
zooplankton

Plankton - from the Greek for "drifter" or "wanderer"

- a diverse collection of organisms unable to propel themselves against a current

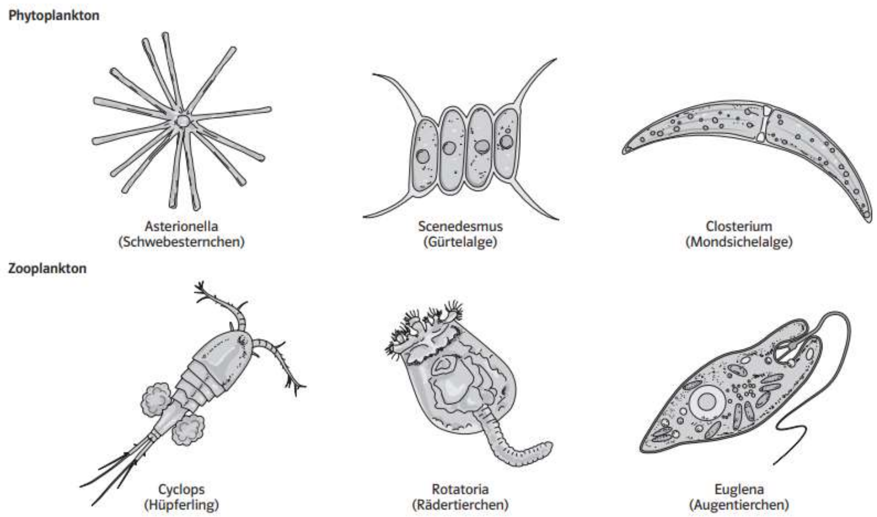
$$\text{sinking velocity} = \frac{\text{overweight}}{\text{form drag x viscosity}}$$

Adaptations to avoid /reduce sinking:

- flat bodies,
- lateral spines

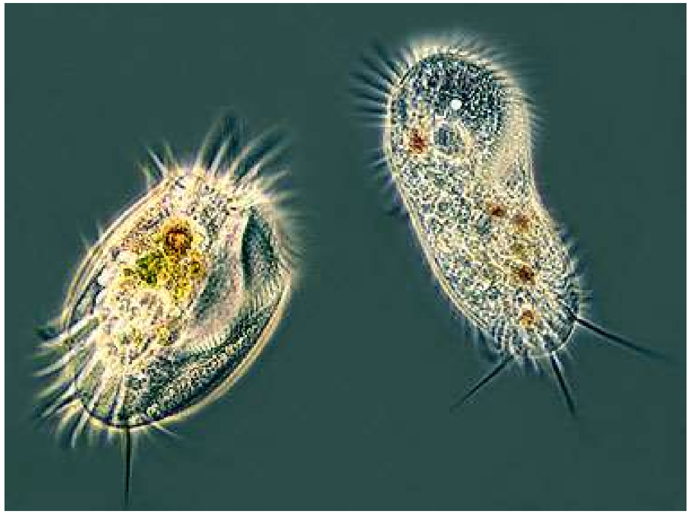
increasing the surface area while minimizing the volume of the body

- oil droplets,
- floats filled with gases,
- sheaths made of gel-like substances,
- ion replacement



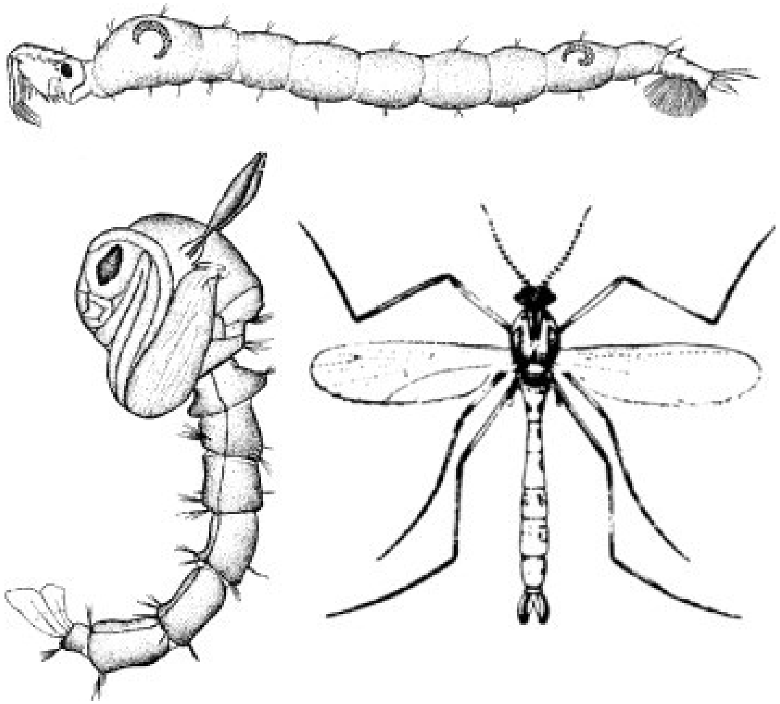
Dominant Taxa:

Ciliata *(unicellular protists):*



Euplotes (left) and *Stylonychia* (right)
(Mic-UK: Ciliates (microscopy-uk.org.uk))

Diptera,
Chaoboridae (Büschelmücken)



Fourth instar larva (top), pupa (left), and adult (right) of *Chaoborus punctipennis*. Adapted from Johannsen OA (1934) Aquatic Diptera. Part I. Nemocera, exclusive of Chironomidae and Ceratopogonidae. *Memoirs of the Cornell University Agricultural Experimental Station* 164: 1–70.

Dominant Taxa:

Rotatoria:

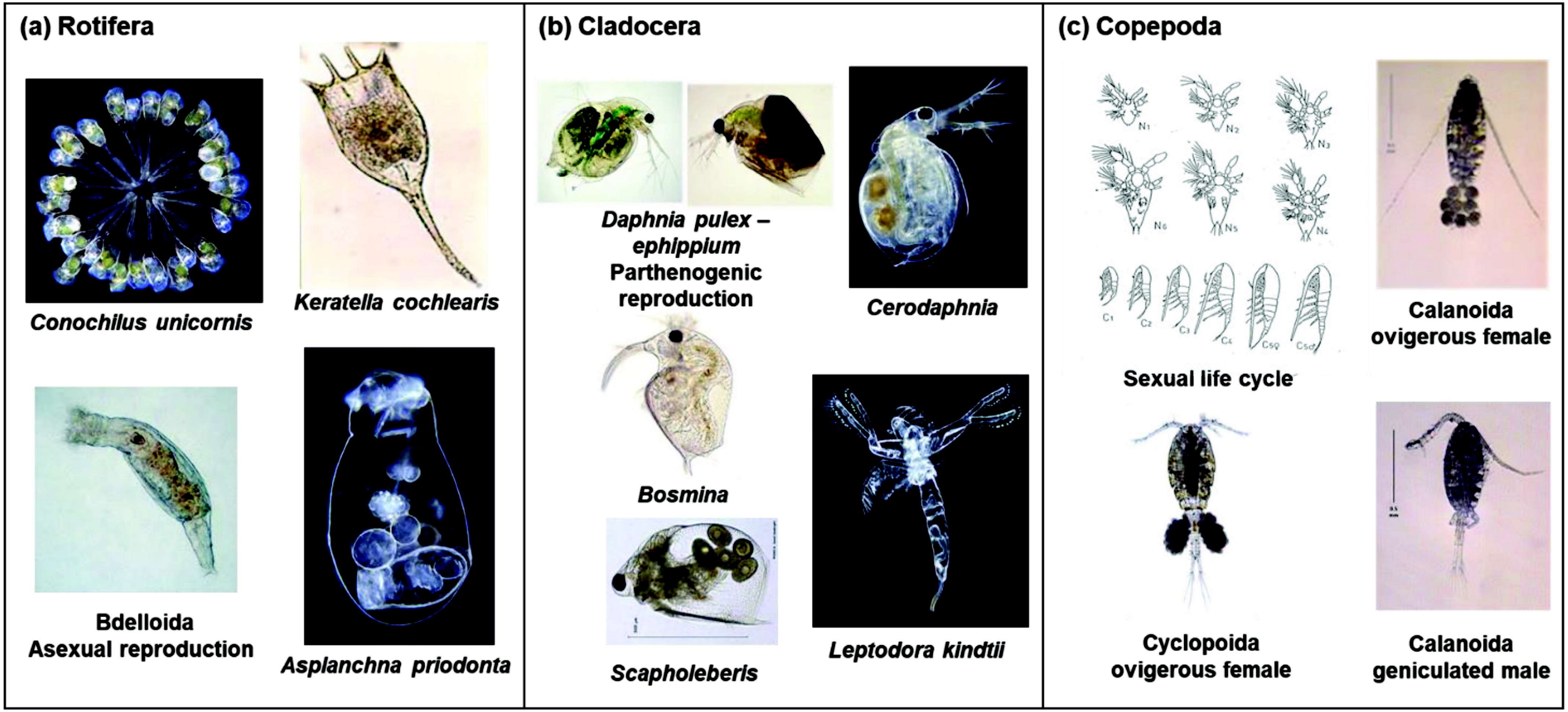
Crustacea:

