= Chitinozoan =

Chitinozoa (singular : chitinozoan , plural : chitinozoans) are a taxon of flask @-@ shaped , organic walled marine microfossils produced by an as yet unknown animal . Common from the Ordovician to Devonian periods (i.e. the mid @-@ Paleozoic) , the millimetre @-@ scale organisms are abundant in almost all types of marine sediment across the globe . This wide distribution , and their rapid pace of evolution , makes them valuable biostratigraphic markers .

Their bizarre form has made classification and ecological reconstruction difficult . Since their discovery in 1931 , suggestions of protist , plant , and fungal affinities have all been entertained . The organisms have been better understood as improvements in microscopy facilitated the study of their fine structure , and there is mounting evidence to suggest that they represent either the eggs or juvenile stage of a marine animal .

The ecology of chitinozoa is also open to speculation ; some may have floated in the water column , where others may have attached themselves to other organisms . Most species were particular about their living conditions , and tend to be most common in specific paleoenvironments . Their abundance also varied with the seasons .

= = Appearance = =

Chitinozoa range in length from around 50 to 2000 micrometres . They appear dark to almost opaque when viewed under an optical microscope . External ornamentation is often preserved on the surface of the fossils , in the form of hairs , loops or protrusions , which are sometimes as large as the chamber itself . The range and complexity of ornament increased with time , against a backdrop of decreasing organism size . The earliest Ordovician species were large and smooth @-@ walled ; by the mid @-@ Ordovician a large and expanding variety of ornament , and of hollow appendages , was evident . While shorter appendages are generally solid , larger protrusions tend to be hollow , with some of the largest displaying a spongy internal structure . However , even hollow appendages leave no mark on the inner wall of the organisms : this may suggest that they were secreted or attached from the outside . There is some debate about the number of layers present in the organisms ' walls : up to three layers have been reported , with the internal wall often ornamented ; some specimens only appear to display one . The multitude of walls may indeed reflect the construction of the organism , but could be a result of the preservational process .

" Immature " or juvenile examples of Chitinozoans have not been found ; this may suggest that they didn 't " grow " , that they were moults (unlikely) , or that the fossilisable parts of the organism only formed after the developmental process was complete .

Most chitinozoans are found as isolated fossils , but chains of multiple tests , joined from aperture to base , have been reported from all genera . Very long chains tend to take the form of a spring . Occasionally , clusters or condensed chains are found , packed in an organic " cocoon " .

= = Classification = =

Alfred Eisenack 's original description of the Chitinozoans placed them in three families , spanning seven genera , based on morphological grounds . Further genera were identified , at first on an annual basis , as time progressed . Since its publication in 1931 , Eisenack 's original classification has been much honed by these additional discoveries , as well as advances in microscopy . The advent of the scanning electron microscope in the 1970s allowed the improved detection of surface ornamentation which is hugely important in identification - as can be appreciated by a comparison of the images on this page . Even the light microscope image here is of far greater quality than could have been achieved earlier in the century , using poorly preserved specimens and less advanced microscopes . The original three families proposed by Eisenack represented the best classification possible with available data , based largely on the presence or absence of chains of organisms and the chamber 's shape . The orders were subsequently revised to conform better to Linnean taxonomy , placing related organisms more closely together . This was made possible as scientific

advances permitted the identification of distinctive traits in organisms across Eisenack 's groups . Features of the base and neck , the presence of spines , and perforations or connections are now considered the most useful diagnostic features .

= = Relationships = =

= = = Amoebæ = = =

Alfred Eisenack 's original guess was that the Chitinozoa were of the rhizopod order Testacea , since similar chitin @-@ based tests were produced by the extant members of this group . However , the chemistry of these tests differs from that of the fossils , and modern Testacea are almost exclusively fresh @-@ water - an extremely different environment . Within a year , he had abandoned this initial idea .

= = = Photosynthesisers = = =

Arguments put forwards by Obut (1973) proposed that the organisms were one @-@ celled " plants " similar to the dinoflagellates , which would now be grouped into the chromalveolata . However , as mentioned previously , spines and appendages are attached from the exterior of the vessel : only animals have the cellular machinery necessary to perform such a feat . Further , no analogy for the cocoon envelope can be found in this kingdom .

= = = Young graptolites = = =

The graptolites are colonial organic walled fossils which also occurred from the Ordovician to the Devonian ; only part of their life cycle is known and it is not clear how they reproduced . It has been suggested that the Chitinozoa may represent the pre @-@ sicula stages of graptolites - the period between the colony 's sexual reproduction , and the formation of a new colony . This hypothesis appears to be supported by the co @-@ occurrence of graptolite and chitinozoan fossils , whose abundances appear to mirror one another . The similar chemical composition of the fossils has been seized by both sides of the argument . Proponents suggest that the use of the same chemical framework is an indicator that the two may be related . However , this factor means that situations favouring the preservation of one will also tend to preserve the other - and the preparation techniques used to extract the fossils will also favour or disfavour the two groups equally . Therefore , the apparent co @-@ occurrence of the two fossils may merely be an artifact of their similar composition . The hypothesis struggles to explain the continuing abundance of chitinozoans after the middle Devonian , when graptolites became increasingly rare .

