all the time! In the section about cottons, I will show the reader how to distinguish different kinds of fibres and how to find out that what have bought really is what you is being claimed it is. Furthermore, you will be shown how to distinguish different kinds of plastic and which can be used and which cannot and what varnish should be used to treat acid kinds of wood. We will also deal with protection through sorbents and a number of identification tests.

I hope that this additional information will offer a solution to the many unanswered questions for readers who do not possess an elaborated chemical background.

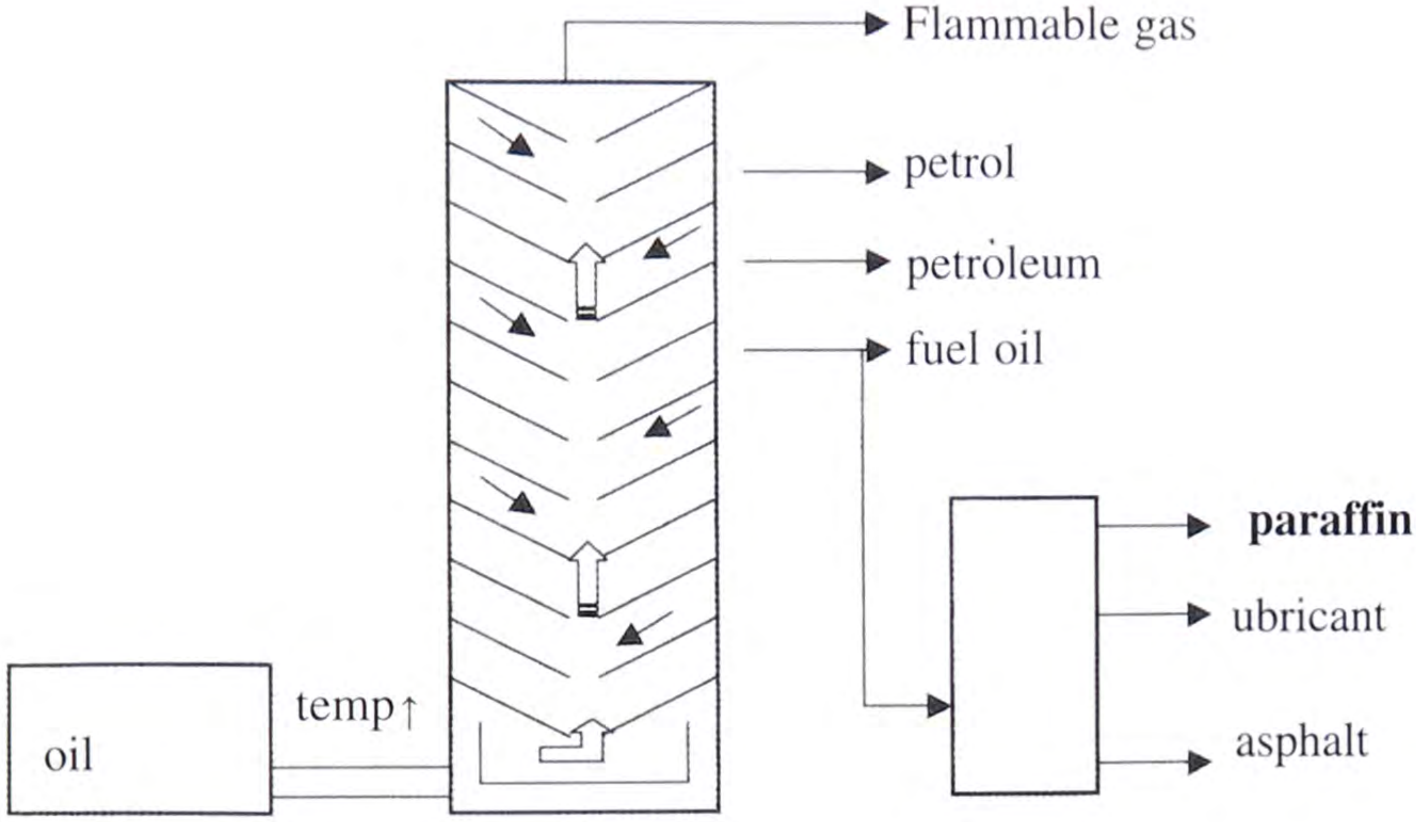
7.1. OILS

Collectors often ask me what kind of oil they should use to give their shells a fresh and shiny appearance again. They have all heard or read somewhere that one should only use mineral oil, but the reason why was not always clear, let alone how to find out whether a particular oil has a vegetable, animal or mineral origin.
In this chapter, I try to show the differences in an easy way, to answer the question 'why use mineral oil' and to name a few kinds of oil.

