

A standardized method of describing fossils, using Echinoidea as an example

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The main purpose of a research paper in palaeontology, or any scientific discipline, is to spread information within the field. In this paper, suggestions are made concerning the structure and organisation of systematic palaeontological papers, using the Echinoidea as an example. A comprehensive table of echinoid morphological features is presented. It is intended that authors following these guidelines will be facilitated in writing research papers that enable expeditious retrieval of information.

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Introduction

The purpose of this communication is to demystify the description of fossils, using the echinoids as an example, and to explain some of the steps involved on the path to publication. Although other papers with broadly similar aims have been published widely (e.g., Riedel, 1978; van der Hammen, 1986), our experiences show that some, perhaps many, authors would still benefit from more instruction in this, one of the basic methodologies of our science. In part, it should be regarded as a supplement to the 'Instructions to Authors' of *Scripta Geologica*, although we trust that it will be of wider use for the authors of systematic papers in neontology and palaeontology.

Geology is a descriptive science. Description - and curation of the material - starts in the field with the ubiquitous field notebook (Tucker, 1982, pp. 12-13). This is used to record diverse details of, for example, the surface geomorphology of an area - a hillside, beach, quarry or whatever - as well as the solid geology. Measured sections through sedimentary sequences, orientation data pertaining to structure or palaeocurrent directions would be included, together with first impressions and interpretations of specimens found, collected and safely wrapped up for transport. All these data help with the analysis of the specimens and interpretation of what they mean.

Description continues in the laboratory, whether it be a research facility in a museum or university, or the corner of a room at home where you keep your rock collection.

More detailed observations can be made using a stronger lens than you had in the field or, if available, a microscope. Those specimens that are significant, unusual and unique demand our special attention, and are worthy of detailed description(s). The process of description itself gives a rigour to our methodology of observation, and can lead, following further research and perhaps the hunt for additional specimens, to publication in the scientific literature.

The main purpose of a scientific paper is to spread information to others working in that field, in this case palaeontology. In order to achieve this, the information has to be easily accessible and in an intelligible form, for we write both for those who speak our own language, and for those who do not and have to rely on translations using a dictionary. If the task can be made simpler by a standard presentation, information dissemination and retrieval will be much easier, and rapid comparisons can be made between taxa.

It is also important for curators in museums to be able to extract information from geological and palaeontological publications, in order to bring their databases (both electronic and paper) of specimens up-to-date. Having to search undifferentiated, sometimes turgid, descriptions looking for such elementary data as a locality or a geological horizon is irritating and time-consuming. It is, therefore, desirable to establish a standard layout for this kind of information. There is also a need to develop a standard layout 'pro forma' checklist for each group of taxa, in which all possible characters are listed in a regular order and each character is dealt with in turn (Table 1).

Methodology (1): Supporting information

Although this paper is written as a general introduction, it is nevertheless helpful to illustrate some of the discussion below by reference to particular examples. Although we focus on the echinoids (Table 1), they are only illustrative; the recommended methodology is applicable to other palaeontological taxa. First and foremost, taxonomic publications concerning animals or plants must conform to the laws laid down in the International Code of Zoological Nomenclature (1999) or Greuter *et al.* (2000), respectively. A new taxon has to have a detailed, accurate description and (at least) adequate figures. A proper sequence in the description of new taxa would include the following sections, with related sub-headings.

Taxonomy – Each first description of a taxon in a published work has the taxonomy given in full, with subsequent related taxa requiring only the parts that differ. This saves space in the publication, something which journal publishers, editors and readers appreciate. For example (following the classification of Smith & Wright, 1989):-

Class Echinoidea Leske, 1778
Order Cidaroida Claus, 1880
Family Cidaridae Gray, 1825
Subfamily Psychocidarinae Ikeda, 1935
Genus *Tylocidaris* Pomel, 1883
Subgenus *Tylocidaris* Pomel, 1883
[Species] *Tylocidaris (Tylocidaris) clavigera* (Mantell, 1822)

The author is included with the date of the first description, ensuring that readers are aware of the taxonomic priorities. This also helps with the identification of references in the bibliography. The first citation of any species in the text should be associated with the name of the author(s) and date of publication, which are treated as references and will appear in the reference list (Kelt & Palma, 1992). Within the body of the text the genus (and, if so subdivided, subgenus) can be reduced to the capital letter *T.* only - *T. (T.) clavigera* - except at the start of a sentence. The author can at this stage be omitted. The next taxon within the cidarids might then be:-

Subfamily Cidarinae Gray, 1825
Genus *Prionocidaris* A. Agassiz, 1863
etc.