= = = Tintinnids = = =

The cyst forms of a particular group of ciliates , the tintinnids have been suggested to be affiliated to Chitinozoans .

= = = Eggs = = =

The test of the Chitinozoa was fixed - there was no scope for any parts of it to move or rotate . This makes it seem likely that the tests were containers , to protect whatever was inside - whether that was a " hibernating " or encysted organism , or a clutch of hatching eggs . There are several arguments behind an association of the chitinozoans with annelids or gastropods , and it is not impossible that the chitinozoans are a convergent phenomenon laid by both groups . In fact , the spirally coiled nature of chitinozoan chains has been used to suggest that they were laid by a spirally coiled organism , such as the gastropods ; were this inference true , uncoiled chains could

be to be attributed to the (straight) annelid worms or other organisms .

Recent excavations of the Soom Shale , an Ordovician konservat @-@ lagerstätten in South Africa , have yielded chitinozoans alongside a wide range of other organisms . It has been suggested that if whatever organism created the Chitinozoa was fossilisable , it would be present in the Soom biota ? from which gastropods and graptolites are notable in their absence . Most organisms present in the shale can be ruled out for a variety of reasons , but polychaete worms , Promissum conodonts and orthocone cephalopods remain as likely candidates . However , further evidence connecting chitinozoans to any of these groups is circumstantial at best .

= = Ecology = =

It is not immediately clear what mode of life was occupied by these improbably shaped fossils , and an answer only becomes apparent after following several lines of reasoning .

The fossils ' restriction to marine sediments can be taken as sound evidence that the organisms dwelt in the Palæozoic seas - which presents three main modes of life :

Infaunal ? living within the sediment - the " burrowers "

Benthic ? dwelling upon the sea floor , perhaps anchored in place - the " sitters "

Pelagic ? free @-@ floating in the water column - the " drifters "

An infaunal mode of life can be quickly ruled out , as the fossils are sometimes found in alignment with the depositing current ; as nothing attached them to the bottom , they must have fallen from the water column .

The ornament of the chitinozoans may cast light on the question . Whilst in some cases a defensive role - by making the vessel larger , and thus less digestible by would @-@ be predators - seems probable , it is not impossible that the protrusions may have anchored the organisms to the sea floor . However , their low @-@ density construction makes this unlikely : perhaps more plausible is that they acted to attach to other organisms . Longer spines also make the organisms more buoyant , by decreasing their Rayleigh number (i.e. increasing the relative importance of water 's viscosity) ? it is therefore possible that at least the long @-@ spined chitinozoans were planktonic " floaters " . On the other hand , the walls of some chitinozoans were probably too thick and dense to allow them to float .

Whilst little is known about their interactions with other organisms , small holes in the tests of some chitinozoans are evidence that they were hosts to some parasites . Although some forms have been reinterpreted as " pock @-@ marks " caused by the disintegration of the diagenetic mineral pyrite , the clustering of cylindrical holes around the chamber ? where the flesh of the organism was likely to be concentrated ? is evidence for a biological cause .

Corals in Gotland with daily growth markings have been found in association with abundant chitinozoans , which allow the detection of seasonal variation in chitinozoan abundance . A peak in abundance during the late autumn months is observed , with the maxima for different species occurring on different dates . Such a pattern is also observed in modern @-@ day tropical zooplankton . The diversity of living habits is also reflected by the depth of water and distance from the shore . Different species are found in highest abundance at different depths . While deeper waters around 40 km from the shoreline are generally the optimal environment , some species appear to prefer very shallow water . On the whole , chitinozoans are less abundant in turbulent waters or reef environments , implying an aversion to such regimes when alive , if it is not an effect of sedimentary focusing . Chitinozoans also become rarer in shallower water - although the reverse is not necessarily true . They cannot survive freshwater input .

= = Stratigraphic application = =

Since Alfred Eisenack first recognised and named the group in 1930 , the Chitinozoa have proven incredibly useful as a stratigraphic markers in biostratigraphy during the Ordovician , Silurian and Devonian periods . Their utility is due to the rapidity of their morphological evolution , their abundance ? the most productive samples bearing almost a thousand tests per gram ? and the easy

identification (due largely to the large variation in shapes) and short lifetimes (< 10 million years) of most species . They are also widely distributed and appear in a variety of marine depositional settings , making correlation easier ; better still , they can often be recognised in even quite strongly metamorphosed rocks . However , convergence of morphological form to similar environments sometimes leads to the mistaken identification of a species in several areas separated by vast differences in space and time , but sharing a similar depositional environment ; clearly , this can cause major problems if the organisms are interpreted as being the same species . Aside from the acritarchs , chitinozoans were the only reliable means of correlating palæozoic units until the late 1960s , when the detailed study of conodonts and graptolites fully unleashed their stratigraphic potential .