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***Ventogyrus*, a possible siphonophore-like trilobozoan coelenterate from the Vendian Sequence (late Neoproterozoic), northern Russia**

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Abstract: Complex internal anatomy is documented for the first time in a Neoproterozoic soft-bodied invertebrate. New data suggests that *Ventogyrus*, originally described as a sessile, boat-shaped form belonging to the enigmatic Neoproterozoic group Petalonamae, is actually composed of three, identical modules, arranged around an axial rod. Each module has one longitudinal and numerous transverse septa, which delimit chambers of decreasing size from one end to the other. Three distinct longitudinal channels with alternating lateral branches make up an internal network, perhaps a circulatory system. *Ventogyrus* is a most unusual form, particularly in the quality of its three dimensional preservation of a complex internal structure and a three-fold symmetry, a symmetry shared by many Ediacarans.

Ediacaran metazoans of the late Neoproterozoic are attracting growing attention as key evidence of an early radiation of the Metazoa. Different specialists consider many, if not all, of these fossilized remains are representatives of a totally extinct group while others suggest that at least some Ediacarans gave rise to living groups (Glaessner 1984; Seilacher 1989, 1992; Gehling 1991; Jenkins 1992; Runnegar & Fedonkin 1992; Fedonkin

1992, 2003; Fedonkin & Waggoner 1997; Dzika 2003). The perplexing issue remains—what are the exact relationships between these enigmatic Ediacaran organisms and to which known groups might they belong? Current studies are underway in a variety of fields—comparative anatomy, molecular and developmental biology (Lipps *et al.* 1998; Ayala *et al.* 1998; Valentine 2004; Valentine *et al.* 1999; Peterson & Butterfield 2005).

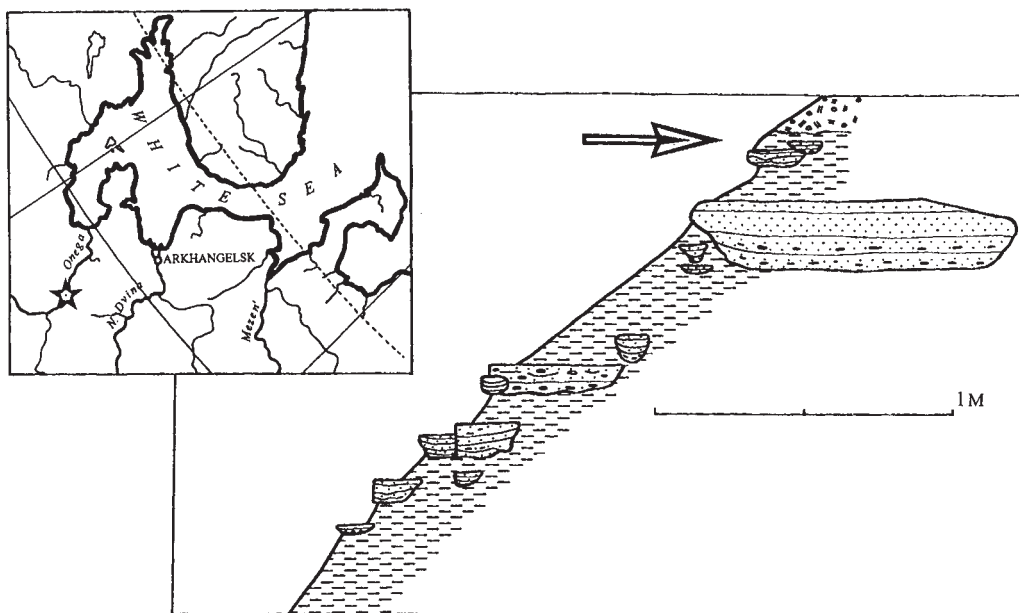


Fig. 1. Location of *Ventogyrus* fossil locality (starred) and geological setting of the outcrop on the Onega River. Sandstone lenses are shown in cross-section.

