DINOFLAGELLATE CYST STRUCTURES: WALLS, CAVITIES, AND BODIES

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ABSTRACT. The present status of terminology for walls, cavities, and bodies of dinoflagellate cysts is discussed. Evidence is presented to show why an objectively based terminology is preferable to one based on subjectively arrived at concepts. It is proposed that the terms wall, cavity, and body be used to refer to the walls, cavities and bodies of dinoflagellate cysts, and that they be designated by the numbers 1, 2, 3, 4 . . . *n* beginning with the innermost structure and counting outward.

THE fundamental structural elements of dinoflagellate cysts are walls, cavities and bodies. A descriptive terminology for each of these structures is necessary, but some of the terms that have been proposed are vaguely defined or seem to convey different implications than are intended. In particular, technical terms with classical roots tend to suggest a fuller understanding of the named structures than actually exists, and may imply homologies for which there is little or no evidence. The objectives of this study are to discuss the uniqueness of the walls, cavities and bodies, to consider their importance for taxonomic purposes, and to suggest a simple procedure for designating these structures that will facilitate precise description and yet avoid many of the disadvantages of the existing terminology.

A host of different terms has been applied to the walls and bodies of single- and double-walled cysts. Cavities have played such a minor role in cyst taxonomy that specific terminology for these structures has, only recently, been proposed. Although the meanings of terms used to designate different walls and bodies are generally obvious when read in context, the variety of terms in use and their inconsistent application present a confusing picture to one attempting to compare observations recorded by different taxonomists. For example, in the literature, alternatives to 'wall' include thecal wall, cyst wall, layer, membrane, lamella, shell, shell membrane, shell layer, shell surface. The adjectives 'inner' or 'outer' often precede these terms to insure reference to a specific wall. At least four types of cyst bodies are implied by the ways such terminology has been applied to dinoflagellate cysts. They are: the body of a single-walled cyst, the inner and outer bodies of a double-walled cyst, and the main body of a cyst whose outer surface supports processes or spines. Table 1 illustrates the variety of terminology applied to these bodies.

Downie and Sarjeant (1966) were aware of the chaotic state of the available terminology for walls. In the hope of providing a solution for this problem, they coined a new and distinctive terminology. In their study they also recognized the potential taxonomic value of cyst cavities. They did not suggest new expressions for bodies. Their proposals included endophragm, periphragm, and ectophragm for walls and endocoel and pericoel for cavities. Definitions for these terms must be taken from the context of their proposals as no formal definitions were provided. On describing endophragm and periphragm (p. 10), they say: 'These cysts are smaller than the motile stage cell and are

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TABLE 1. Terminology used to describe cyst bodies since 1961

Reference	*Cyst types*			
	Single-walled cyst	*Double-walled cyst*		*Cyst whose outer wall bears spines or processes*
	Body	*Outer body*	*Inner body*	*Cyst exclusive of processes*
Evitt, W. R. (1961)		outer cyst (p. 397) theca (p. 408)	inner cyst (p. 397) cyst (p. 408) inner body (p. 391)	
Cookson, I. C. and Eisenack, A. (1962)	shell (p. 488)	shell (p. 486)	capsule (p. 486)	shell (p. 493)
Pocock, S. A. J. (1962)	theca (p. 81)	theca (p. 78)	cyst (p. 80)	vesicle (p. 82)
Manum, S. and Cookson, I. C. (1964)	shell (p. 15)	shell (p. 7) membrane (p. 10) theca (p. 21)	shell (p. 7) capsule (p. 7)	shell (p. 11)
Singh, C. (1964)	theca (p. 134)			vesicle (p. 140)
Norris, G. (1965)				midbody (p. 793)
Stanley, E. A. (1965)	cyst (p. 224)	outer cyst (p. 219)	inner cyst (p. 219)	cyst (p. 231)
Sarjeant, W. A. S. (1966*a*)	theca (p. 111) shell (p. 118)	theca (p. 125) shell (p. 115) enclosing body (p. 203) outer shell (p. 210)	inner body (p. 137)	shell (p. 142)
Sarjeant, W. A. S. (1966*b*)		periphragm (p. 191)	capsule (p. 191) central body (p. 220)	
Williams, G. L. and Downie, C. (1966*a*)			internal cyst (p. 63)	
Williams, G. L. and Downie, C. (1966*b*)		outer cyst (p. 63)	inner body (p. 61)	body (p. 49)
Wilson, G. J. (1967*a*)	shell (p. 65)	shell (p. 18)		main body (p. 43)
Clarke, R. F. A. and Verdier, J. P. (1967)	body (p. 64) main body (p. 68)	outer membrane (p. 61)	cyst (p. 17)	test (p. 24)
Drugg, W. S. (1967)	test (p. 15)	test (p. 15)		tract (p. 186)
Drugg, W. S. and Loeblich, A. R. Jr. (1967)	tract (p. 182) cyst (p. 182)			cyst (p. 184)
Evitt, W. R. (1967)	cyst (p. 42)		inner body (p. 7)	
Davey, R. J. (1969)	shell (p. 140)			shell (p. 146) central body (p. 146)