Phyllopoda, Blattfußkrebse

Cladocera (Wasserflöhe)

Maxillopoda, Copepoda,

(Ruderfußkrebse, Hüpferlinge)

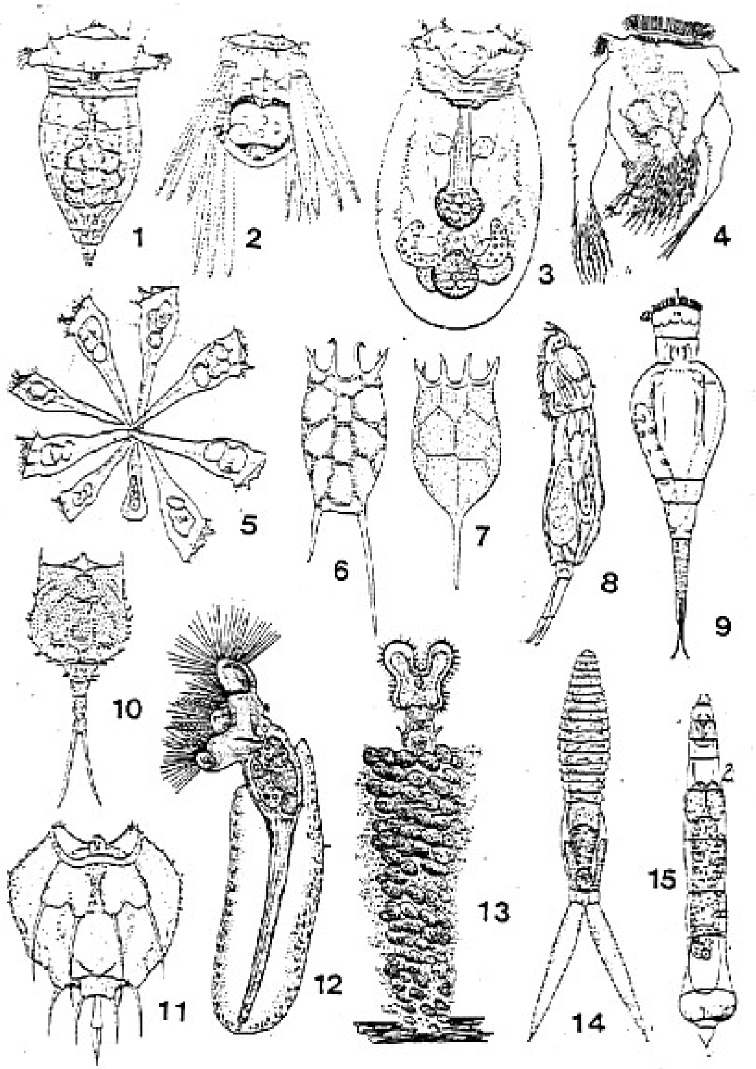


(Bernadette Pinel-Alloul et al. 2021)

Zooplankton as a source of biodiversity in forms and functions: (*a*) Rotifera, (*b*) Cladocera, (*c*) Copepoda. [Colour online.]