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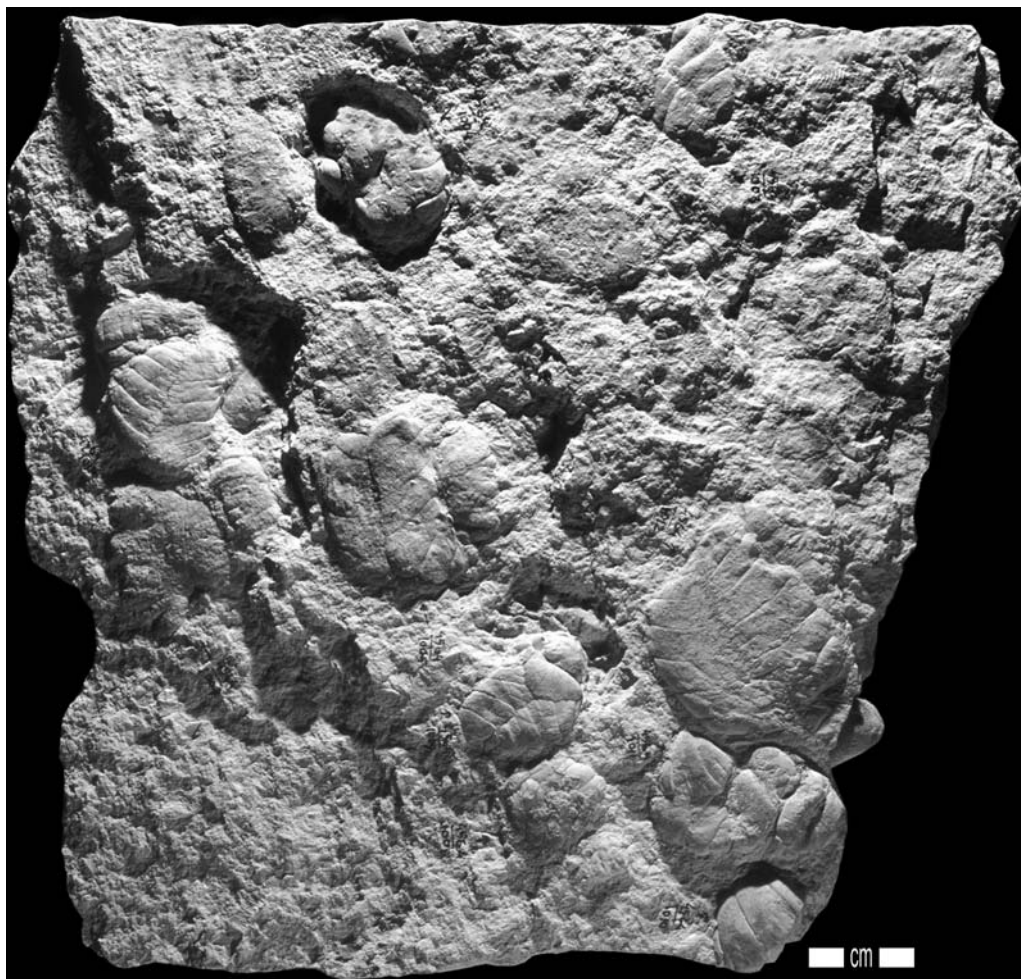


Fig. 2. *Ventogyrus chistyakovi*, Paleontological Institute, Russian Academy of Science, Moscow PIN No 4564/1006-1014, light from the top, internal cast of several modules, Yarnema, Onega Peninsula, White Sea region, northern Russia (F. Coffa).

Of the more than 200 species of Ediacaran metazoan fossils described to date, only a few show any details of their internal anatomy. *Ventogyrus chistyakovi* (Ivantsov & Grazhdankin 1997) is exceptional because abundant fossils are preserved in three dimensions. Complex casts record imprints of this form's internal structure in a fine-grained sandstone. The fossils occur in the lower part of the Ust'-Pinega Formation, a part of the Vendian sequence, which crops out along the Winter Coast of the White Sea in Russia's north, to the west of Arkhangel'sk (Chistyakov *et al.* 1984; Ivantsov & Grazhdankin 1997; Fedonkin *et al.* 1999).

Originally *Ventogyrus* was interpreted as a solitary, sessile, immobile organism, reaching up to 60 mm wide $\times$ 120 mm long and 40 mm high,

thought to have been buried in life position. The supposed boat-like shape of this organism was structurally supported by a single, longitudinal septum with additional septa branching off it, with several orders of branching. These septa surrounded regular chambers that decreased in volume with increasing distance from the central axis. One unique, unpaired chamber occurs at one end of the structure. The impression of a thin layer of enclosing tissue is preserved as an external cast, and the branching channels of an internal tubular system are preserved in exquisite detail (Ivantsov & Grazhdankin 1997).

