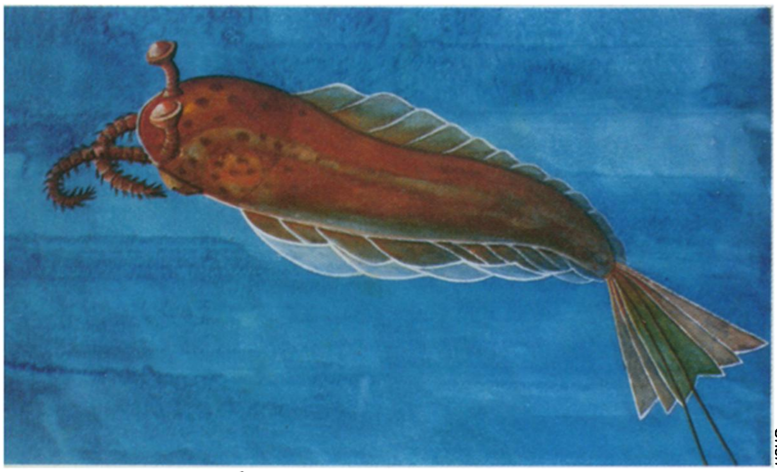
The First Monsters

Long before sharks, *Anomalocaris* ruled the seas

By RICHARD MONASTERSKY

The doomed trilobite scuttled across the floor of some prehistoric ocean, oblivious to a pair of bulbous eyes projecting up out of the muck like twin periscopes. As the unsuspecting animal passed, the camouflaged predator bolted from its lair, raising a cloud of obscuring silt.

The trilobite rolled into an armored ball, its hardened shell forming a nearly impenetrable shield. But against this opponent, the defensive gesture provided little protection. Two grasping limbs plucked the trilobite off the seafloor and popped it into a circular mouth unlike any known on the planet today. A ghastly ring of teeth crushed the shell as if it were a nut.



Chen

Anomalocaris — *a stranger no more.*

Just as it terrorized the seas of Earth's Cambrian period a half billion years ago, this nightmarish creature called *Anomalocaris* has plagued paleontologists since the 1880s, when parts of the strange beast first surfaced. A century passed before researchers could finally piece together the different parts of this anatomical oddity. Today, *Anomalocaris* and its kin are yielding new secrets, thanks to specimens recently uncovered in southwest China and other regions.

"We have found the earliest monsters," declares Jun-yuan Chen of the Nanjing Institute of Geology and Paleontology, referring to the extreme antiquity of the Chinese animals. These anomalocaridids are the oldest-known large predators in the fossil record, and their presence in the Cambrian seas reveals that an elaborate ecosystem had developed far earlier than paleontologists previously thought.

The anomalocaridids appeared at a turning point in the history of life. Prior to the start of the Cambrian period 544 million years ago, animals had extremely simple bodies capable of limited motion. A zoo at the close of Precambrian time would have displayed a relatively mundane array of creatures related to jellyfish and coral; the star attractions would have been wormlike animals, which distinguished themselves with their ability to slither across the seafloor.

At the beginning of the Cambrian, however, life took a sudden turn toward the complex. In a few million years — the equivalent of a geological instant — an ark's worth of sophisticated body types filled the seas. This biological burst, dubbed the Cambrian explosion, produced the first skeletons and hard shells, antennae and legs, joints and jaws. It set the evolutionary stage for all that followed by giving rise to most of the major phyla known on Earth today. Even our own chordate ancestors got their start during this long-past era.

Yet alongside the familiar arthropods, echinoderms, mollusks, and other phyla, this frenzy of innovation produced many creatures that defy imagination. The history of *Anomalocaris* research, littered with errors, demonstrates the difficulty paleontologists have experienced in trying to crack some of these conundrums.

"The unfolding story of the anomalocaridids (the group including *Anomalocaris* and its near relatives) is almost as unlikely as the animal itself," declares paleontologist Derek E.G. Briggs of the University of Bristol in England in the May 27 SCIENCE.

Through the years, researchers have misidentified almost all major parts of *Anomalocaris*, sticking them on a variety of other animals almost like a game of pin the tail on the donkey. Even the creature's name, which means "odd shrimp," has its origins in a mistake. When Canadian paleontologist J. F. Whiteaves found the front appendages of *Anomalocaris* in 1886, he identified them as the body of a shrimplike crustacean with an unknown type of head, recounts Stephen J. Gould in his book *Wonderful Life: The Burgess Shale and the Nature of History* (1989, Norton).