This avoids repeating the higher taxonomy (class, order, family), which is the same for both genera. Bengtson (1988) provided much sensible advice regarding the use and format of open nomenclature.

Synonymy list – This is a list that includes all previously published identifications and references to a given taxon. For example, the Chalk echinoid *Gauthieria radiata* (Sorignet, 1850) has been previously called:-

Cyphosoma radiatum Sorignet, 1850 [this was the original designation]
Cyphosoma subradiatum Sorignet, 1850 [originally perceived as a separate species, but subsequently synonymised]
Phymosoma heberti Desor, 1858 [Desor thought differently]

and several other designations until 1888 when Lambert erected the genus *Gauthieria*, with *Gauthieria radiata* (Sorignet, 1850) designated as the type species.

Synonymy lists can be exhaustive or selective; in the latter case, only the most notable references are listed. There are taxa whose complete synonymy lists would require a whole paper in themselves, such as the fossil bird *Archaeopteryx*. The preferred format of a synonymy list for *Scripta Geologica* should follow the style used by Taylor & McKinney (2006). For detailed comments on the construction of synonymy lists, see Matthews (1973).

Diagnosis – The diagnosis of a taxon is expressed in concise sentences which define the essential features of that taxon alone, using characters that are appropriate to the particular taxonomic level. No two species can have identical diagnoses. The diagnosis is a kind of shorthand whose purpose is to present all the salient characters for the taxon under consideration, whether species, genus or higher group. The amount of detail in the diagnosis will depend on the relevant characters present.

Etymology (derivatio nominis) – This gives the background to the name being given to the new taxon. This is useful to know, apart from the obvious interest, because it will help with the pronunciation of the taxonomic name, especially if given in honour or

Table 1. An example of a checklist of morphological features that should be included in a description of a member of a particular group of fossils, in this case an echinoid. Although not all features may be present or preserved, noting the absence of a feature may be as important as describing those structures that are apparent. For explanations of morphological terms, see Melville & Durham (1966) and Smith (1984, 2003). Note that, under sections (1, 2, 15, 16, 17, 19), contrasting characters such as 'tall/low', 'large/medium/small', 'wide/narrow', 'large/small', 'long/short' and 'slender/fat' appear; in all of these examples, some sort of quantification is required of the author of a taxon.

1. Test regular	ad-anterior	rotulae
Periproct within apical system	ad-posterior	teeth
central	monocyclic	grooved
offset from centre	dicyclic	keeled
	hemiolicyclic	compasses
2. Test irregular	6. Ocular plates (I-V)	cidaroid
Periproct not within apical system	insert	aulodont
apical	exsert	stirodont
marginal	7. Genital plates (1-5)	camarodont
supramarginal	five present	11. Coronal sculpturing
inframarginal	one plate/gonopore	sculptured
oral	present	unsculptured
posterior end	tetrabasal (1-4)	12. Coronal plate imbrication
3. Shape	monobasal (1-5)	imbricated
oblate spherical (sub-spherical)	madreporite (2)	tesselated
globular	large	simple butt-joint
plano-convex	small	sutural pegging
conical	ethmolytic	flexible
flattened oro-apically	ethmophract	rigid
oral surface depressed	5 genital pores	13. Ambulacra
oral surface inflated	4 genital pores (1-4)	non-petaloid
oral surface plane	8. Suranal plate	sub-petaloid
tall	present and tesselated into disc	petaloid
low	not tesselated into disc	open
elongated (axis III-5)	9. Peristome	closed
quadrate	shape	depressed/sunken
outline	circular	raised/convex
circular	oval	wide cf. interambulcra
angular	D-shaped	narrow cf. interambulcra
heart-shaped	asymmetric	two columns
rostrate	position	more than two columns
truncate	central	(pluriserial)
4. Size	anterior	14. Ambulacral plates
large	perignathic girdle	simple
medium	auricles/apophyses/mixed	pseudo-compound
small	buccal clefts ("gill slits" or buccal notches)	compound
sexual dimorphism (yes/no)	no buccal clefts	diadematoïd
5. Apical Disc	10. Lantern	arbacioïd
circular	absent in adults	acrosalenioïd
elongated	present in adults	echinoïd
disjunct	demi-pyramids	echinothurioid
position	tops pitted	reduced plates
central	tops unpitted	demi-plates
	epiphyses	occluded plates
		included plates
		pore pairs