The construction in *Ventogyrus* (one longitudinal septum, with numerous transverse septa surrounding chambers) was originally supposed to

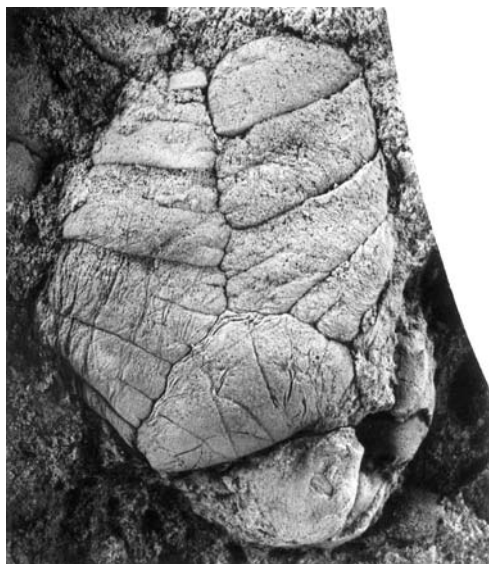


Fig. 3. *Ventogyrus chistakovi*, PIN No. 4564/1009, internal cast of module with well-preserved basal chamber. Yarnema, Onega Peninsula, White Sea region, northern Russia (M. Leonov).

be an architecture shared with other members of the Petalonamae, in particular with *Pteridium*. *Ventogyrus* was thus assigned to the family Pteridinidae of Richter (1955). The taxonomic status and true nature of this group remains today uncertain and is the centre of much ongoing discussion. In fact, the Phylum Petalonamae may well be a

heterogeneous group, not a natural or homologous phylogenetic grouping.

The questioning of the assignment of *Ventogyrus* to the Petalonamae arose when specimens in this genus with unusual preservation were collected by the authors from a new locality on the Onega River in 1997–1999 (Fig. 1). The fossil assemblage at this locality includes complex casts of *Ventogyrus* (Figs 2–7), numerous tubular forms called *Calyptrina*, rare forms that show similarity to *Podolimirus*, *Swartpuntia* and a few other new taxa, including a conulariid-like fossil *Vendiconularia* with three-fold symmetry (Ivantsov & Fedonkin 2002). *Calyptrina* itself was originally described based on specimens recovered in a drill core from the Ust'-Pinega Formation on the northern Russian Platform (Sokolov 1968), later found elsewhere in the lower part of the Upper Vendian sequence (Gnilovskaya 1996; Sokolov 1997). *Podolimirus* was originally described from deposits near the base of the Vendian sequence in outcrops along the Dniester River of the Ukraine (Fedonkin in Velikanov *et al.* 1983). *Swartpuntia*, on the other hand, was known from the uppermost part of the Neoproterozoic section in Namibia (Narbonne *et al.* 1997).

This new find is of significant importance, because a few specimens are preserved with their axes oriented vertically within a small sand channel. These specimens broke apart along their median septa, and reveal a far more complex internal construction than was previously known (Fig. 4). Three, not one, major longitudinal septa connected the outer wall with an axial rod (Fig. 7). The overall form of the organism was

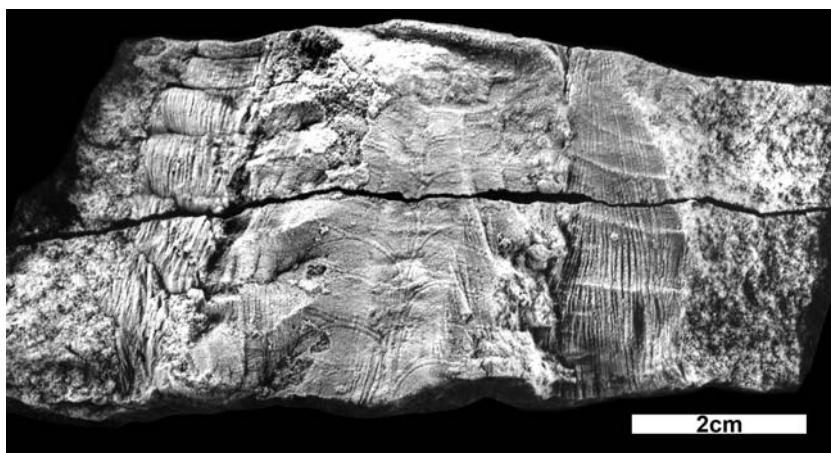


Fig. 4. *Ventogyrus chistakovi*, PIN No. 4564/1025, details of internal anatomy including the branching channel system in the middle part. The imprint was situated vertically in the host rock. Onega Peninsula, White Sea region, northern Russia (M. Leonov).