formed by the deposition of an ellipsoidal or spherical wall some distance inside the motile stage envelope (or theca if hardened). This wall in fossil and Recent cysts is often seen to be constructed of two layers which we propose to call the endophragm and the periphragm. The outer layer or periphragm usually carries extensions either in the form of spines or as lists, which extend out to the position of the formal thecal wall and appear to have acted as supports during the period of cyst formation.' Ectophragm is described (p. 15) thus: 'In some cyst groups the processes may be connected distally by narrow solid rods (trabeculae); in others a thin membrane (ectophragm) may still persist between the distal ends. This ectophragm must have been laid down very close to the motile cell envelope.' Endocoel and pericoel are described (p. 13) in this way: '. . . there is a third group, here called the cavate cysts, in which a space, or spaces of notable size, occurs between the periphragm and the endophragm. This space is here named the pericoel; it separates an inner body (capsule) formed by the endophragm from the outer cyst wall, the cavity of this body is called the endocoel.'

The terminology proposed by Downie and Sarjeant is not conducive to effective communication. Their definitions are too brief and the descriptive statements that accompany these definitions are restrictive, subjective and occasionally tend to convey more information than is warranted by the available evidence.

Downie and Sarjeant (p. 10) state that periphragm and endophragm refer to those cysts bounded by a single, two-layered wall. The meanings of 'wall' and 'layer' here are not clear. It may be that the terms refer to such cysts as *Spiniferites* and *Hystrichosphaeridium* where the two walls, or layers, are more or less continuously so closely appressed that they may collectively be considered to constitute a single two-layered wall. It is unlikely that the proposed terms are meant to apply to the walls of cysts like *Deflandrea*, *Odontochitina*, or *Wallodinium*, although this application is indirectly suggested in the definition of pericoel. These walls are distinct from each other and are commonly separated by a wide cavity or space. They cannot be considered as two layers of a single wall but are rather two distinct walls. If the authors intended these terms to refer to layers of a wall rather than to distinct walls, a new terminology is necessary to refer to walls. Alternatively, their terms may be considered to refer to distinct walls, rather than layers, regardless of the size of the cavity that separates them.

If the proposed terminology is broadly interpreted to refer to all two-walled cysts, new terms will be required to designate the walls and cavities of single-walled cysts and of cysts with more than two walls. Three-walled cysts have recently been discovered (W. R. Evitt, personal communication 1968; also Pl. 7, figs. 10*a*, 11*a*, 12*a*). *Wetzeliella* (*Wetzeliella*) *clathrata* Eisenack, *W.* (*W.*) *homomorpha* var. *quinquelata* Williams and Downie, *W.* (*W.*) *coelothrypta* Williams and Downie, *W.* (*W.*) *tenuavirgula* var. *crassoramosa* Williams and Downie are possible further examples of cysts with three walls. Other cysts such as *Netrelytron trinetron* Sarjeant and *Paranetrelytron* Sarjeant may also be included in this category provided the cloak of adherent matter referred to by Sarjeant (1966*b*) in his taxonomic descriptions is considered to be a wall. Cysts with more than three walls almost certainly will be discovered in the future. Each discovery of an additional wall will necessitate an additional terminology for that new group of cysts. To completely describe walls, cavities, and bodies of single-walled, two-walled, and three-walled cysts, without implying homologies, presently requires eighteen distinct terms. The addition of a four-walled cyst type would increase the total number

of necessary terms to thirty. The confusion that such a complex array of terms would engender could smother effective communication.