straight	16. Primary Tubercles	miliaries
oblique	large	fascioles
conjugate	small	internal
non-conjugate	tubercles sunken	peripetalous
pore columns	tubercles flush	lateral
simple (uniserial)	regular series	latero-anal
bigeminate (biserial)	alternating series	subanal
trigeminate (triserial)	perforate	anal
polyporous	non-perforate	granules
phyllodes	parapet crenulate	19. Appendages
(phyllodes + bourrelets	parapet non-crenulate	Spines (=radioles)
= floscelles)	neck straight	primary or secondary?
spheroidal pits	neck undercut	long
oral	platform	short
aboral	flush	slender
perradial	impressed (with	fat
adradial	parapet)	straight
one pair	scrobicule	curved
2-4 pairs	basal terrace	clavate (clubbed)
multiple	17. Secondary tubercles	spinules
15. Interambulacra	perforate	smooth
wide	non-perforate	ornamented
narrow	large	solid
2 columns	small	hollow
more than 2 columns	scrobicular ring	verticillate
(= pluriserial)	contiguous	non-verticillate
labral plate	confluent	cortex
sternum	complete	no cortex
protosternous	non-confluent	Pedicellariae
meridosternous	tangential	globiferous
amphisternous	non-confluent	tridentate
bourrelets	separated	ophicephalous
(bourrelets + phyllodes	18. Other tubercles, etc.	triphylous
= floscelles)	aboral naked zone	Clavulae
		Spheridia

commemoration of a person, place or thing. Long species names can be immensely daunting to newcomers, who can better understand how to pronounce the words if they understand the origins and how the name is constructed. An invaluable reference when choosing a trivial name for a new species is Brown (1956).

Material – All of the specimens used in writing the description are listed, including the holotype or other primary types (see below), paratypes and other material. Under each category the following should be included:-

- details of the museum(s) or other repository where the specimens are kept;
- registration and/or accession number(s) of the specimen(s); and
- a brief description of the preservation of the specimen(s).

The name of the collection, collector and any other such details can be included, if appropriate. Type specimens are needed to define the species and may belong to a type

series, a group of specimens used in the description of the species. This series can be conveniently divided into the primary type(s) (see below) and the paratypes. Technically, the primary type is the only specimen which can be called by the species name; all other such named specimens are merely compared with them. Assuming there has been no misidentification of the type specimen(s) (taxonomic and other complications arise when this happens), its species name never changes. Conversely, paratypes and non-type specimens which have been identified as one taxon can be re-named if they are re-identified as something else. Indeed, they may even become the basis for new species. The various forms of primary types are explained below (Davies, 1961; International Code of Zoological Nomenclature, 1999; Greuter *et al.*, 2000).