Rotatoria

About 2,375 species of rotifers in freshwater, only 125 in the ocean



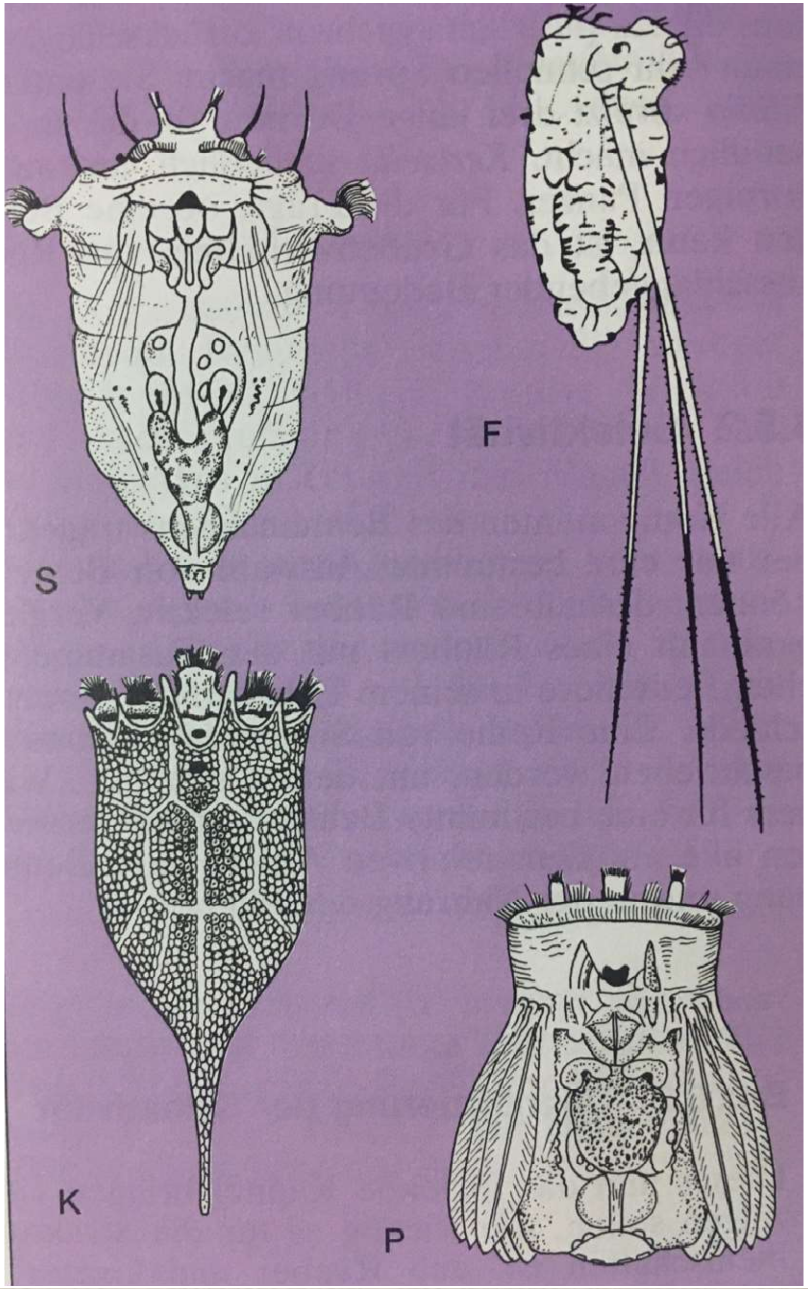
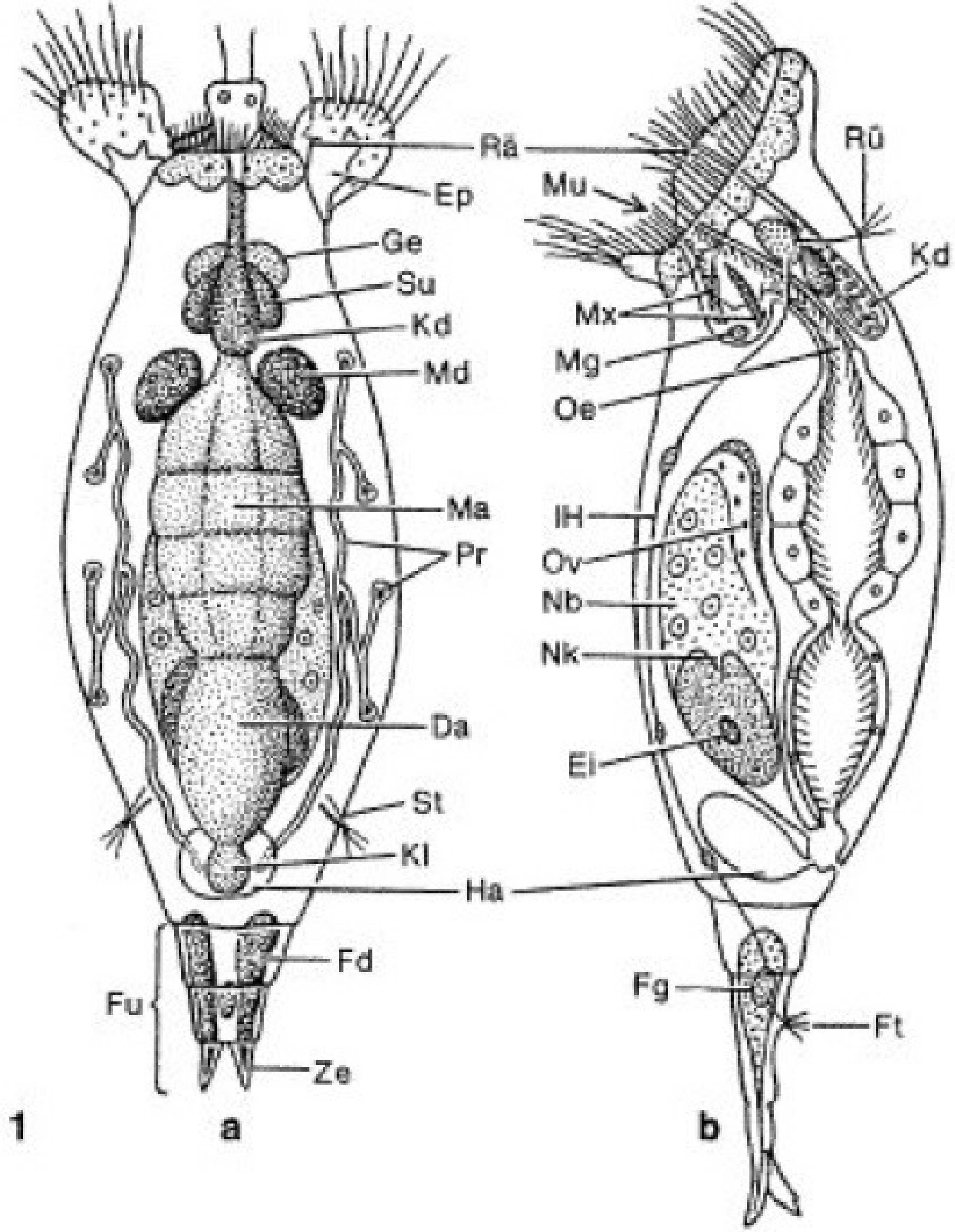
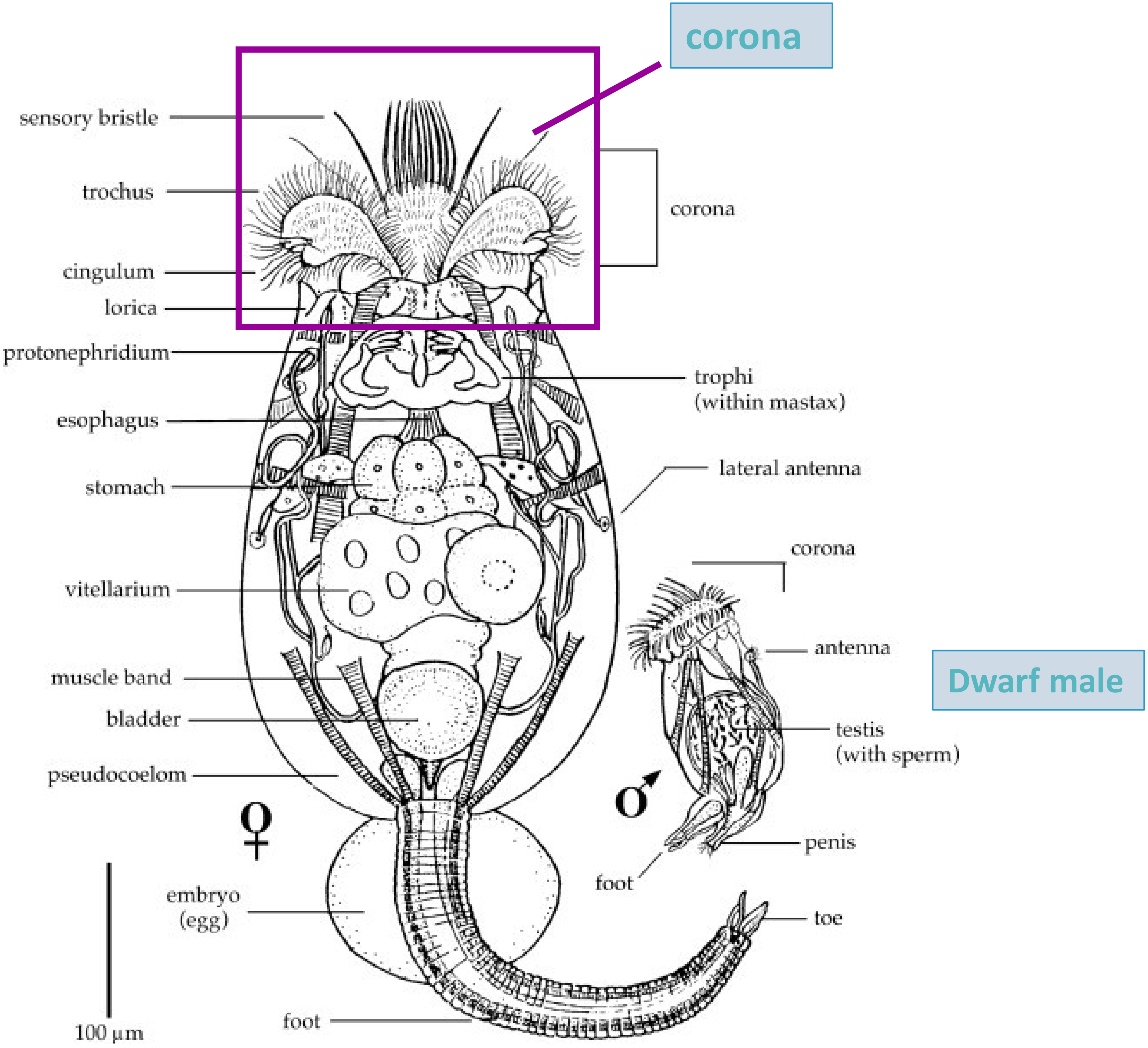


