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Frontispiece

Radiolarian-inspired art design: Simplification and identification

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The makeup of a certain organism has been applied to human design activities, including architecture and art. Radiolaria, a type of holoplanktonic protozoa, contain siliceous shells that develop into various forms. Several artists have become interested in geometrically complex structures of radiolarians, and have created works of the art based on radiolarians (e.g. Hart, 1998, 2000; Morgante, 2017; Vones, 2018). These artificial expressions are diverse, ranging from the realistic to the abstract, and have been applied to several materials, such as the simplified image (Fig. 1A), silver model (Fig. 1B) and bead model (Figs. 1C, D). De Wever (2016) and Jungck *et al.* (2019) introduced several reproductions and architectural designs that were inspired by radiolarians. Nagai and Shiraki (2017a, b) reported on hand-sized realistic radiolarian models as an educational tool, which were either made in Europe or the United States from the late 19th century.

When an abstraction inspired by real organisms is created, the original forms are often simplified. Some scientific information is therefore lost. However, the simplified images of radiolarians illustrated by Moria (Fig. 1A)

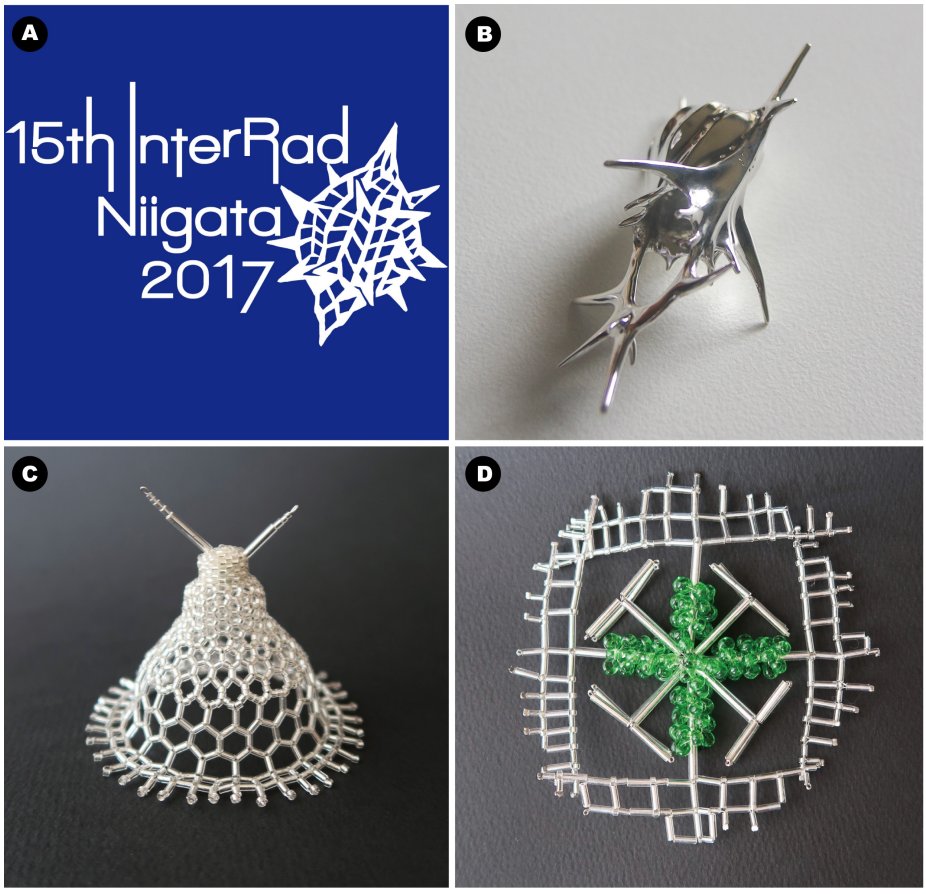

Fig. 1 Radiolarian-inspired artwork. A: Logo for InterRad XV in Niigata 2017 including simplified image of *Unuma echinatus* Ichikawa and Yao (created by Moria). B: Silver model of *Holoeciscus renzae* Schwartzapfel and Holdsworth, Devonian radiolaria (created by Yokoyama H.). C: Bead model of *Cycladophora pliocenica* (Hays), Neogene radiolaria (created by Ishiwata S.). D: Bead model of *Lithoptera muelleri* Haeckel, recent radiolaria (created by Ishiwata S.).

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have retained this scientific information, which is identifiable at the species level. In other words, Moria's simplified images were drawn through science-based selective simplification. Meanwhile, the radiolarian silver models created by Yokoyama, H. (Fig. 1B) were precisely-reproduced to retain as much of the original scientific information as possible. The bead models created by S. Ishiwata (Figs. 1C, D) were modified from original species under the limit of the materials, i.e. the models are composed of rod-shaped beads. Green beads of the model (Fig. 1D) expressed symbiotic algae of *Lithoptera muelleri* Haeckel.