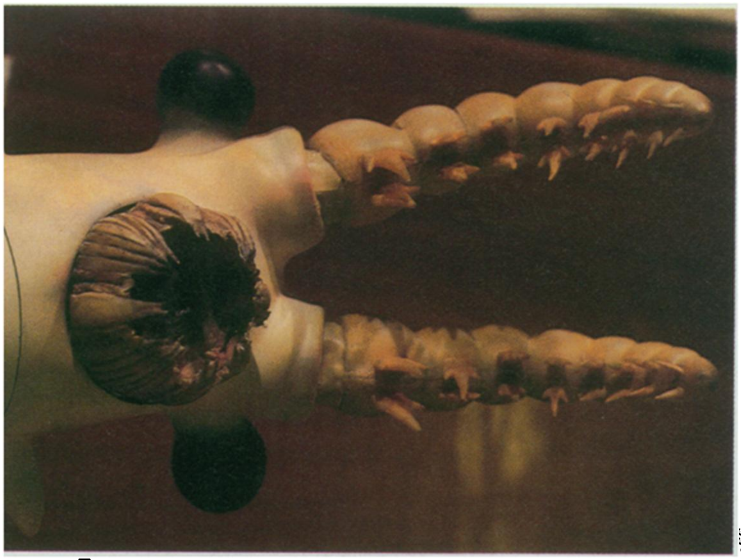
Charles Doolittle Walcott made the next set of errors after discovering the rich deposit of Cambrian fossils in Canada's Burgess Shale in 1909. He classified the broad *Anomalocaris* body as the squashed remains of a sea cucumber. At the same time, he put an *Anomalocaris* appendage on the head of a different creature called *Sidneyia*. As for the peculiar ring-shaped mouth, Walcott identified this as a flattened jellyfish with a hole in the middle.

For over 70 years, the giant predator lay disassembled and unknown, until Harry B. Whittington of the University of Cambridge in England and his then-student Briggs finally put the pieces of the puzzle together. During careful study of fossils from the Burgess Shale, they discovered the feeding appendages, mouth, and body of *Anomalocaris* in their bizarre but true-to-life positions.

In their reconstruction, Whittington and Briggs envisioned a 60-centimeter-long animal that raised and lowered its side flaps as a form of underwater wings. The resulting undulating motion would have resembled the way modern manta rays swim. Compared to most other Cambrian animals, which measured no longer than a finger, this flounder-sized predator qualified as a giant.

Whittington and Briggs noted that the jointed front appendages had just the right reach and flexibility to capture prey and pass it back to the strange circular mouth. Unlike most maws, this ring of 32 teeth could not close completely. Rather, it worked by crunching food and pushing the pieces to additional rings of teeth inside. Some specimens from the Burgess Shale showed three circles of teeth stacked one atop the other.

While the animal made sense anatomically, the researchers could not fit it into any existing taxonomical category. With its jointed feeding appendages and segmented body, *Anomalocaris* looked somewhat like an arthropod — the great



Briggs

Food goes here: A set of sharp teeth surrounded Anomalocaris' *round mouth, positioned on the underside of the animal. Researchers speculate that the tips of the teeth could move toward and away from the body, thereby opening or closing the mouth's aperture. Some Chinese anomalocaridid specimens show up to eight rings of teeth, arranged concentrically, leading into the mouth.*

phylum that includes insects and crustaceans. But the resemblance ended there. Neither the mouth nor the body of the animal showed a connection with arthropods or any other phylum. The only group in which *Anomalocaris* seemed to belong was a grab bag of misfits with the self-explanatory title of "problematica."

A decade later, paleontologists know that *Anomalocaris* was not alone. Excavations from 1990 through 1992 outside the city of Chengjiang in southwest China have turned up three similar, but distinct, creatures belonging to the anomalocaridids, report Chen and Nanjing colleague Gui-qing Zhou, who collaborated with Lars Ramsköld of the University of Uppsala in Sweden. They describe the Chinese finds in the May 27 SCIENCE.

Chen and his colleagues have added more parts to the body of *Anomalocaris.* The Chinese specimens reveal that the animal had a broad tail with a pair of long, trailing spines – elements missing from the creatures described by Whittington and Briggs. The tail and spines are also preserved on a complete specimen collected in 1991 by Desmond Collins of Toronto's Royal Ontario Museum, who is working near Walcott's original quarry in the Burgess Shale.