Abb. 6.**19** Rotatorien mit unterschiedlichen „Verteidigungsmechanismen". Die weichhäutige *Synchaeta* (S) kann nicht entkommen. *Filinia* (*F*) kann drei lange Dornen abspreizen. *Polyarthra* (*P*) kann mit ihren flossenartigen Anhängen schnelle Fluchtsprünge ausführen. *Keratella* (*K*) ist durch einen Panzer geschützt

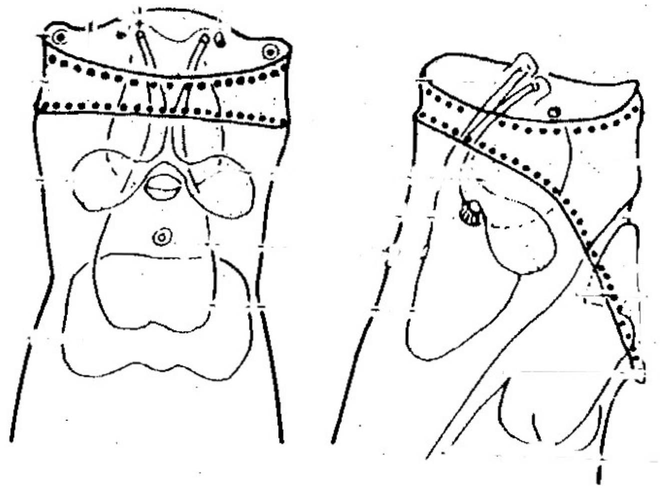


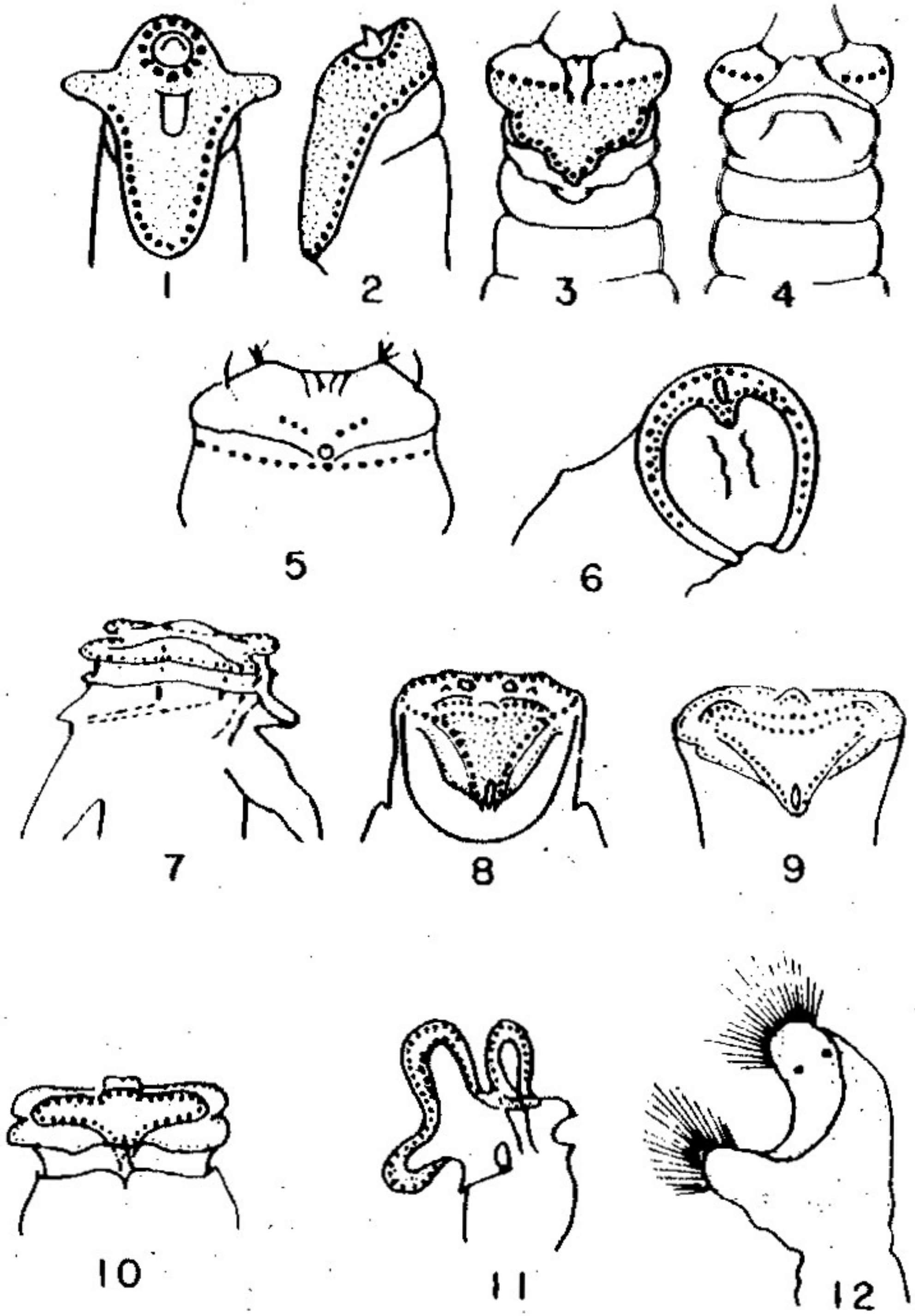
Rädertiere

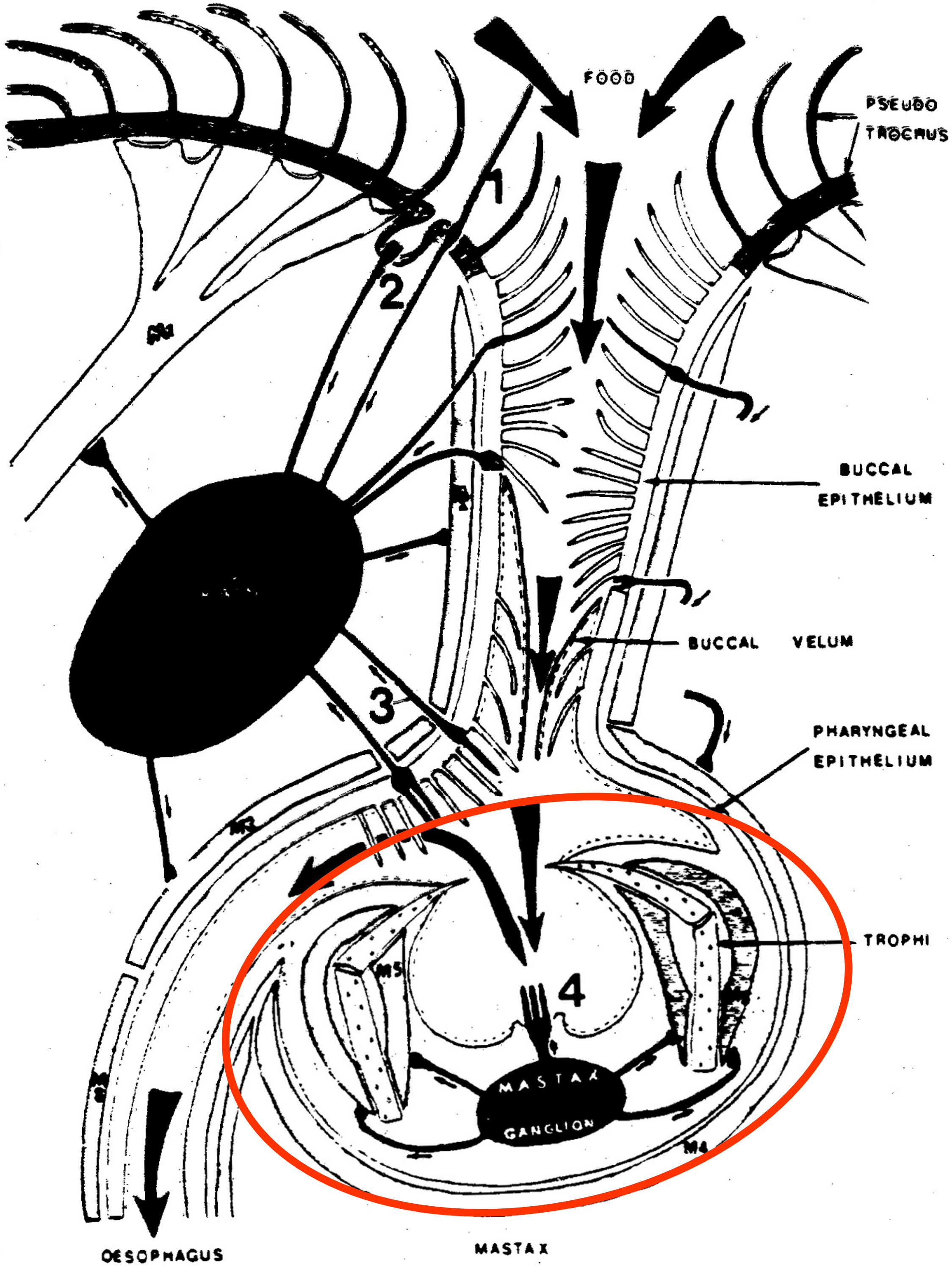
1 Organisationsschema eines Rädertieres, **a** Ventral-, **b** Seitenansicht. Da Darm, Ei Eizelle, Ep Epidermiswulst, Fd Fußdrüse, Fg Fußganglion, Ft Fußtaster, Fu Fuß, Ge Gehirn, Ha Harnblase, Kd Klebdrüse, Kl Kloake, lH linker Hauptnerv, Ma Magen, Md Magendrüse, Mg Mastaxganglion, Mu Mund, Mx Mastax mit Kauer, Nb Nährbezirk, Nk Nährkanal, Oe Oesophagus, Ov Ovar mit Keimlager, Pr Protonephridialsystem, Rä Räderorgan, Rü Rückentaster, St Seitentaster, Su Subcerebraldrüse, Ze Zehe.


corona
sensory bristle
trochus
cingulum
lorica
corona
protonephridium
trophi
(within mastax)
esophagus
lateral antenna
stomach
corona
vitellarium
antenna
Dwarf male
muscle band
bladder
testis
(with sperm)
pseudocoelom
♀
♂
penis
foot
embryo
(egg)
toe
foot
100 µm