Fig. 5. *Ventogyrus chistakovi*, PIN No. 4564/1006, internal cast of two modules joined by their lateral and apical parts. The module on the left is strongly deformed but one can see its medial furrow and alternating position of the lobes. Yarnema, Onega Peninsula, White Sea region, northern Russia.

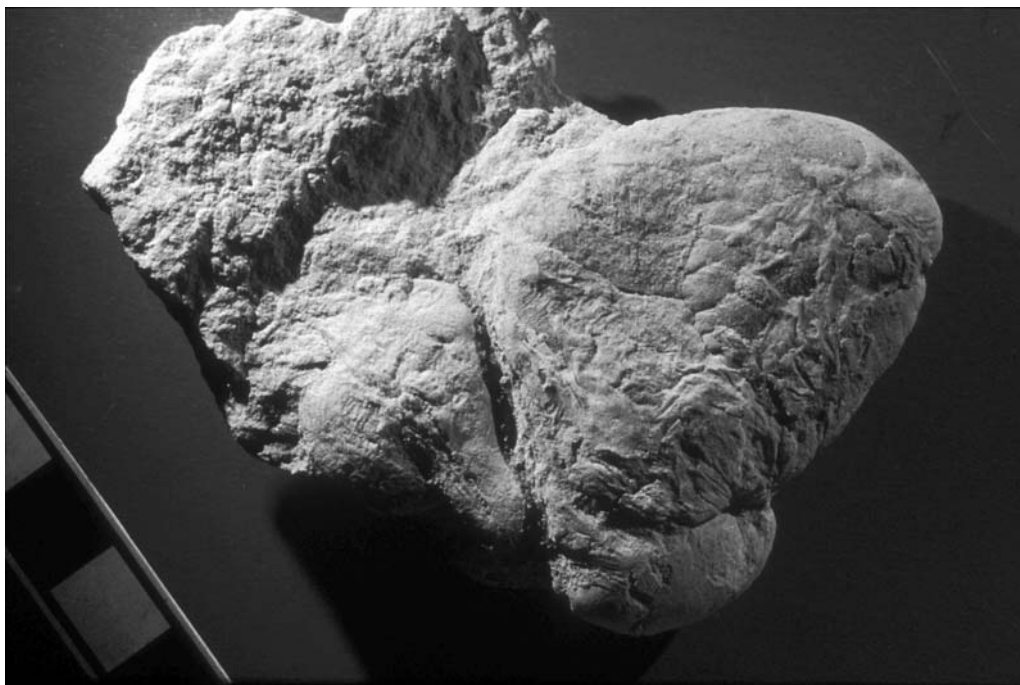


Fig. 6. *Ventogyrus chistakovi*, PIN No. 4564/1026, complex cast showing the external surface of the egg-shape body and the internal casts of the chambers (in the middle). Yarnema, Onega Peninsula, White Sea region, northern Russia.

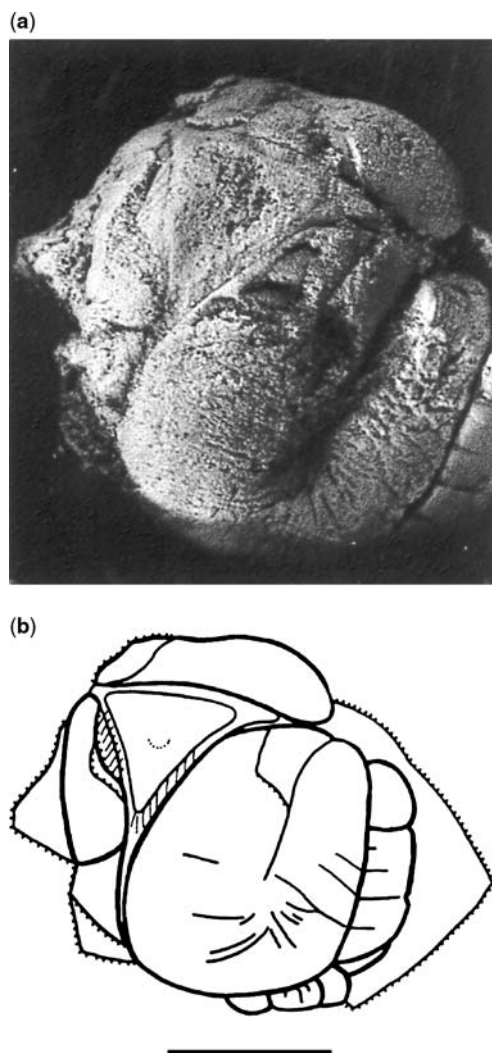


Fig. 7. *Ventogyrus chistyakovi*, (a) PIN No. 4564/1014, light from the top left, fragment of an internal cast viewed from its basal end; triangular base of a possible axial rod bordered by the three basal chambers variously deformed; (b) line drawing based on the photograph (scale: 1 cm).

not, indeed, boat-shaped, but instead more egg-shaped (Ivantsov 2001). The internal space was clearly divided into three distinct modules. The body was covered by thin integument which can sometime be preserved as an external cast (Fig. 6).