7.1.1. MINERAL OILS (not dissolvable in water)

Mineral oils are hydrocarbon compounds and therefore only contain two elements, namely carbon and hydrogen. The number of atoms in their molecule determines whether the hydrocarbons occur in a gassy, fluid or solid state. Molecules with few atoms are gassy, the ones with many atoms fluid or solid hydrocarbons. **They cannot be dissolved in water.** Mineral oil is produced by distilling crude oil in an oil refinery where crude oil is heated and the vapours are lead through a fractionated distillation column. In this column, the vapours are split into parts (or fractions). The ligthest fractions at the top (gas and petrol), followed by petroleum and fuel oil, which is further split into paraffin, lubricant and asphalt as a byproduct. Oil can also be produced by a destuctive distillation of slate..

Scheme of a fractionated distillation of crude oil.



A FEW KINDS OF MINERAL OIL

*paraffin: -fluid (also exist in a solid form)

*vaselin: -fluid = fluid form of paraffin
-white vaselin = bleached soft paraffin
-yellow vaselin = semi-solid mix

*both paraffin and vaselin are used abundantly in pharmacy and cosmetics.

7.1.2. NATURAL OILS (dissolvable in water)

Natural oils come from vegetable and animal fats. Most vegetable fats are fluid oils present in seeds and fruits. Animal fats usually have a solid form (at room temperature). Both vegetable and animal fats are esters, i.e. compounds of fatty acids and glycerol. Natural oils and fats can disintegrate after a certain time and become rancid. Other can turn colour under the influence of sunlight and become darker. This is the case in a.o. linseed oil, that used to be commonly used. This oil becomes yellower and darker after a certain time which makes the shell lose its natural appearance.

A FEW KINDS OF NATURAL OILS

*<u>vegetable</u>: almond oil, corn oil, soya bean oil, olive oil, linseed oil, etc.

*<u>animal</u>: butter, lanoline (wool fat), cod-liver oil, lard, etc.

*These oils are a.o. used in food, soap, candles, paint, etc.

7.1.3. GLYCERINE

Glycerine (glycerol) is a colourless viscose fluid that quite feels like oil. It can be obtained from vegetable oil, from the technical production of soaping fats or from petroleum. It is a polyalcohol that contains 3-OH groups in every molecule. Glycerol is hygroscopic and is therefore abundantly used in cosmetics. Its main function is the protecting the skin from drying out or from the product itself. Because of its strongly hygroscopic character, it is not really fit for our shells.

7.1.4. SILICONES

Silicones are chemical product and as a consequence do not occur in nature. It is very complex oxide polymers of silicon and occur in different shapes. Some quite look like oil, oil look more like putty. Their uses are multi-purpose.
According to my assessments, silicones do not have any negative influences on shells. As an oil, I consider its viscosity too thin which means that it is absorbed way too rapidly (especially with porous materials) and as a consequence increases the quantity needed. I use transparent putty (for a.o. aquarium) to glue loose valves of a bivalved shell together in the hinges. The advantage is that the silicone glue stays elastic after drying, which makes it possibly to study the inside at all times, something that is no longer possible with other glues such as patex, etc.

7.1.5. WHAT OILS ARE BEST FOR SHELLS?

No doubt about it: **mineral oils!**

Why? –They do not dissolve in water
-There is no further desintegration (becoming rancid)
-They are temperature change resistant

Why no vegetable oils?