Ectophragm is defined by Downie and Sarjeant as a special type of membranous wall that rests on the tips of periphragm processes. Since the periphragm is defined as the outer of two walls, the ectophragm must be a third wall. However the term is not defined as a third wall nor do its authors clarify its usage in their published works. Other terms are used to denote structures similar to their ectophragm. Williams and Downie use 'membrane' in their description of *Membranilarnacia* (1966*b*, p. 219), *Wetzeliella* (*Wetzeliella*) *coelothrypta* (1966*a*, pp. 185, 186) and *Cyclonephelium divaricatum* (1966*b*, p. 244) and 'periphragm' in their description of *Thalassiphora* (1966*b*, p. 325). In their remarks on *Chlamydophorella nyei* Cookson and Eisenack, Davey *et al.* use 'outer membrane' (1966, p. 168).

The terminology proposed by Downie and Sarjeant is not satisfactory for the designation of walls and cavities. Unless we adopt a terminology that is not affected by changes resulting from new observations, we will have to retain the system proposed by these authors and continually readapt it to accommodate new information. The resulting patchwork terminology will be needlessly complex and obscure. Our need is for a terminology that is simple and objective, one that does not imply developmental similarity and does not need revision with each new discovery.

The terms (wall, cavity, and body) should be retained as the basis of designates for these cyst structures. These terms are defined in a manner most appropriate to this study in the *Random House Dictionary of the English Language* (1966).

Wall. 6. The outermost film or layer of structural material protecting, surrounding, and defining the physical limits of any object: the wall of a blood cell (p. 1606).
Cavity. 2. Anat. a hollow space within the body (p. 236).
Body. 1. The physical structure and material substance of an animal or plant, living or dead.
10. Geom. a figure having three dimensions of length, breadth and thickness (p. 165).

Walls are considered in both two- and three-dimensional senses: In the two-dimensional sense, the surfaces (inner and outer) of the walls take on importance. Sculptural and structural elements arising from or indented into the surfaces and the patterns the elements make on the surfaces are among the most important of cyst features to be described. The wall is a three-dimensional structure in the sense that it has length, breadth, and thickness. In respect to dinoflagellate cysts, three dimensional aspects of walls should include thickness, pores, depressions, thin areas, thickenings, internal texture and wall continuity.

A cyst body is formed by a wall having such a configuration that it encloses space. The space may be empty (e.g. Pl. 7, figs. 1, 2, 4, 6) in which case it is a cavity, or it may be partially filled (e.g. Pl. 7, figs. 3, 9, 10*a*, 12*a*), and consist of a cavity and an inner body. A wall and the enclosed space together constitute a body (e.g. Pl. 7, figs. 3, 9, 10*a*, 10*b*, 11*a*, 11*b*). The cyst body has a characteristic shape and volume. Specifically, the shape and dimensions of the body are distinct from those of the wall. For example, the shape of a cyst in dorsal-ventral view is the shape of the body, not of the wall. Wilson (1967, p. 477) referred to the rhomboidal outline of the periphragm when what he probably meant was the rhomboidal outline of the body delimited by the periphragm. Because a dinoflagellate cyst may have one, two, three, and possibly more

walls, each of which encloses space, it can consist of one, two, three, and possibly more bodies, one within another. Of significance in descriptions of bodies are the degree of dorsal-ventral flattening and the development of surface projections and any other factors that control their shape.

The cavity of a single-walled cyst is the volume of empty space enclosed by the wall (Pl. 7, figs. 1, 2, 4, 6). When two walls are present, one within the other, the inner cavity lies within the inner wall and the outer cavity lies between the two walls. This outer cavity is continuous when its bounding walls are not visibly in contact (Pl. 7, fig. 3) discontinuous when these walls are locally in contact (Pl. 7, fig. 9) and only locally developed when the walls are in contact over a large proportion of the cyst (Pl. 7, figs. 10*a*, 11*a*) and within hollow processes (Pl. 7, fig. 7*a*). The outer wall may completely enclose the outer cavity or only partially enclose it when discontinuities are present in that wall, for example, the outer wall of *Litosphaeridium* (Pl. 7, fig. 7*a*) forms hollow processes that often are open at their tips. These openings constitute discontinuities in the outer wall. It may be argued that cavities are not structures in the strict sense of the term. However, since the cavities of dinoflagellate cysts can be described in a three-dimensional sense, similar to bodies, they are herein referred to as structures. Downie and Sarjeant (1966) have shown that such features of these cavities as their

EXPLANATION OF PLATE 7

Photographs were made using a Geological Survey of Canada (GSC) Leitz Ortholux microscope and camera (number 65–59). A Leitz 546-nm interference contrast filter was used to increase contrast. Photographs were made on Kodak Plus-X panchromatic film.