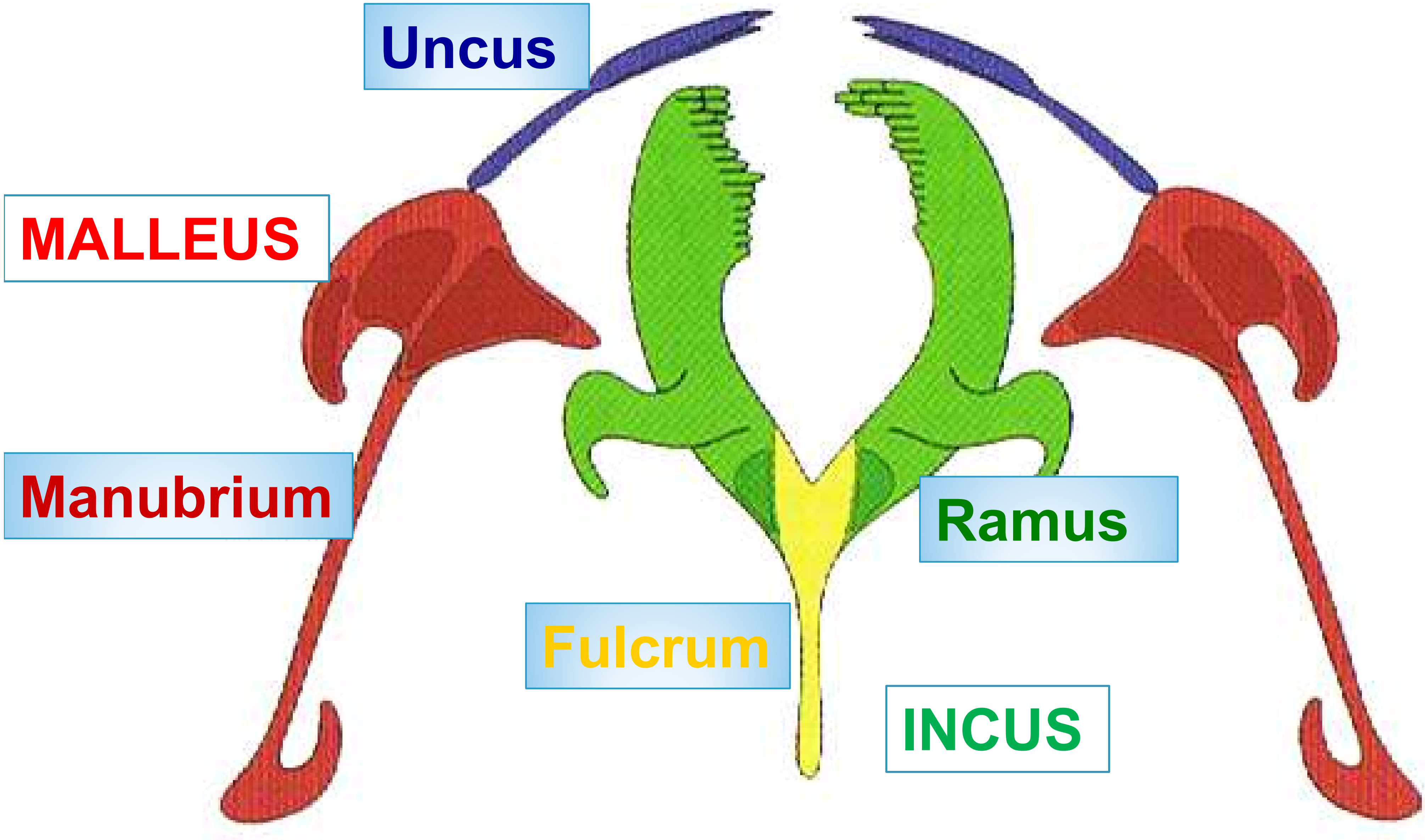
Different types of the corona

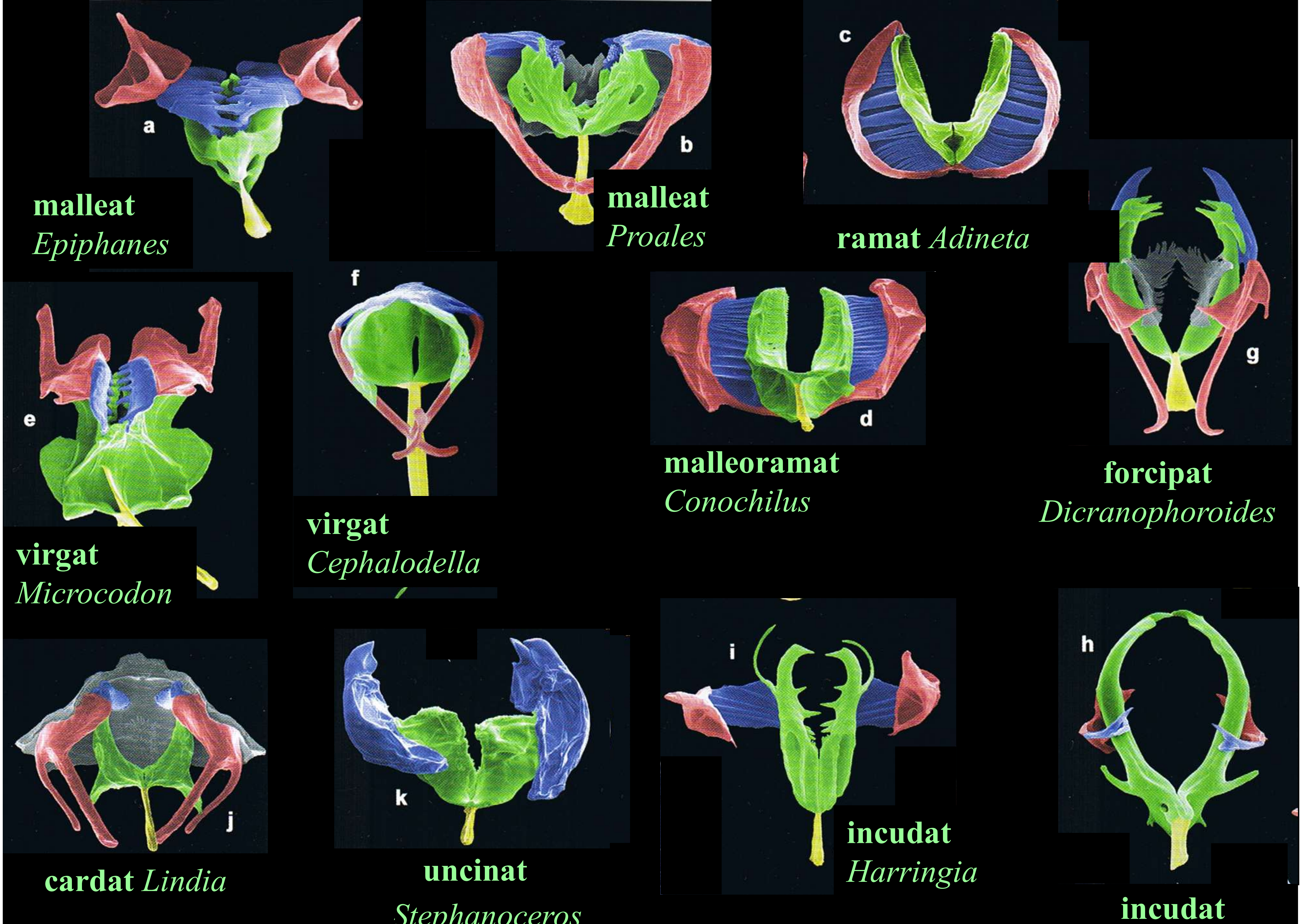




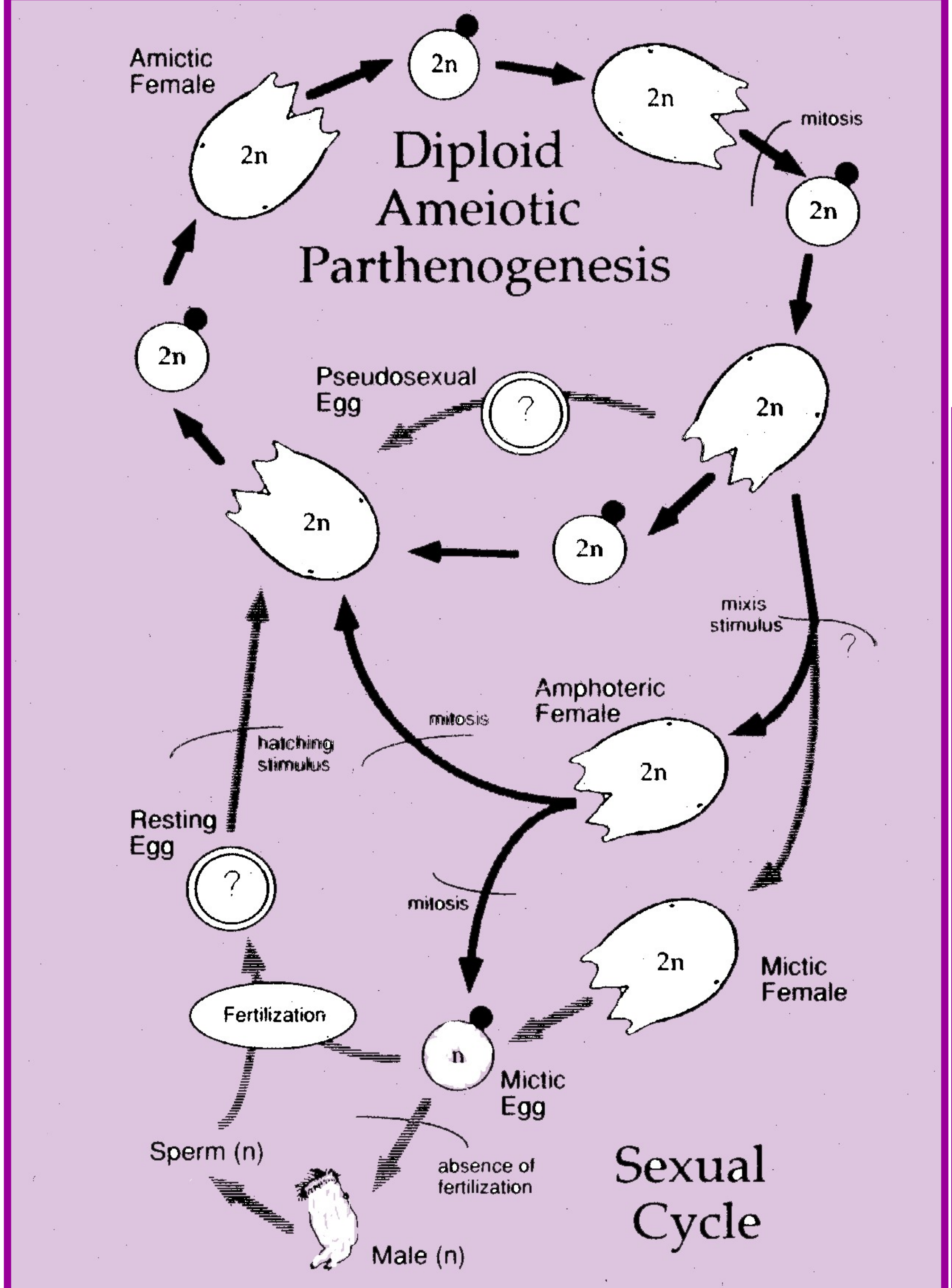

FOOD
PSEUDO
TROCHUS
1
2
3
4
BUCCAL
EPITHELIUM
BUCCAL VELUM
PHARYNGEAL
EPITHELIUM
TROPHI
MASTAX
GANGLION
M5
M4
OESOPHAGUS
MASTAX

Scheme of the trophi („jaws“)