-They are degradable
-They absorb water, including acid moisture
-They are an ideal breeding ground for bacteria and fungi

7.2. COTTONS

Cotton is often used as a basis to glue the operculum, as a plug for small glass tubes with microshells or as a bottom to protect fragile species. However, their use is not without certain dangers, especially when cottons of a natural origin are being used. Cottons can consist of natural, synthetic or mixed fibres. This chapter shows how to recognise the fibres and as a consequence find out the origin of the cottons used at home.

7.2.1. NATURAL FIBRES

a) vegetable fibres

from plants e.g.cotton wool (from the cotton plant)
linen (flax)

Vegetable fibres consist of **cellulose.**

b) animal fibres

from animals e.g. wool (sheep)
silk (silkworm)

Animal fibres consist of **albumines**.

7.2.2. ARTIFICIAL FIBRES

a) Viscose (Syntethic silk)

Bleached new fibres of regenerated cellulose, made according to the rayon procedure.

synthetic fibres

Charcoal and petroleum are used for their manufacturing
e.g.: nylon, dracon, orlon

7.2.3. *HOW TO RECOGNIZE THE DIFFERENT FIBRES*

If the label does not mention the kind of cottons you are buying, you can easily identify the kind of fibre by means of the following test and as a consequence find out whether they are harmful for shells or not.
For the visual test a strong magnifying glass or microscope is necessary: magnification 10x or 20x is enough to distinguish the different kinds of fibre.
For the burning test you take a bit of the material you want to identify with a pair of tweezers and hold in the flame of a burning candle. Especially pay attention to the flame, the remaining ashes and the odour during the burning.

a) Visual

Cotton wool **viscose** **cellulose** **synthetic** **wool**

*__cotton wool__ fibres look a bit like DNA. It is twisted, flattened fibres that are easily recognised.

*__Viscose__ consists of flat, lengthwise grooved lines

*__Cellulose__ is easily recognizable by its vegetable appearance

*__synthetic__ fibres can be recognised by a snarl of massive threads that are of the same thickness and appearance.

* __wool__ at first sight looks like synthetic fibres, but differs in having hollow threads that are not of the same thickness.

b) Burning test

KIND	FLAME	SMELL	ASHES
Cotton wool	Quick, yellow	Burning paper	Little, gry
Wool	Slowly smouldering	Burning hair	Black bubbles that are easily crushed
Synthetic	Melts, no flame	Like celery, baked fish	Black bubbles that are not easily crushed

7.2.4. KINDS OF COTTONS

a) **natural cottons**

*Cotton wool cottons

Bleached seeds of the cotton plant. E.g. cotton wads, cotton buds (most kinds of cottons available in shops)

*Cellulose cottons

Consist of thin, vegetable fibres from wood after removal of the parts that do not contain cellulose that have been woven together. E.g. absorbing cottons

Disadvantages for shells

-Strongly absorbent
-Acid vapours are released during the natural desintegration of cellulose.