The second type of giant predator from Chengjiang resembles *Anomalocaris,* but it had a wider body and shorter front grasping limbs, each armed with daggerlike pincers.

A third type is known only by its imposing jaws: Chen and coworkers found a large ring of teeth measuring 25 cm across, which apparently belonged to another anomalocaridid. Judging from the dimensions of complete *Anomalocaris* specimens, the researchers estimate that this beast would have reached 2 meters in length, making it bigger than most people.

Unlike Whittington and Briggs, Chen's group believes that *Anomalocaris* propelled itself with fishlike movements of its body and tail instead of its side flaps. "Side-flap swimming is very energy-consuming. I don't think they would get any speed that way," Chen says.

Because the predators had flat bodies, Chen and his colleagues suggest that "anomalocaridids may have spent much time partly buried or camouflaged in the bottom sediment, with the stalked eyes protruding over the bottom and scanning the surroundings for swimming prey."

Taken together, the range of new fossils points to a wide variety of eating habits. The two new Chinese forms as well as the original *Anomalocaris* have front limbs well designed for grasping large animals, says Briggs. In the case of the gaping jaws from Chengjiang, this anomalocaridid could easily have consumed something the size of a human head.

A new type of *Anomalocaris* from Australia, however, went for more delicate fare. It had front limbs suited for straining small animals from the water. Another relative, called *Peytoia,* bore long, rakelike appendages apparently adapted for combing through seafloor sediments, Briggs says. He was the first to recognize the use of this limb back in 1979, although he did not know to what creature it belonged until 2 years later.

The anomalocaridid discoveries have forced paleontologists to redraw their earlier, simplistic image of life in the ancient oceans. Not only did the Cambrian explosion produce a diversity of different body types, it also gave birth to a remarkably complex ecology.

"Originally," says Briggs, "people regarded the Cambrian as a rather early stage in the development of ecosystems. The assumption was that predation wouldn't have been a very well developed strategy."

According to this theory, the earliest predators would have started off as relatively simple creatures that then evolved more specialized features over many millions of years. As the predators added to their offensive weaponry, prey would evolve sophisticated defense systems.

But the fossils show that the arms race accelerated almost overnight during the Cambrian explosion. Creatures with hard shells and long spines abound in the Chengjiang fauna, displaying a broad sweep of protective armor. Likewise, *Anomalocaris* appeared on the scene with an array of formidable feeding tools.

"Things like *Anomalocaris* indicate that there were very highly evolved, large, well-adapted predators even in the lower Cambrian. It indicates that the Cambrian ecosystems were not that dissimilar to the types of things that you see today. There were different organisms occupying the niches, but it was the same sort of setup," says Briggs.

Chen agrees that the early Cambrian ecology blossomed quickly. "There was a highly developed ecosystem. The food chain was as complicated as it is today," he says.

When they described *Anomalocaris* a decade ago, Whittington and Briggs regarded the creature as an evolutionary dead end, without a home in any existing phylum. But new interpretations, driven by fossil discoveries, are starting to make sense of these peculiar predators.

Chen and his colleagues see a distinct resemblance between anomalocaridids and two other Cambrian oddballs: a creature from Greenland called *Kerygmachela* (SN: 7/11/92, p.22) and another called *Opabinia* from the Burgess Shale. By Chen's analysis, the Greenland creature was the closest relative of the anomalocaridids because both possessed a pair of movable front appendages, 11 body segments, side flaps and two long rear spines.

Opabinia – which looked somewhat like a swimming vacuum cleaner because of its long , hoselike front appendage – also resembled the anomalocaridids in having large eyes on stalks, side flaps, two rear spines and a similar tail. Chen's team therefore folds anomalocaridids, *Kerygmachela,* and *Opabinia* together in a taxonomic category closely related to arthropods, perhaps even with the phylum Arthropoda.

A once unclassifiable patchwork of body parts, *Anomalocaris* is finally revealing its kinship with the more familiar phyla of animal life. "We no longer need to think of anomalocaridids as something really strange or bizarre. It's beginning to look like quite an important group, one pretty close to the arthropods," says Briggs.

With that, paleontologists are finding the early Cambrian seas an easier place in which to navigate. □