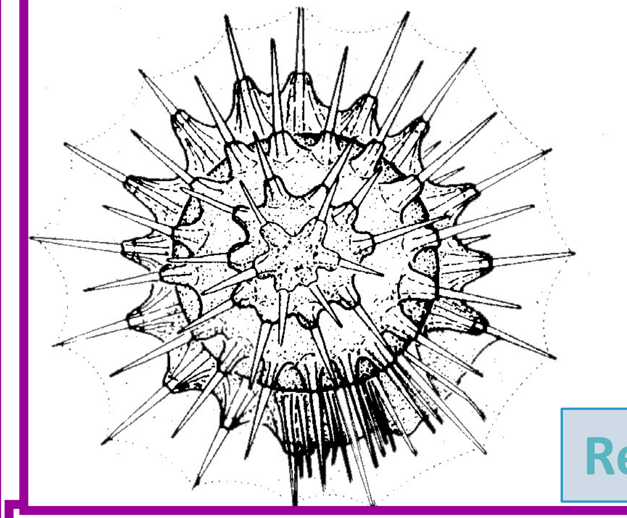




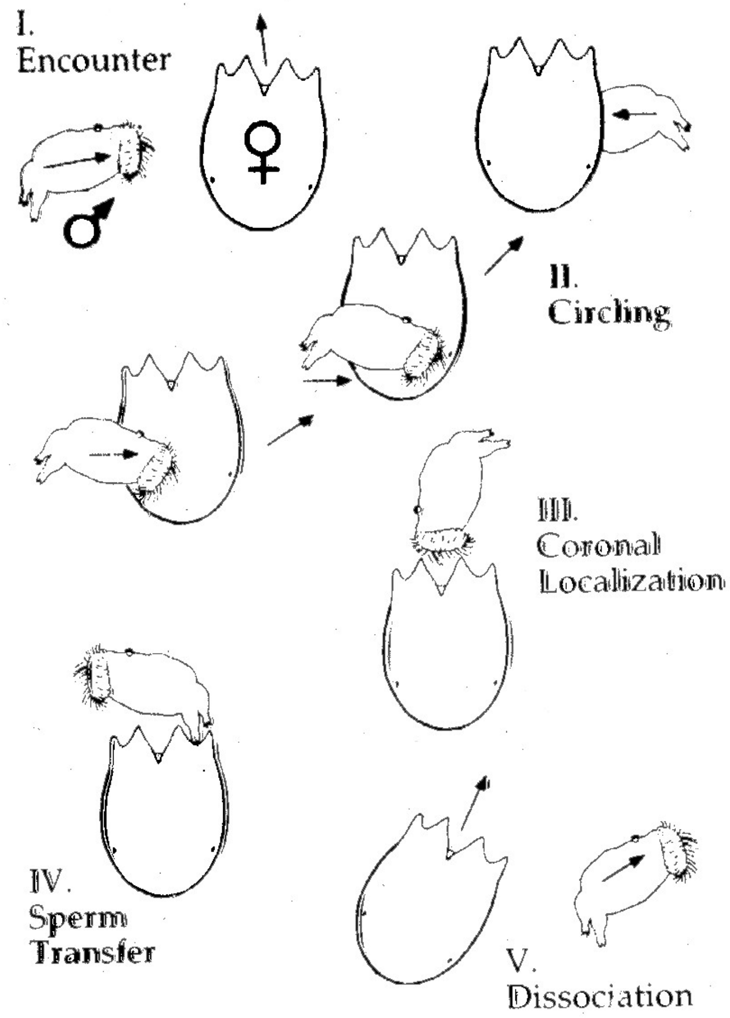
from: Wilts & Wulfken 2011



Amictic Female
2n
Diploid Ameiotic Parthenogenesis
mitosis
Pseudosexual Egg
?
mixis stimulus
Amphoteric Female
mitosis
hatching stimulus
Resting Egg
Mictic Female
Fertilization
n
Mictic Egg
Sperm (n)
absence of fertilization
Male (n)
Sexual Cycle



Resting egg



I. Encounter
II. Circling
III. Coronal Localization
IV. Sperm Transfer
V. Dissociation

Keratella sp.

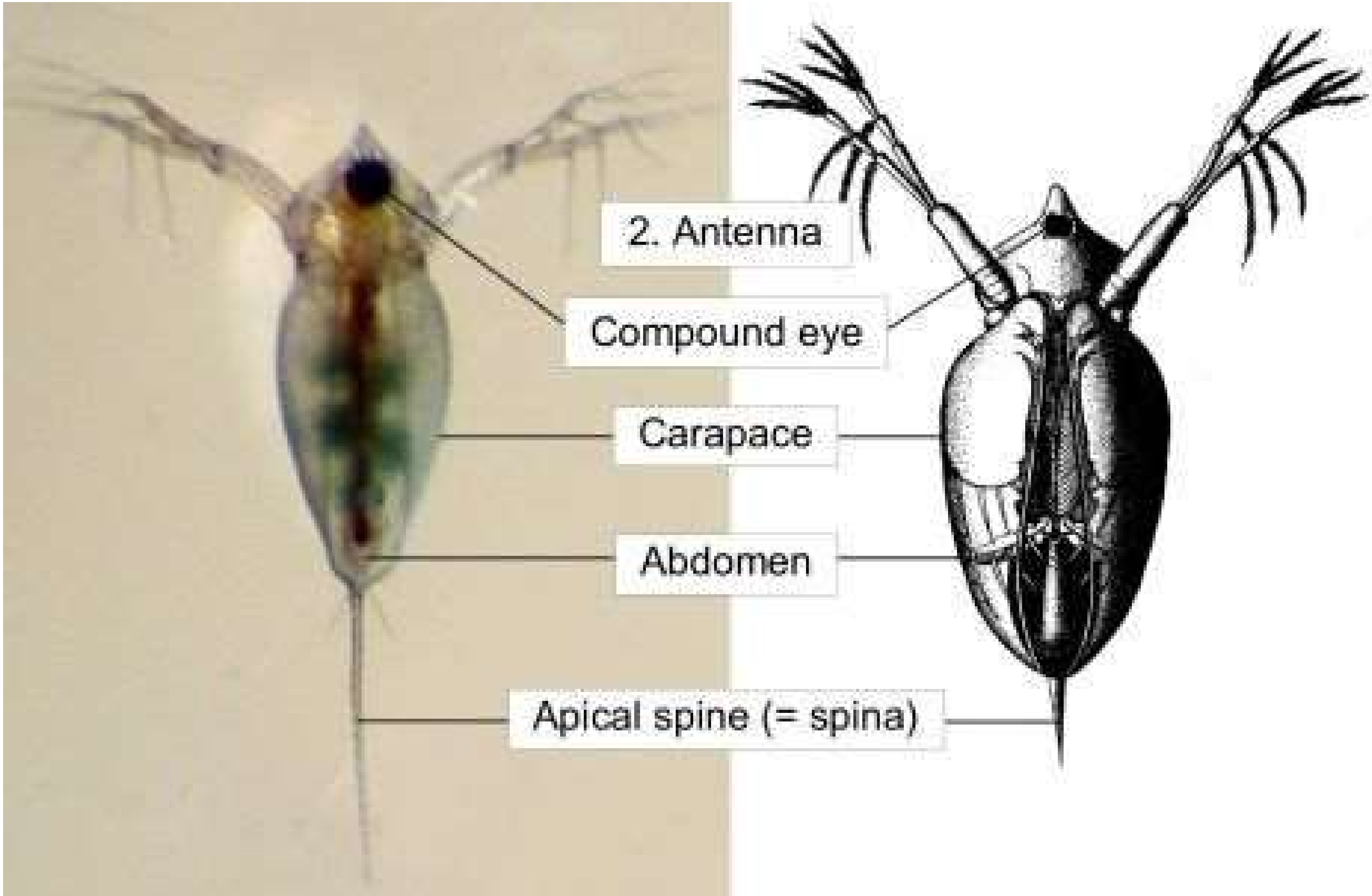
Polyarthra sp.

Synchaeta pectinata

Cephalodella sp.

Brachionus sp.