b) mixed cottons

Consist of 50% cotton wool and 50% viscose e.g. some surgical cottons

Disadvantages for shells

-slightly less absorbent
-desintegration of cellulose still possible

c) synthetic cottons

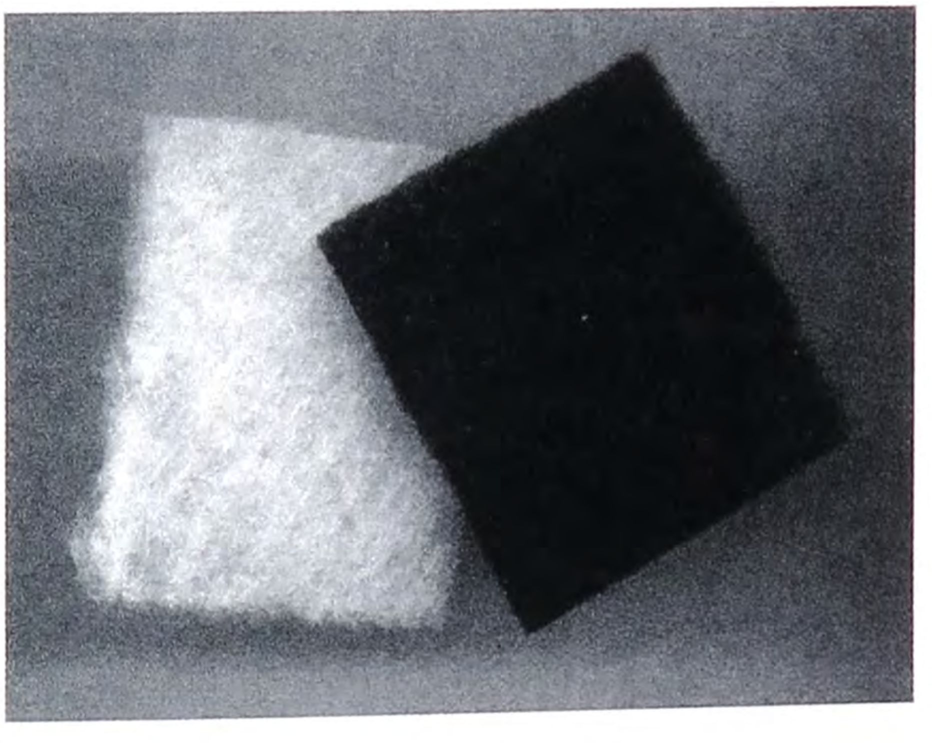
Consist of synthetic fibres (polyester).g. Soffban®, Cellona®

Disadvantages for shells ⟶ NONE!

-not absorbent
-no release of acid vapours
-adjusting function with temperature changes

7.2.5. ALTERNATIVES

An alternative for cottons is filters for cooker hoods or padding for jackets. These are of a synthetic origin and therefore harmless. Only disadvantage is that they are rather stiff. However, they are very useful as a bottom for boxes as they are of a constant thickness and easily cut in strips. There are sometimes even black-coloured, but these are somewhat harder to find. The black filters for cooker hoods contain carbon.
Another possibility to glue the operculum in the aperture is the use of a removable, non-aggressive glue, re-usable adhesive or simply putting it in a separate, numbered plastic bag.



.7.3. PLASTIC

Shells are kept in all kinds of plastic packing materials in order to protect them from dust and damage, to store them individually or because of practical and esthetical reasons. Bags with or without ziplock and boxes in many sizes are to be found in almost every collection, but plastic is not just plastic and some kinds of plastic are not really suitable for our shell collections. What is plastic and what kinds can be used to store shells? Two questions about a complex matter I will try to explain in an easy way.

7.3.1. A SIMPLE EXPLANATION

About a century ago, Leo Backeland, a Belgian-born chemist who later on moved to the United States, mixed phenol and formaldehyde during one of his tests. Other chemists had done this before him and wondered how to get the dirty, sticky stuff that had been formed out of the test tubes. However, Leo Backeland approached the problem from another point of view and asked himself what the use of this brew could be. He started to study it and the result was the first kind of modern plastic: bakelite. In the meantime, hundreds of plastics have been developped and this process is still going on. Their uses are multi-purpose and one can find something made of plastic about everywhere.

Plastic is in fact a collective name for a big number of synthetic macromolecular substances. Plastics are polymers, which means that a vast amount of identical molecules have adhered into macromolecules through a reaction of polymerization.
Plastics can be divided into two groups according to certain characteristics. The one group is the thermo-hardening plastics, the other one the thermoplastic plastics.

a) thermo-hardening plastics

These are monomers connected to each other with atom compounds. They can only be moulded once during the production process and are no longer transformable afterwords. They are used in e.g. television sets, radios, telephones, sockets, etc.

e.g. Bakelite

b) <u>thermoplastic plastics (thermoplasts)</u>

They consist of long molecular chains that are kept together with "vanderwaals" forces and sometimes also hydrogen bonds. In contrast with thermo-hardening plastics, they have a processing point, which means that they can be transformed above this temperature and e.g. woven into threads. They are used for e.g. inflatable balls, boats, boots, hoses, etc.

e.g. polystyrene, polyvinyl

To find out the difference between these two, one can hold a small piece of plastic in a flame (e.g. candle) with a pair of tweezers. Most thermo-hardening plastics do not burn, but release a strong smell. Most thermoplasts do burn, but sometimes extinguish when you take them out of the flame.