Fig. 1. *Broomea* sp. sensu Alberti 1961, ×500; sample 57, depth 1142′ 7″–1152′ 7″, slide PAL-57D, 33·8–116·8, GSC type specimen 25611, Ashville Formation, Albian.

Fig. 2. *Deflandrea* sp., ventral view, ×500; sample 119, depth 1020′–1025′, slide PAL-119L, 45·1–119·6, GSC type specimen 25612, Vermilion River Formation, Boyne Member, Santonian.

Fig. 3. *Deflandrea* sp., dorsal view, ×500; sample 119, depth 1020′–1025′, slide PAL-119L, 24·3–111·9, GSC type specimen 25613, Vermilion River Formation, Boyne Member, Santonian.

Fig. 4. Forma A, ×500; sample 58, depth 780′–787·5′, slide PAL-58D, 36·3–124, GSC type specimen 25614, Vermilion River Formation, Morden Member, Turonian.

Fig. 5. *Chlamydophorella nyei* Cookson and Eisenack; sample 56, depth 1192′ 7″–1202′ 7″, slide PAL-56E, 15·7–115·5, GSC type specimen 25615, Ashville Formation, Albian. 5*a*, ×500. 5*b*, Apical region, ×750.

Fig. 6. *Dinogymnium* sp., dorsal view, ×500; sample 115, depth 915′–920′, slide PAL-115A, 29·8–109·8, GSC type specimen 25616, Lea Park Formation, Campanian.

Fig. 7. *Litosphaeridium siphoniphorum* (Cookson and Eisenack) Davey and Williams; sample 1, depth 929′ 2″–937′, slide PAL-1A, 16·2–114·6, GSC type specimen 25617, Ashville Formation, Cenomanian. 7*a*, ×500. 7*b*, Enlarged processes, ×750.

Fig. 8. *Spiniferites* sp., ×500; sample 103, depth 1255′–1260′, slide PAL-103A, 40·7–119·5, GSC type specimen 25618, Ashville Formation, Albian.

Fig. 9. *Dingodinium* sp., ×500; sample 90, depth 1320′–1325′, slide PAL-90A, 39·2–117, GSC type specimen 25619, Ashville Formation, Albian.

Figs. 10, 11. Forma B, dorsal view. 10*a*, 10*b*, Sample 57, depth 1238′ 2″–1245′, slide PAL-57D, 25·5–124·7, GSC type specimen 25620, Ashville Formation, Albian. 10*a*, ×500. 10*b*, Operculum and apex enlarged, ×750. 11*a*, 11*b*, Sample 55, depth 1142′ 7″–1152′ 7″, slide PAL-55A, 20–124·4, GSC type specimen 23786, Ashville Formation, Albian. 11*a*, ×500. 11*b*, Enlarged apex, ×750.

Fig. 12. Forma C, ventral view; sample 692-3, 49′–58′ above base of cliff, slide PAL-692–3A, 28·8–111·1, GSC type specimen 25621, Late Cretaceous. 12*a*, ×500. 12*b*, Optical view of walls and processes, ×750, 12*c*, Apical region, ×750.

presence or absence, degree of development, shape, and symmetry of distribution (text-fig. 2*c*) are taxonomically useful.

I propose to use wall, body, and cavity as the basic terms for all walls, bodies, and cavities in dinoflagellate cysts and to make clear the number and positional relationship of these structures in any one cyst by a simple system of numbers, as indicated in Table 2 (note that the numbering begins always with the innermost structures):

TABLE 2. Proposed terminology for the designation of dinoflagellate cyst walls, bodies, and cavities