Indeed, selective simplification is also important when conducting scientific activities (e.g. creating accurate sketches and schematic models). As such, this study discusses case examples of art designs that were inspired by both organisms and science-based simplification. Here, we introduce simplified images and precisely reproduced silver models involving two radiolarian species (i.e. *Unuma echinatus* and *Neoalbaillella pseudogrypus*).

***Unuma echinatus* Ichikawa and Yao**

The Middle Jurassic *Unuma echinatus* Ichikawa and Yao was a symbolic radiolaria at InterRad XV in Niigata 2017 (the 15th Meeting of the International Association of Radiolarists). That is, the InterRad XV logo implemented this species into its design (Fig. 1A), which was used in the meeting's publication materials (e.g. Matsuoka and Ito, 2017; Ito *et al.*, 2017).

Ichikawa and Yao (1976) described this species as *Unuma* (*Spinunuma*) *echinatus* (Fig. 2A). Subsequent studies have generally not used the subgenus *Spinunuma*. Thus, the subgeneric diagnosis is currently an essential descriptor for this species. The diagnosis is as follows: "*Unuma* with well-developed apical horn, numerous stout

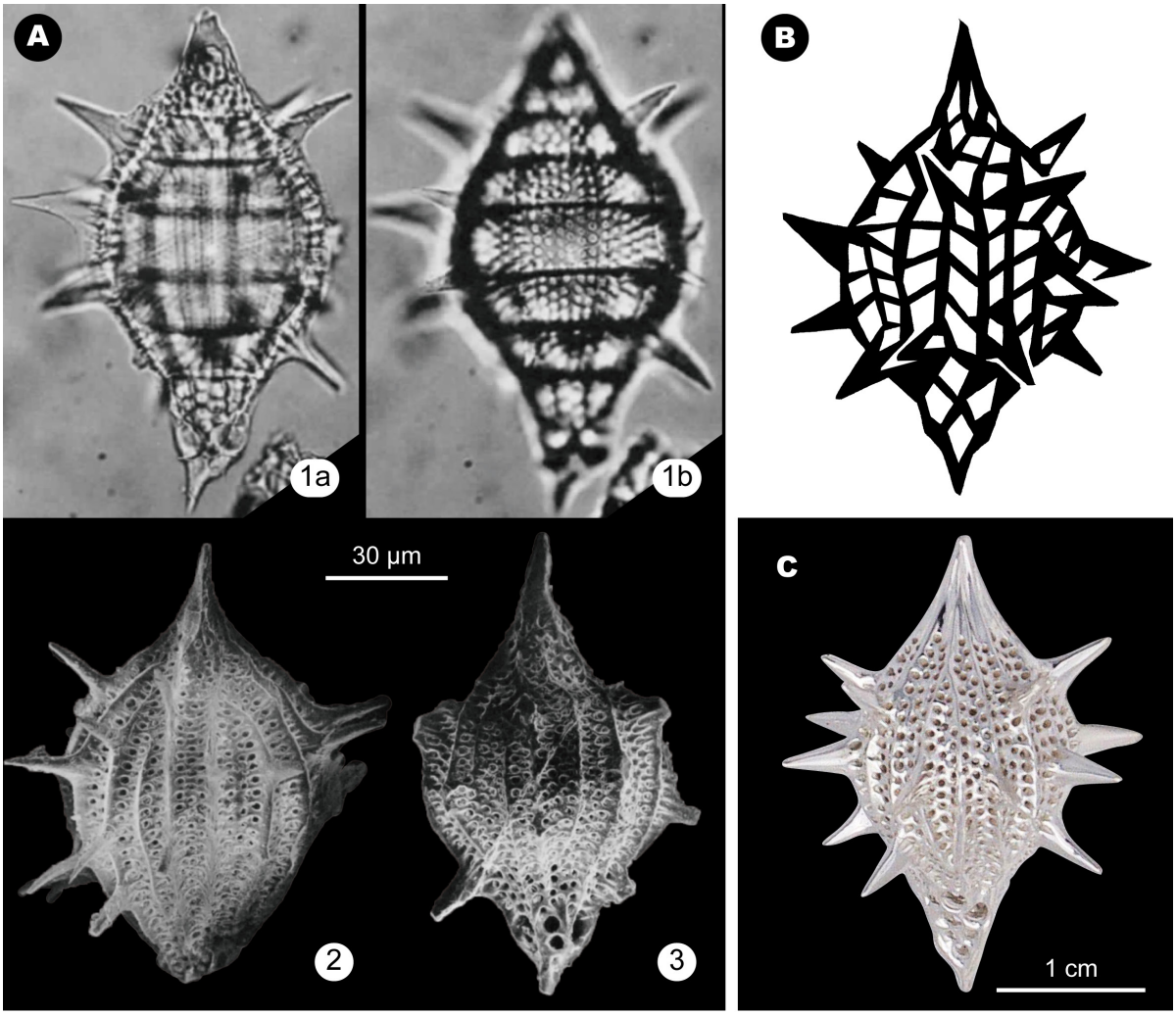

Fig. 2 *Unuma echinatus* Ichikawa and Yao. A: Reprinted type specimens from Ichikawa and Yao (1976). (1) Transmitted photomicrographs of holotype. (2) Scanning electron microscopy (SEM) image of paratype. (3) SEM image of paratype. B: Simplified image illustrated by Moria. C: Silver model created by H. Yokoyama.

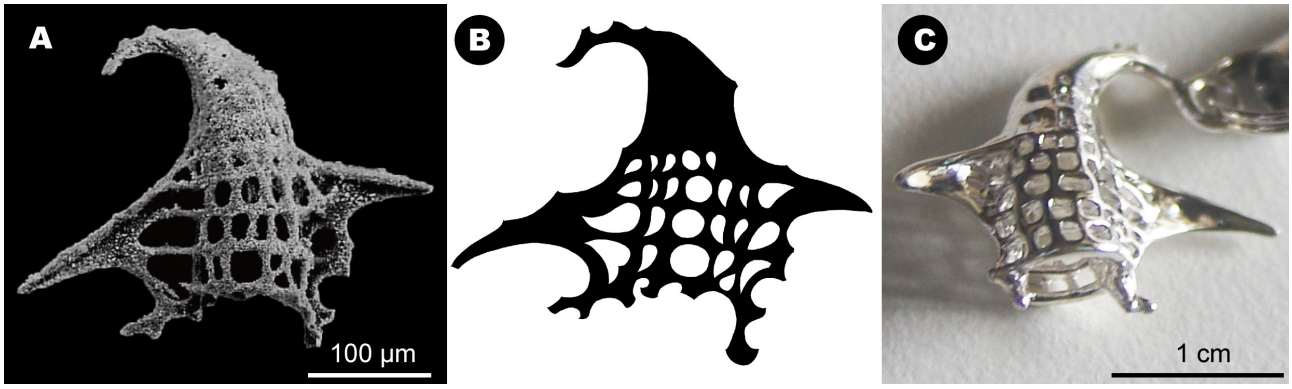

Fig. 3 *Neoalbaillella pseudogrypus* Sashida and Tonishi. A: Reprinted type specimen (SEM image of holotype) from Sashida and Tonishi (1988). B: Simplified image illustrated by Moria. C: Silver model created by H. Yokoyama.