- The holotype is the single reference specimen for a named species. When several specimens are used for a description, those apart from the holotype may be named paratypes. These are named as such by the author, who may also refer to any further specimens used as 'other material,' if appropriate. In earlier literature, paratypes may not have been designated as such and hence all other specimens used in such descriptions are regarded as paratypes.
- A syntype has the same status as a holotype. A syntype(s) is one or one of several specimens of a type series for which no holotype was designated. All the specimens used in that original description are syntypes.
- A lectotype is a specimen which is selected from syntypes, or from a paratype series in which the holotype was not defined or has been lost. It is the specimen which best represents the original concept of the species and has the same status as a holotype. The remaining syntypes (if any) are then referred to as paralectotypes.
- A neotype ('new type') is a specimen which is selected when the holotype is lost or unidentified within a collection and there are no recognised syntypes or paratypes. The neotype would be chosen from specimens which best represent the original concept of the species and has the same status as a holotype. Ideally it is chosen from specimens which came from the same locality and horizon as the original type. This may not always be possible, however, especially if the original locality was not known or is no longer accessible.

The term 'type species' (not to be confused with type specimen) is applied to the species which characterises a genus. For example, the type species of *Hyposalenia* is *Salenia stellulata* L. Agassiz, 1838, with several other species assigned to the genus *Hyposalenia*. The type species of *Hyposalenia* will never change, but the other species assigned to that genus can be placed in other genera if revisions occur.

Localities – The locality details of the type and other specimens are given so that the reader can, ideally, exactly identify the source site of the material. Do not assume that the reader will know where the locality is - some may even be uncertain of the country - so state the obvious, for example, "Barton-on-Sea, Hampshire, England" (as distinct from, for example, "Barton, Devon, England"). Locality maps show from where the material comes. It is a good idea to include not only a detailed map of a locality, but also a much larger scale map to show where it is in relation to elsewhere, such as the country of origin.

A locality is made up of several different components which can be broken down into smaller units, especially useful if the information is to be added to a database. The reason for doing this is for retrieval in a variety of forms (for example, a card index), and is particularly important for more advanced nested and other relational electronic databases. Conventionally, the information is given in order of increasing rank, closing with the country of origin. The latitude and longitude can be given when known, together with, or as an alternative to, the local national grid reference. This might be appropriate if copyright information for the grid reference is likely to be infringed or permission is difficult to obtain. The use of GPS information has greatly simplified determination of latitude and longitude.

Stratigraphy – As with locality details, in order that readers unfamiliar with the geological data being presented can find their way around the stratigraphy, do not assume that they are familiar with the stratigraphy; once again, state what to you may appear to be obvious. The stratigraphy is given in descending rank order, and breaks down the essential information into three main areas and progressively smaller units:-

- Chronostratigraphy deals with time alone - period, age, stage, *etc.*; for example, Cretaceous; Coniacian. It simply tells the reader how old the material is. There is no implication of what fossils are present, nor the rock types in which they were found. This is important information for readers who do not know the minutiae of the stratigraphy involved.
- Biostratigraphy deals with the details of where exactly in the geological column the fossils occur. Here are included the formal biozones and subzones which locate the fossils within their time bands, for example, *Micraster cortestudinarium* Biozone (or just Zone) (note that 'Biozone' and 'Zone' take a capital letter). Again, there is no implication of any rock types.
- Lithostratigraphy deals with the rocks themselves. Rock masses are divided into more manageable units in descending order - group, formation, member, bed, *etc.* The main groups have formal names, but the smallest units may only be known by their local or informal names.

Rawson *et al.* (2002) provided comprehensive advice on stratigraphic usage. The latest in the Cambridge series of geologic time scales was recently published (Gradstein *et al.*, 2004). Shaw (1971) provided a succinct critique of the poor use of stratigraphic data in palaeontology.

Methodology (2): The description proper

Gross morphology: size and shape – This is described before the formal description to acquaint the reader with an idea of how big the organism might be. Overall measurements can be given here although they are not obligatory, but details of component parts are preferably left to the relevant section. Indeed, illustration(s) at some easily recognisable scale (for example, $\times 1$, $\times 5$, $\times 100$), in conjunction with these details in the text, will do more to convey the gross morphology at this stage than too many measurements.