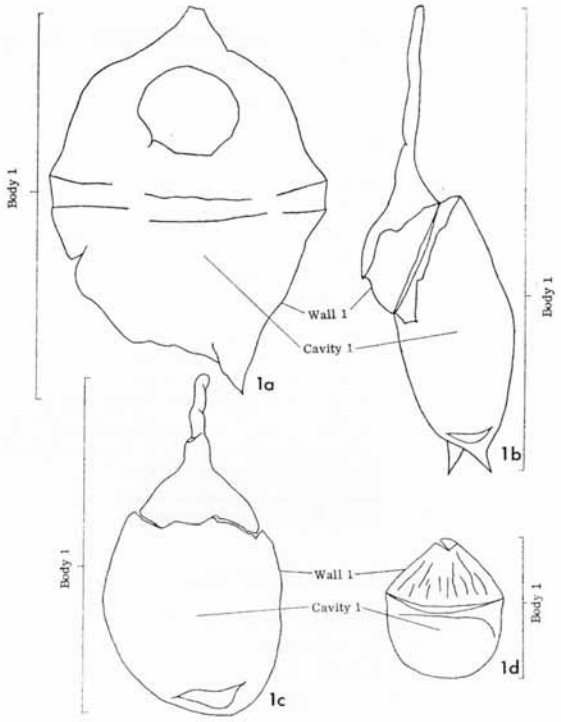
For single-walled cysts:	Wall 1 (i.e., the wall) Cavity 1 (i.e., the cavity) Body 1 (i.e., the body)
For double-walled cysts:	Wall 1 (i.e., the inner wall) Wall 2 (i.e., the outer wall) Cavity 1 (i.e., the cavity within wall 1) Cavity 2 (i.e., the cavity between wall 1 and wall 2) Body 1 (i.e., the inner body) Body 2 (i.e., the outer body)
For three-walled cysts:	Wall 1 (i.e., the inner wall) Wall 2 (i.e., the middle wall) Wall 3 (i.e., the outer wall) Cavity 1 (i.e., the cavity within wall 1) Cavity 2 (i.e., the cavity between wall 1 and wall 2) Cavity 3 (i.e., the cavity between wall 2 and wall 3) Body 1 (i.e., the inner body) Body 2 (i.e., the middle body) Body 3 (i.e., the outer body)

The advantages of the proposed terminology are:

1. Simplicity: The terms wall, cavity, and body are simple and easily understood. Each designate is based on only one parameter that is normally easily observed: the spatial position of the structure relative to the centre of the cyst. An individual term should convey no more information than spatial position.
2. Consistency: For example, the innermost wall is always wall 1, regardless of its physical properties.
3. Symbolism: The use of numbers in orderly sequence quickly establishes a mental picture of the position of the structure. The numbers are easily verbalized and written.
4. Utility: The system is open-ended, new observations will not alter the basic concept of the designates which can be expanded to accommodate new information. For example, the outer wall of a four-walled cyst will be wall 4, and the outer wall of a cyst with n number of walls will be designated wall n.

Alternative systems were considered before the proposed terminology was adopted. The designates inner, middle, and outer were rejected because a system formed using these terms would not be open-ended. The discovery of cysts with more than three walls would force another revision of such terminology. Various number and letter

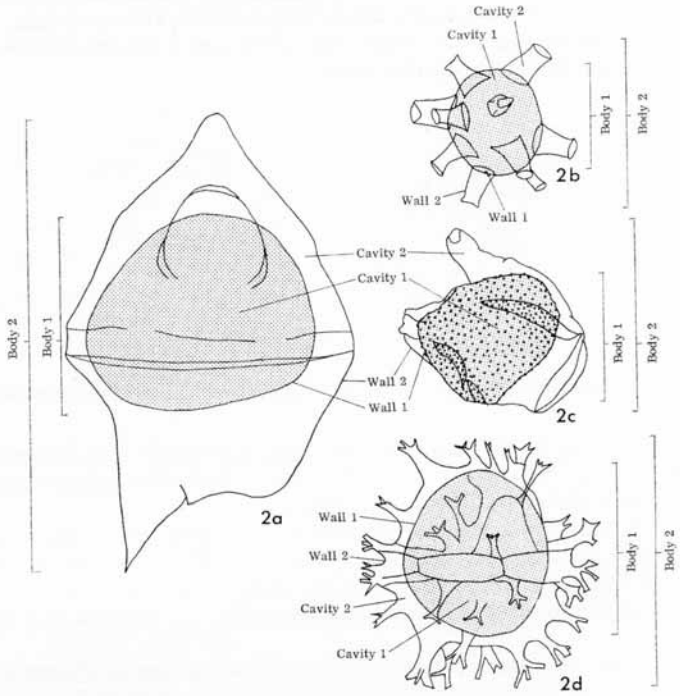
combinations were tried. For example, terms for the inner, middle and outer walls of a three-walled cyst were designated respectively as wall 1 of 3, wall 2 of 3, and wall 3 of 3. Although it is open-ended and probably less prone to homologous interpretations than any other system, this system was found to be awkward and confusing when used repeatedly in taxonomic descriptions and so was rejected.