radial spines, and distinct basal spine." The silver model reproduced the diagnosis (Fig. 2C). The simplified image of *U. echinatus* (Fig. 2B) reflects this diagnosis as well, i.e. it contains a well-developed apical horn, numerous stout radial spines and a distinct basal spine. However, some points have been modified to differ from the original characteristics. For example, the surface pores of these specimens are small and circular (Figs. 2A, 2C), while those of the simplified image are large and polygonal (Fig. 2B).

***Neoalbaillella pseudogrypus* Sashida and Tonishi**

The diagnosis of the late Permian radiolaria *Neoalbaillella pseudogrypus* Sashida and Tonishi is "*Neoalbaillella* containing a bilaterally symmetrical shell with strongly curved apical cone and cylindrical pseudoabdomen having 3 to 4 horizontal rows of large square to rectangular windows" (Fig. 3A) (Sashida and Tonishi, 1988). The silver model reproduced the diagnosis as well (Fig. 3C). There are a few similar species, including *Neoalbaillella grypus* Ishiga, Kito and Imoto. However, *N. grypus* has a long pseudoabdomen (Ishiga *et al.*, 1982).

The simplified image of *N. pseudogrypus* (Fig. 3B) possesses the above characteristics (i.e. a strongly curved apical cone and cylindrical pseudoabdomen having 3 to 4 horizontal rows of large square to rectangular windows). However, the surface pores of these specimens and the silver model are grid-like (Figs. 3A, 3C), while those of the simplified images are circular and teardrop-shaped (Fig. 3B).

As is the case in *U. echinatus*, the shape of the surface pores of *N. pseudogrypus* differs between the original specimens and the simplified image. The simplified image of *U. echinatus* has polygonal pores (Fig. 2B) although the original specimens possess circular ones (Fig. 2A), i.e. the surface pores of the simplified image are more angular than those of the original specimens. Contrastively, the simplified image of *N. pseudogrypus* expressed more circular pores (Fig. 3B) compared to the original specimens (Fig. 3A).

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