7.3.2. A FEW KINDS OF PLASTIC

*__Polyvinyl chloride,__ or PVC is a thermoplast that is a.o. used in the building industry (drainpipes, gutters, ...)

*__Polystyrene__ is one of the most important plastics. It is a thermoplast and a commonly used insulator in the form of boards or foam. Furthermore, it is used to make quite a number of items of everyday use such as boxes, mugs, etc.

*__Polyethene or polyethylene__ likewise belongs to the thermoplasts and is a commonly used plastic. Plastic bags, boxes and wrapping material are only a few of its applications.

*__chlorine ethene or vinylchloride__ is a raw material used to make PVC.

7.3.3. WHAT PLASTICS SHOULD BE AVOIDED?

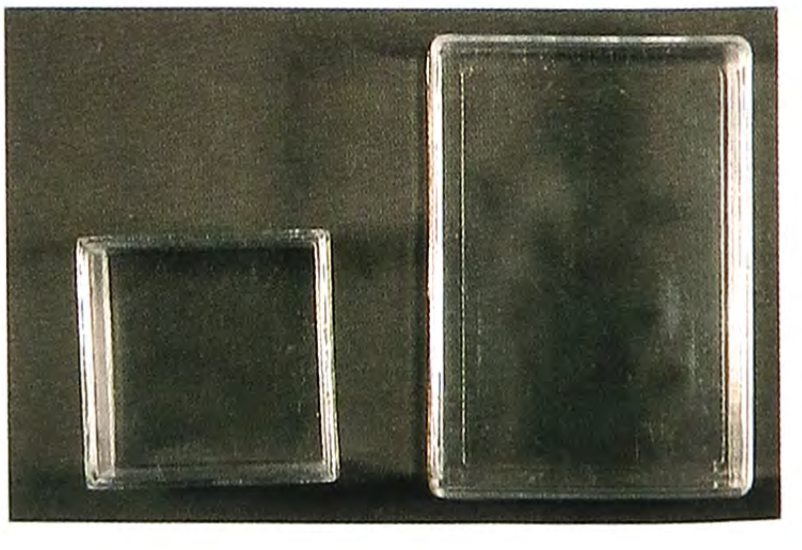
***It is better not to use bags or boxes made of PVC**. This plastic will always release some chloride after some time, which can cause the shells to corrode and fade.

*__Poysterene foam plastic boards__ that are sometimes used as a bottom for boxes and drawers are **not very suitable** as they are instable and possibly release harmful and volatile elements.

7.3.4. WHAT PLASTICS CAN BE USED?

* All kinds of **bags and boxes made of polyethylene plastics are harmless** for the storage of shells. Most small bags collectors use (such as Ziplock and Minigrip) are made of this material and therefore harmless.

* **Polystyrene in solid form** is –as apposed to the foam boards- **stable and harmless**. Many transparent boxes in all sizes are made of this material and do not cause any problems. Micromounts (see photo) mineral collectors often use are also made of polystyrene. I myself use them to store my microshells. They save place, are bright, inexpensive and a nice alternative for glass tubes.



7.4. PAINT AND VARNISH

If shell cabinets are made of wood, it is advisable to treat this wood, even if it belongs to a category with a smaller degree of harmfulness. When you are about to treat the wood in order to limit the release of volatile elements, it is good to think about the kind of paint that can be used.
The common latex paints, based on acrylic, are not suitable as latex does not block organic acids. However, it provides a limited protection from formaldehyde vapours. The common wood varnishes, cellulose varnish, enamel paints and mordants are likewise insufficient: they often provide a waterproof layer, but as they still allow air to come through and thus allow the wood to 'breathe', they are not suitable for this use. The only kind of paint that is really effective and provides a good protection is polyurethane varnish. This varnish is very longwearing and is a.o. used in parquet and to treat the decks of sailing boats.
This varnish can consist of a one or two component basis of which the latter must be well-mixed before use. Applying at least two layers within a certain time is absolutely necessary.
Be careful when buying varnish: varnishes on a basis of alkyd resins are often sold as polyurethane varnishes and polyurethane-acrylic paints are also available, yet none of these are useful to us. Asking your local dealer for advise is advisable.
Do not forget to include the inside, bottom and backside of drawers and cupboards as well as the wooden conductors of the drawers (if present) in the treatment. When used intensively, these conductors will quickly show signs of wear and it is therefore advisable to treat them regularly.