TEXT-FIG. 1. Single-walled cysts. *a*, *Deflandrea* sp., ×*c*. 500, Plate 7, fig. 2; *b*, *Broomea* sp. sensu Alberti, 1961, ×*c*. 500, Plate 7, fig. 1; *c*, Forma A, ×*c*. 500, Plate 7, fig. 4; *d*, *Dinogymnium* sp., ×*c*. 500, Plate 7, fig. 6.

Examples of dinoflagellate cysts illustrating application of the proposed terminology are shown on Plate 7 and on text-figs. 1, 2, 3, and 4. Plate 7, figs. 1, 2, 4, and 6 and text-fig. 1 illustrate single-walled cysts. Plate 7, figs. 3, 7*a*, 7*b*, 8, and 9 and text-fig. 2 illustrate cysts with two walls. An example of a three-walled cyst is given on Plate 7, figs. 10*a*, 10*b*, 11*a*, and 11*b* and on text-fig. 3. Plate 7, figs. 5*a*, 5*b*, 12*a*, 12*b*, and 12*c* and text-fig. 4 show examples of cysts where the number of distinct walls is so difficult to determine that until more, detailed studies are made, terminology for the structures cannot be regarded as final and any terms used must be accompanied by qualifying statements.

Two specimens of *Deflandrea* sp., from the same lithologic sample, are illustrated on text-figs. 1*a* and 2*a*. In text-fig. 1*a*, the cyst consists of only one body (body 1). This body has a peridinioid outline. In text-fig. 2*a* it consists of two bodies, an inner body (body 1) and an outer peridinioid body (body 2). Examples of the absence of such an inner body are common among peridinioid dinoflagellates. The reason, or reasons,

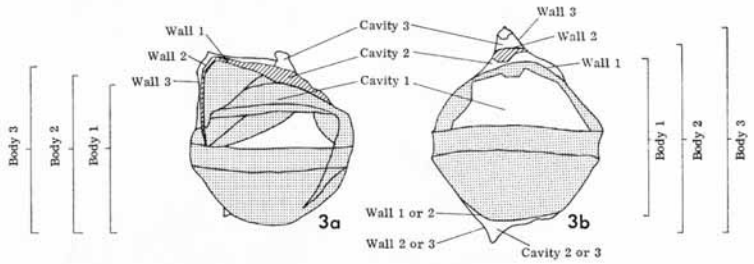


TEXT-FIG. 2. Two-walled cysts. *a*, *Deflandrea* sp., ×*c.* 500, Plate 7, fig. 2; *b*, *Litosphaeridium siphoniphorum* (Cookson and Eisenack) Davey and Williams, ×*c.* 500, Plate 7, fig. 7*a*; *c*, *Dingodinium* sp., ×*c.* 500, Plate 7, fig. 9; *d*, *Spiniferites* sp., ×*c.* 500, Plate 7, fig. 8.

for such a phenomenon is unknown. It may be biological, palaeoecological, or diagenetic or a combination of these factors. Because these cysts (text-figs. 1*a* and 2*a*) are similar in all other features, they are probably conspecific. Application of the proposed terminology to these cysts is not completely satisfactory. It is awkward to refer to two obviously homologous structures (i.e. the peridinioid bodies) using different designates. However, it is at this point that the decision must be made to use terminology in a purely objective sense: to record only what is observed. Furthermore, future studies of the presence or absence of a given body may reveal new palaeoecological, biological,

or diagenetic differences. Reference to both peridinioid bodies by the same designate may obscure the significance of such differences.

Litosphaeridium siphoniphorum (Cookson and Eisenack) Davey and Williams (text-fig. 2*b*) is interpreted as having two walls and therefore two bodies and two cavities. The innermost wall outlines a subspherical body, body 1. It is distinct only beneath the processes. Wall 2 arises as a distinct wall at the bases of the processes; it forms the processes. Cavity 2 is discontinuous; it is clearly defined only within the processes. Body 2 may be said to be echinate; the spines being hollow, blunt, and open-ended. Whether such cysts as *Hystrichosphaeridium*, *Oligosphaeridium*, and *Tanyosphaeridium* also have two walls will be determined by further study.



TEXT-FIG. 3. Three-walled cysts. *a*, *b*, Forma B, ×*c*. 500, Plate 7, figs. 10*a*, 11*a* respectively.