Morphological description of the taxon – The component parts of a taxon are described under easily located sub-headings, following a regular and consistent order, dependent on the group being described. A checklist is developed for each main group of structures that may be met in that group of organisms (Table 1). This not only ensures that the writer can describe the taxon quickly and know that all the relevant information has been given, but also that the reader can compare individual taxa quickly and easily. Such a checklist will aid observers in realising what is absent as much as what is present.

The essence of a good description is to keep it clear and simple. Remember that some readers have to translate using a dictionary. Technical terms may be unavoidable or preferable because they act as scientific ‘shorthand;’ for example, “adambitally” meaning “towards the ambitus” or the widest part of an echinoid test. When simpler alternatives are available they should be used; for example, rather than write ‘cothurniform,’ if a fossil is ‘boot-shaped,’ then say so.

Plates, figures and tables – An old adage says that a good photograph is worth a thousand words. The purpose of good illustrations in a systematic description is to acquaint the reader with what the taxon actually looks like, and helps to bring to the attention of the reader all the relevant characters of the species. This can be achieved with photographs and artwork. Specimens are photographed with the lighting conventionally biased from the top left hand side (colloquially know as ‘top left lighting’). Hand-drawn artwork is useful to emphasise a feature not necessarily obvious in a photograph. Standard views of the taxon are needed, for example, top, bottom, side, front, back and various close-ups; all should be included whenever possible.

Whether the illustrations are published as plates or text figures, or both, depends on the journal style. Whichever style is used, adequate explanations of the figures are needed, and should at least include the name of the image, its view, its museum or institution reference number, if appropriate, and a scale. More detailed information can also be included (for example, the locality and geological information), but that may also depend on journal policy. It is a general rule that a good figure can only be further enhanced by an informative caption.

The scale can be expressed either as a magnification of the original specimen (for example, $\times 5$), or as a scale-bar of given length. Magnification can be an unreliable expression, because a journal article may be photocopied to a different size or the publication’s page may appear on a computer screen at another size to the original; in both cases a magnification given as, say, ‘ $\times 5$ ’ may be very inaccurate. Scale bars are arguably preferable because the reader can determine the size of a feature by direct observation and comparison with the scale bar. Thus, if a bar represents 10 mm, it is simple enough to subdivide the bar into smaller millimetre units and use it to judge the size of a feature. This is not as easy to do ‘by eye’ with a magnification.

Tables present data about specimens. They can be graphs, lists of measurements or other data that can be expressed in tabular form (e.g., Table 1).

Comparisons and discussion/remarks – Comparisons between similar taxa are made to justify the decisions made by the author. For example, in describing a new species, an author should explain the unique features that differentiate it from closely related and other taxa within the same major group that occur in the same bed or suite of beds.

Species may be compared on the basis of a number of other criteria, as considered appropriate by the author.

The discussion deals with other items relevant to the taxonomic descriptions and comparisons. Here there may be information, for example, about the possible phylogenetic relationships or why a character should be seen as important. Stratigraphic position and/or geographic distribution may be discussed, with a range extended or reduced. Similarities and differences between species from different geographic locations may throw light on the evolution of the taxon. There are many points which can be talked about here, depending on the bias of the paper, whether it be primarily taxonomic or stratigraphic.

Conclusions – This is the final section of the science of the paper and summarises the content as well as drawing together conclusions, if any, from the discussion. Thus, the main conclusion of this paper is that, if authors follow the suggestions given herein, the structure and layout of their papers will be clear, and organised so that information can be retrieved quickly and easily.

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Bibliography/References – This gives a complete listing of all the references used by the author in the paper. All references that appear in the text must also be included in the reference list and *vice versa*. The journal style dictates how these are expressed. For example, some journals require the title of a referenced publication to be given in full, whereas others ask for an abbreviation to be used, for example, *Proceedings of the Royal Society of London* is abbreviated *Proc. R. Soc.*

And finally... – Journals produce guidelines as to how an author needs to set out the paper. This is usually known as ‘Instructions to Authors’ and can be found printed on parts of the cover pages of the journal, as a separate guide or on a website. Authors are well-advised to follow these, because re-formatting manuscripts is time consuming, and a poor initial format could result in rejection of the paper.

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