7.5. SORBENTS

The use of sorbents as a protection against acid vapours was already thoroughly examined by Agnes Brokerhof [1]. She examined different kinds of acid sorbents and tested them on egg shells that had been exposed to acetic acid. The tests revealed that white copying paper (Data Copy) and potassium hygroxide (KOH) impregnated filterpaper show very good results. Together with airing the room regularly, this is possibly a good and cheap solution to reduce the accumulated acid vapours.
Moreover, the copying paper or the KOH impregnated filterpaper can be used as a barrier between the wood of the drawers and the shells. The paper's white colour has the advantage that the saturation point can be checked by means of a pH indicator such as Thymol blue ($pH>7,6$ = blue; $pH<6,0$ = yellow) when the paper has lost its alkalic character.

[1] **Brokerhof A., 1998**. "Application of sorbents to protect calcareous materials against acetic acid vapours.' IAP 1998, presentation 10.

7.6. IDENTIFICATION TESTS FOR VOLATILE ORGANIC ACIDS AND FORMALDEHYDE

There are quite a number of tests to trace the presence of volatile organic acids and formaldehyde. The most commonly used test in museums is the Oddy test, which allows for the tracing of a broad spectre of corrosive, volatile organic acids. Its big disadvantage is the rather long waiting period for the results. Other possible tests are the iodide-iodate test and the chromotropic acid test to respectively trace organic acids and formaldehyde.
All these tests aim at a quick detection of volatile corrosive elements.
With exception of the chromotropic acid test, which detects formaldehyde, additional analytic tests are necessary to find out what elements we are really faced with.

Oddy test *(Oddy, 1973)*

Complete corrosion test. It gives an indication value of the presence of volatile corrosive gases such as organic acids from wood, board material, paint, plastic, etc.
The procedure of this test is to imitate the effect of what happens in a museum room or collection cupboard, but much faster.
The test takes place in a closed glass vessel which contains a sample of the substance we want to test (e.g. wood), a leaden test strip , cupper, silver and distilled water. In order to create a hight humidity, this vessel is kept under a temperature of 60°C for 28 days. Because lead is very sensitive to corrosion caused by organic acids and formaldehyde, the result –if positive- can be seen on the leaden strip.

Iodide-Iodate test (*Feigl, 1954*)

This test is based on the reaction of an acid with iodide and iodate ions which creates iodine. When iodine reacts with starch, we can notice is a violet-blue colour.
This test takes place in a closed glass vessel which contains the test material and a reaction solution (KI 2%, KIO_3 4% en 0,1% strach solution). The vessel is then put in a 60°C oven for 30 minutes. If the solution has turned violet blue, the test for volatile organic acids is positive.

Chromotropic Acid test (*West & Sen, 1956*)

This test uses a solution of 1% chromotropic acid (1,8-dihydroxynaphtalene-3,6-disulfonic acid) in concentrated sulfuric acid (97% w/w).
The test takes place in a closed glass vessel in an oven at 60°C. If any formaldehyde is present in the test material, the solution will turn purple.

AFTERWORD

If you should be faced with deterioration in one kind or another, this need not immediately mean the end of an exciting voyage of discovery through the world of molluscs. I hope that this paper will be a useful tool to identify and solve most problems. I have deliberately tried to combine the scientific and the understandable, in order to allow laymen to use the information, too.
As I have already mentioned in the foreword, it is not my aim to be exhaustive and some aspects are indeed in need of further surveys.
As a conclusion, I would like to add that 'the perfect environment' does not exist. It is even remarkable how some objects and shells have been stored in extreme circumstances for years and have managed to persist perfectly without showing serious signs of deterioration. But, if they were transported to our ideal environment, a lot of problems would pop up all of a sudden. If everything is kept within certain boundaries, precautionary measures are taken, adjustments are done once in a while and extreme situations are prevented, I think we are on the way to allow our offspring to enjoy the things that have made our life exciting and beautiful.

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