Dingodinium sp. (text-fig. 2*c*) illustrates a discontinuous cavity that is asymmetrically disposed about an apical-antapical or polar axis. This feature appears constant for *Dingodinium* and therefore is of taxonomic value.

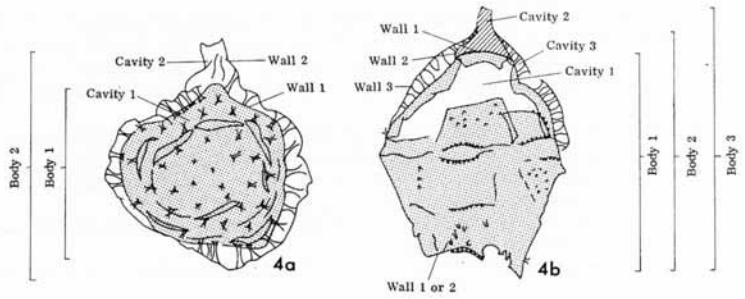
Spiriferites sp. (text-fig. 2*d*) is interpreted as a two-walled cyst based on studies by Jux (1968) and on personal investigations. The inner wall bounds a subspherical body. The outer wall forms the sutural lists and the gonal and intergonal furcate spines. Body 2 is echinate while cavity 2 is discontinuous and best developed near the base of the lists.

Text-figs. 3*a* and 3*b* illustrate two specimens referred to here as Forma B, a three-walled cyst. In text-fig. 3*b* and Plate 7, figs. 11*a* and 11*b*, the three walls are well defined at the apex of the cyst. The operculum of Forma B consists of 1a, 2a, 3a, 3″, 4″, and 5″; this series of plates forms the operculum in all three bodies. In text-fig. 3*a*, although the dorsal surface of the specimen is obscured by complex folding of walls from the ventrum, the operculum clearly illustrates the presence of three walls. A small cavity is developed by the separation of two walls at the antapex. Presently it is not possible to distinguish which walls have separated so the terminology the antapical region is left open pending further studies.

Text-fig. 4 is included to illustrate some unresolved problems that can only be resolved by ultrathin sections and detailed microscopic analysis such as the study by Jux (1968). Text-fig. 4*a*, *Chlamydophorella nyeii* is labelled as a two-walled cyst. If the processes that arise from wall 1 can be shown to constitute a new wall, then *C. nyeii* will be designated as a three-walled cyst. Text-fig. 4*b* illustrates Forma C which resembles Forma B in its mode of archeophyle formation. Forma C is here labelled as a three-walled cyst.

However if the processes between wall 2 and wall 3 can be shown to constitute a distinct wall, then Forma C becomes a four-wall cyst. The terms that designate the walls, cavities and bodies of *C. nyeii* and Forma C are therefore regarded as provisional.

The terms suggested here are only tools. They are intended to be applied only after one decides on the cyst-type (number of walls present) and on the position of the structure being identified relative to the cyst centre. The decision as to whether a given



TEXT-FIG. 4. Cysts illustrating difficulties in the application of terminology: *a*, *Chlamydophorella nyeii* Cookson and Eisenack, × *c.* 500, Plate 7, fig. 5*a*; *b*, Forma C, × *c.* 500, Plate 7, fig. 12*a*.

layer, or partial layer, is a wall or not must be made prior to application of the terminology. If subjectivity is involved in this decision, then an explanation for the decision must accompany the term.

It is hoped that this discussion will be useful insofar as it draws attention to a problem. The simplicity, versatility and graphic nature of the proposed solution to that problem should be apparent once the problem is appreciated. However, no system is a panacea and the value of any system depends as much on how it is used as on how it is designed.

Information about samples. All specimens illustrated on text-figs. 1, 2, 3, and 4 and on Plate 7 were recovered from shale samples of Cretaceous (Albian to Maestrichtian) age. Samples 1, 55, 56, 57, and 58 were obtained from the International Minerals and Chemical Co. k2 potash shaft (lsd. 7, secn. 27, twp. 19, rge. 32 W 1 Meridian), south-east Saskatchewan. Samples 90, 103, 115 and 119 were obtained from Alwinsal Potash of Canada Ltd. potash shaft (lsd. 4, secn. 28, twp. 33, rge. 23, W 2 Meridian), south Saskatchewan. Sample 692-3 is from the outcrops along the Horton River, Northwest Territories, about 15 miles south of its mouth (lat. 69° 49′, long. 126° 51′). Samples and slides are stored in the Geological Survey of Canada (GSC) type collection. GSC locality numbers for the samples are: sample 1 = C-5214, sample 55 = C-5223, sample 56 = C-5222, sample 57 = C-5221, sample 58 = 69318, sample 90 = C-5249, sample 103 = C-5246, sample 115 = C-5227, sample 119 = C-5234, sample 692-3 = C-5272.