In the course of original study, fine linear structures were identified on what was thought to be the body surface of *Ventogyrus* (Ivantsov & Grazhdankin 1997). These structures have now been interpreted as likely part of a circulatory system, which

occurred beneath a thin membrane covering the body. New material clearly illustrates that these structures make up a complex internal system, consisting of at least three major channels (or tubes) that course along the axial rod (Figs 4, 8d). Each of the major channels branches laterally, originating from the axis in alternating order—the ‘symmetry of gliding reflection’ possessed by many of the Ediacarans. Lateral branches of the channels bifurcate a few times distally in a regular fashion. The width of these channels decrease step-wise at each branching point as they course away from the midline towards the periphery. This channel system spreads over the surfaces of the septa. The distal ends of channel branches intersect the transverse septa at points where these transverse septa meet the medial septum.

The complex system of septa certainly produced a stiffened organism. Additional rigidity of the entire body of *Ventogyrus* could have been provided by the content of the chambers themselves. Those could have been filled with body fluids or gas. *Ventogyrus* certainly exhibits a wide range of body deformation, and the fact that the chambers and module as a whole are preserved only when filled with sand supports the view that there was no cellular material or tissue inside the chambers.

If the chambers were filled with gas, it might have produced a strong positive buoyancy of such an egg-shaped organism. Such buoyancy could have allowed the organism to float or at least maintain a position in the water column above the sea floor. The bipolar structure of *Ventogyrus* may reflect an environmental gradient and suggest a vertical orientation of the body axis in life. Rare specimens which preserve the basal side of the body demonstrate the presence of a triangular cross-section of what appears to be an axial rod with a circular structure at its centre (Fig. 7a, b). We suggest that this round structure could represent the site where a stem could have attached, either to tether *Ventogyrus* to the bottom or to act as a stabilizer similar to such a structure known in recent floating cnidarian siphonophorans (Fig. 8). So far, however, no such stem has been found directly attached to the *Ventogyrus*. Numerous tubular and globular fossils (sand casts) associated with *Ventogyrus* may be parts of the same organism, but the more evidence must be obtained in the course of further field work to clarify such interpretations. Some researchers have suggested an alternative hypothesis—*Ventogyrus* reconstructed as an egg-shaped ctenophoran (Dzik 2003) floating with its wider end up (Ivantsov 2003).

Ventogyrus is best preserved in the submarine channel deposits, emplaced when storm or seasonal input brought about downslope avalanches, cut into the offshore platform and marine slope settings. It is

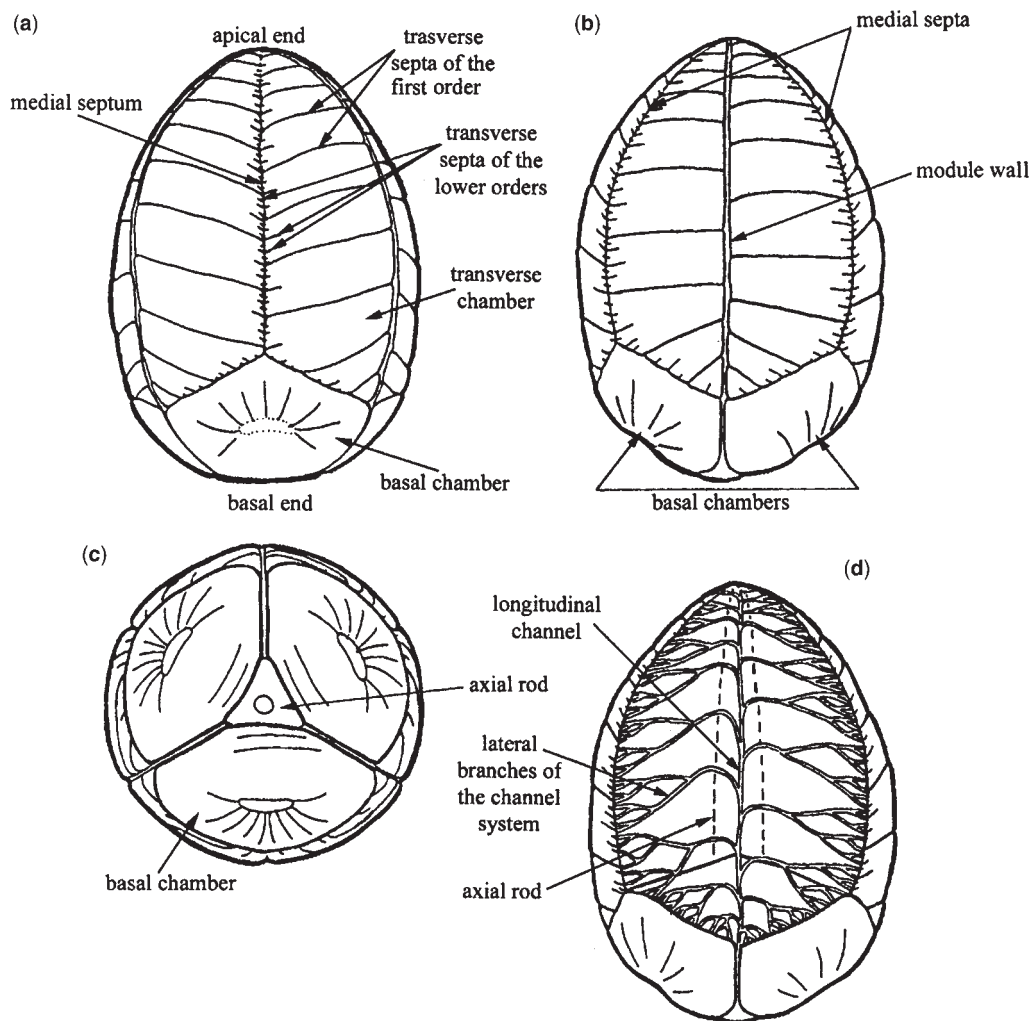


Fig. 8. Reconstruction of the internal anatomy of *Ventogyrus* with the cover tissue removed. (a) side views with one medial septum and a basal chamber in view; (b) side view of the same body rotated 60 degrees around the axis; (c) basal view; (d) view in the same position as (b), with two sectors of adjacent modules removed, morphology of one of three identical channel systems (after Ivantsov 2003).

rarely preserved in sediments that were deposited outside of these channels. The most abundant accumulation occurs well above the base of these channels, indicating that they were deposited within the sediments that were moving down the slope and not bottom dwellers that were suddenly overwhelmed by the sand avalanche. But, once again, further collection, careful mapping of the occurrence and association with other taxa need to be carried out before establishing the mode of life of this unusual organism.

At this point, too, it is difficult to relate the detail of the preserved material to any extant group.

Ventogyrus possesses a unique body plan, rather different from Phanerozoic organisms, but consistent with that of some other Ediacaran-Early Cambrian metazoans. The three-fold symmetry that so commonly makes its appearance in forms such as *Alburnares*, *Anfesta*, *Tribrachidium*, *Pteridinium* and *Hallidaya* is a linkage between all of these taxa and the reason the Class Trilobozoa was erected originally (Fedonkin, 1990, 3–120.). Such organisms may, in fact, be part of a high-ranking taxon that was replaced by the ‘new kids on the block’, which developed in the early part of the Phanerozoic, as metazoans gained hard