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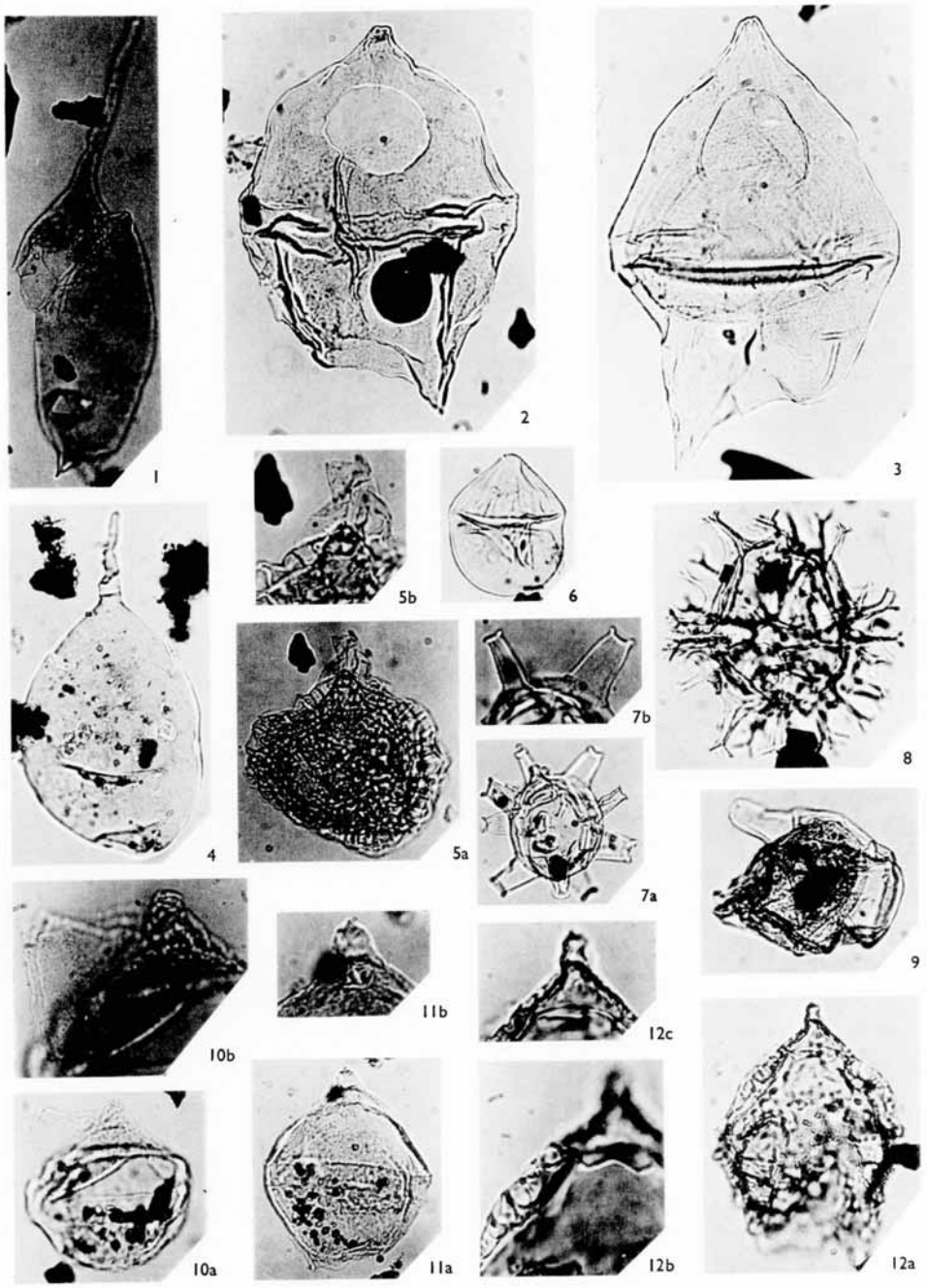

COX, Cretaceous dinoflagellate cysts