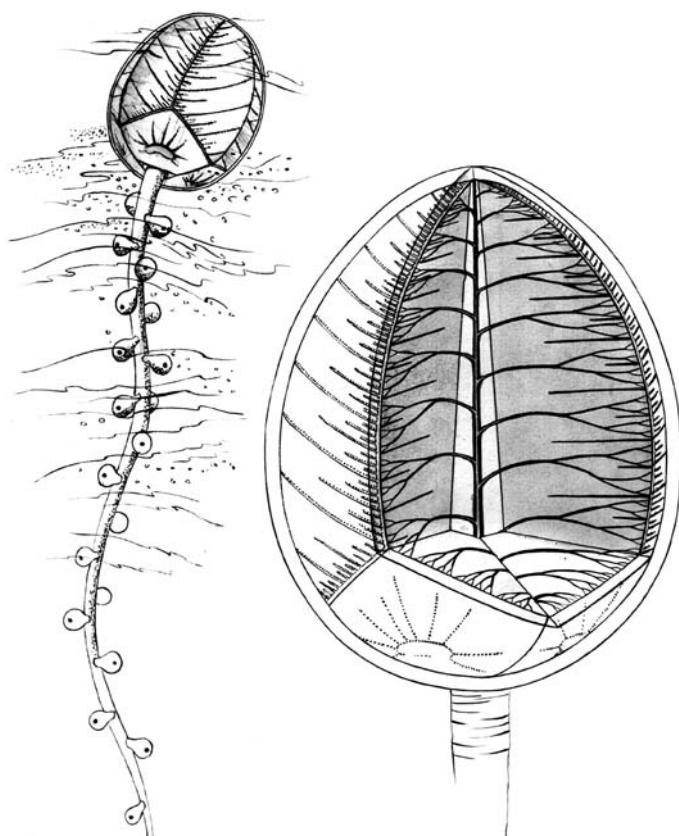


Fig. 9. Reconstruction of *Vento-gyrus* as a siphonophore-like coelenterate.

mineralized parts, the ability to burrow deeply and exploit effectively the food resources of the ocean and in doing so changed the world forever.

Comparison of soft body fossils (both casts and molds) of Ediacarans with skeletal remains of Cambrian organisms encounters some difficulties when one attempts to determine phylogenetic ties between the metazoans of these two periods. In the case of *Vento-gyrus* there is remarkable similarity of its axial rod with three major septa and similar structures found in Early Cambrian anabaritids—phosphatic conical fossils bearing outer septa, e.g. *Selindeochrea ternaria* or *Anabarites tricarinatus* (Missarzhevsky 1989; Rozanov & Zhuravlev 1992) and structures which certainly represent internal skeletons.

Vento-gyrus has such outstanding preservation of its detailed architecture that it needs considerably more attention—both in the field and in the laboratory—for it holds great promise for giving an indepth understanding of at least one high-rank taxon of the Ediacaran organisms.

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References

- AYALA, F. J., RZHETSKY, A. & AYALA, F. J. 1998. Origin of the metazoan phyla: Molecular clocks confirm paleontological estimates. *Proceedings of the National Academy of Science*, **95**, 606–611.
- CHISTYAKOV, V. G., KALMYKOVA, N. A., NESSOV, L. A. & SUSLOV, G. A. 1984. On the presence of the Vendian deposits in the mid-stream of Onega River and on the possible existence of tunicates (Tunicata: Chordata)

- in the Precambrian. *Vestnik of the Leningrad State University*, **6**, 11–19 [in Russian with English summary].
- DZIK, J. 2003. Anatomical information content in the Ediacaran fossils and their possible zoological affinities. *Integrative Comparative Biology*, **43**, 114–126.
- FEDONKIN, M. A. 1990. Non-skeletal fauna of the Vendian: promorphological analysis. In: SOKOLOV, B. S. & IWANOWSKI, A. B. (eds) *The Vendian System. 1. Paleontology*, Springer-Verlag, Berlin, 7–120, 132–137.
- FEDONKIN, M. A. 1992. Vendian faunas and the early evolution of Metazoa. In: LIPPS, J. H. & SIGNOR, P. W. (eds) *Origin and Early Evolution of the Metazoa*, Plenum Press, New York, 87–129.
- FEDONKIN, M. A. 2003. The origin of the Metazoa in light of the Proterozoic fossil record. *Paleontological Research*, **7**, 9–41.
- FEDONKIN, M. A. & WAGGONER, B. M. 1997. The late Precambrian fossil *Kimberella* is a mollusk-like bilaterian organism. *Nature*, **388**, 868–871.
- FEDONKIN, M. A., IVANTSOV, A. Y. & GRAZHDANKIN, D. V. 1999. Biostratigraphic potential of the Vendian fauna. In: *Stratigraphy, Paleontology, and Perspectives for Oil of the Riphean and Vendian of East Part of the East-European Platform, Proceedings*, Pt. 1 7–11, Pt. 2, 77–78 [in Russian].
- GEHLING, J. G. 1991. The case for Ediacaran fossil roots to the Metazoan tree. In: RADHAKRISHNA, B. P. (ed.) *The World of Martin Glaessner*. Geological Society of India Memoir, **20**, 181–224.
- GLAESSNER, M. F. 1984. *The Dawn of Animal Life—A Biohistorical Study*. Cambridge University Press, Cambridge.
- GNILOVSKAYA, M. B. 1996. New saarinids from the Vendian of the Russian Platform. *Doklady Rossiiskoi Akademii Nauk*, **348**, 89–93.
- IVANTSOV, A. Y. 2001. Dependence of reconstructions on the preservation character of the Ediacaran organisms. In: PONOMARENKO, A. G., ROZANOV, A. Y. & FEDONKIN, M. A. (eds) *Ecosystem Restructurings and Evolution of Biosphere*. Moscow, Paleontological Institute RAS, **4**, 64–67 [in Russian].
- IVANTSOV, A. Y. 2003. Vendian organisms are identified by the imprints. *Priroda*, **10**, 3–9 [in Russian].
- IVANTSOV, A. Y. & GRAZHDANKIN, D. V. 1997. A new representative of the Petalonamae from the Upper Vendian of the Arkhangelsk Region. *Paleontological Journal*, **31**, 1–16.
- IVANTSOV, A. Y. & FEDONKIN, M. A. 2002. Conulariid-like fossil from the Vendian of Russia: a metazoan clade across the Proterozoic/Palaeozoic boundary. *Palaentology*, **45**, 1219–1229.
- JENKINS, R. J. F. 1992. Functional and ecological aspects of Ediacaran Assemblages. In: LIPPS, J. H. & SIGNOR, P. W. (eds) *Origin and Early Evolution of the Metazoa*. Plenum Press, New York, 131–176.
- LIPPS, J. H., COLLINS, A. G. & FEDONKIN, M. A. 1998. Evolution of biological complexity: Evidence from geology, paleontology and molecular biology. In: HOOVER, R. B. (ed.) *Instruments, Methods, and Missions for Astrobiology*. Proceedings of the International Society for Optical Engineering, **3441**, 138–148.
- MISSARZHEVSKY, V. V. 1989. Oldest skeletal fossils and stratigraphy of Precambrian and Cambrian boundary beds. *Transactions of the Geological Institute, USSR Academy of Sciences*, **443**, 1–237 [in Russian].
- NARBONNE, G. M., SAYLOR, B. Z. & GROTZINGER, J. P. 1997. The youngest Ediacaran fossils from Southern Africa. *Journal of Paleontology*, **7**, 953–967.
- PETERSON, K. J. & BUTTERFIELD, N. J. 2005. Origin of the Eumetazoa: Testing ecological predictions of molecular clocks against the Proterozoic fossil record. Proceedings of the National Academy of Sciences, **102**, 9547–9552.
- RICHTER, R. 1955. Die ältesten Fossilien Sud-Afrikas. *Senckenbergiana Lethaea*, **36**, 243–289.
- ROZANOV, A. Yu. & ZHURAVLEV, A. Yu. 1992. The Lower Cambrian fossil record of the Soviet Union. In: LIPPS, J. H. & SIGNOR, P. W. *Origin and Early Evolution of the Metazoa*. Plenum Press, New York, 205–282.
- RUNNEGAR, B. N. & FEDONKIN, M. A. 1992. Proterozoic metazoan body fossils. In: SCHOPF, J. W. & KLEIN, C. (eds) *The Proterozoic Biosphere. A Multidisciplinary Study*. Cambridge University Press, New York, 369–388.
- SEILACHER, A. 1989. Vendozoa: Organismic construction in the Proterozoic biosphere. *Lethaia*, **22**, 229–239.
- SEILACHER, A. 1992. Vendobionta and Psammocorallia: Lost construction of Precambrian evolution. *Journal of the Geological Society of London*, **149**, 607–613.
- SOKOLOV, B. S. 1968. Vendian and Early Cambrian Sabelliditidae (Pogonophora) of the USSR. *Proceedings of the 23rd International Geological Congress*, 79–86.
- SOKOLOV, B. S. 1997. *Essays on the Advent of the Vendian System*. KMK Scientific Press, Moscow [in Russian with English summary].
- SOKOLOV, B. S. & IWANOWSKI, A. B. 1990. *The Vendian System. Volume 1*. Springer Verlag, Heidelberg.
- VALENTINE, J. W. 2004. *On the Origin of Phyla*. University of Chicago Press, Chicago.
- VALENTINE, J. W., JABLONSKI, D. & ERWIN, D.H. 1999. Fossils, molecules and embryos: New perspectives on the Cambrian Explosion. *Development*, **126**, 851–859.
- VELIKANOV, V. A., ASEVA, E. A. & FEDONKIN, M. A. 1983. *The Vendian of the Ukraine*. Naukova Dumka, Kiev [in Russian].