Cladocera
(~150 species in Europe)



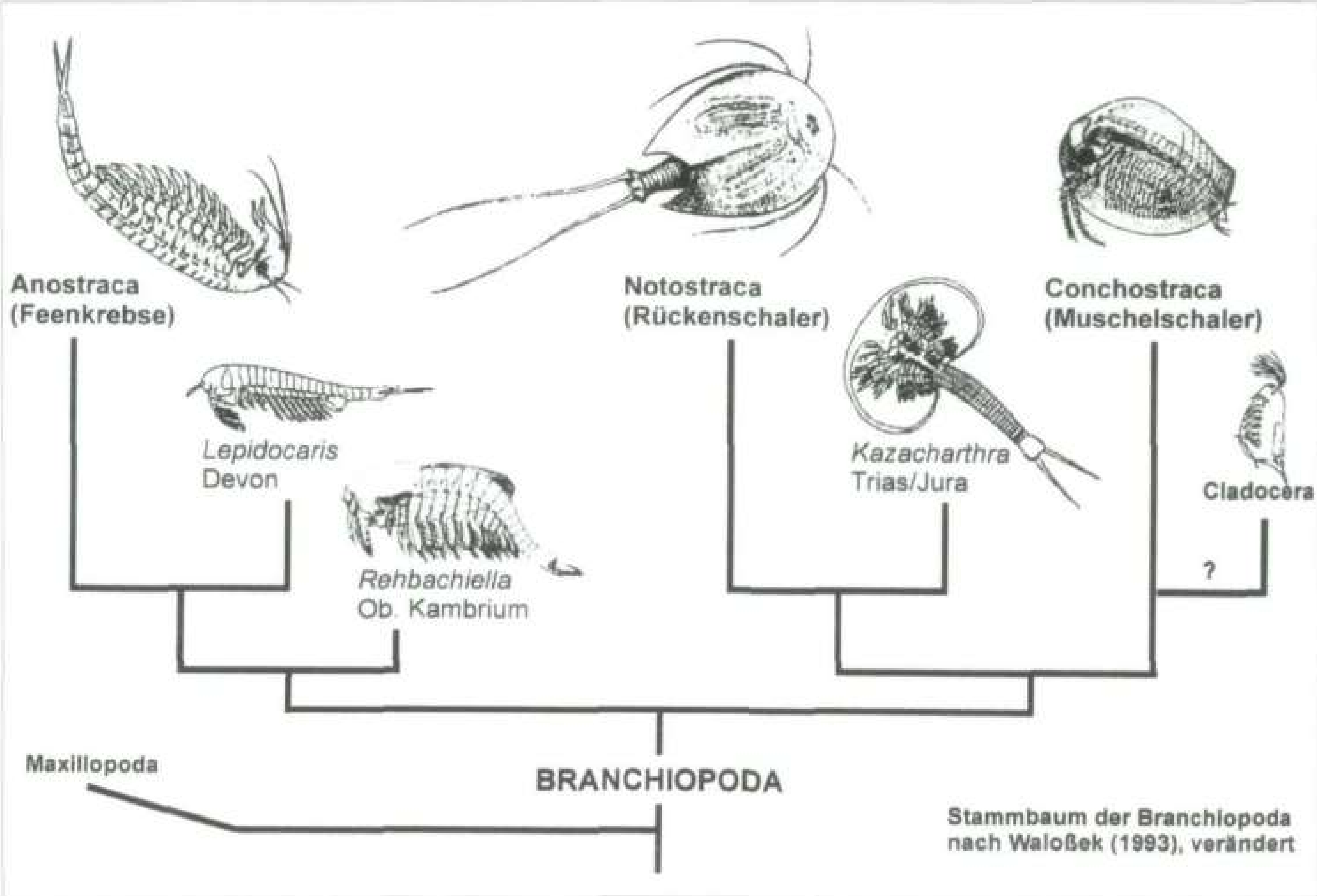
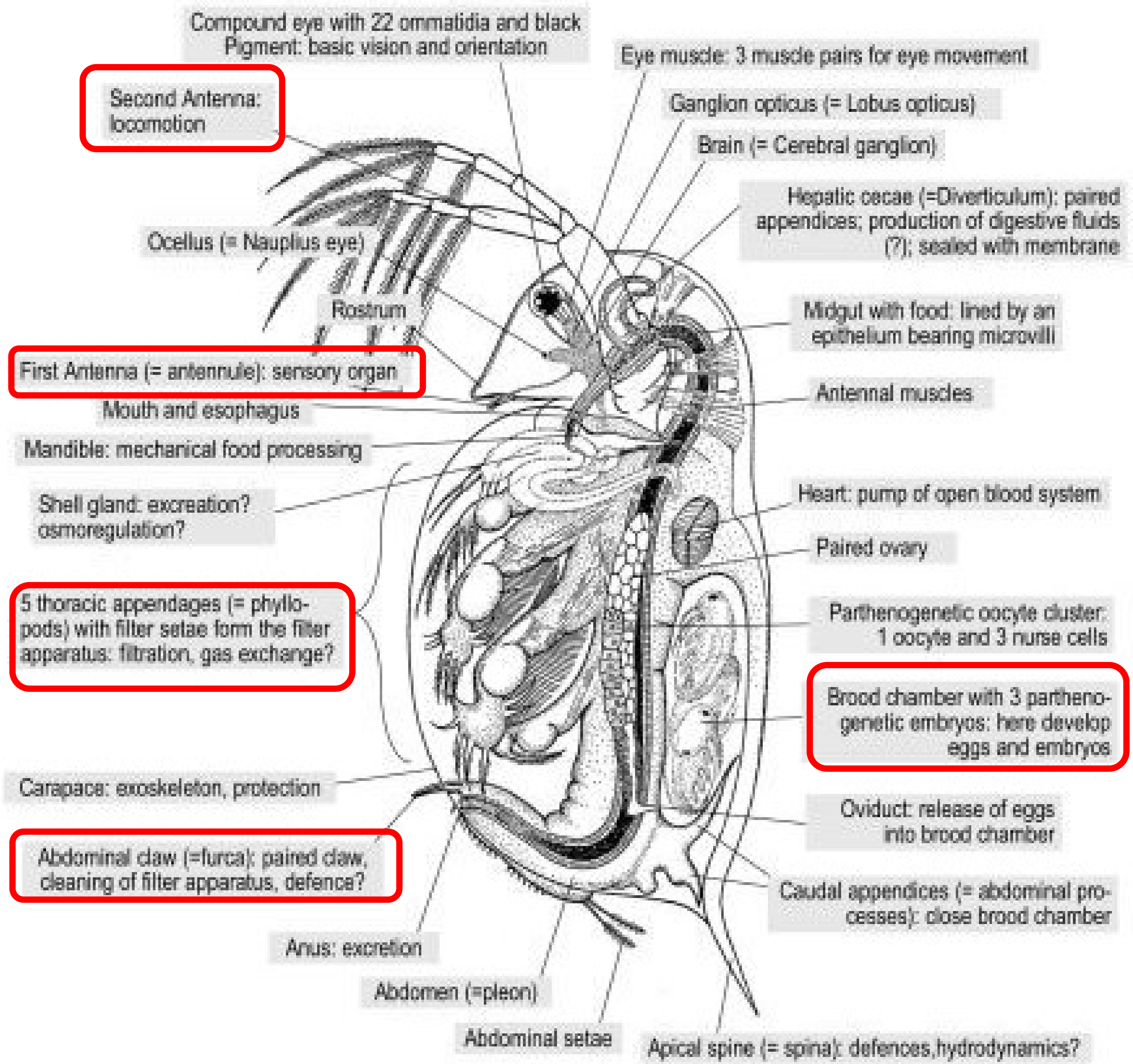
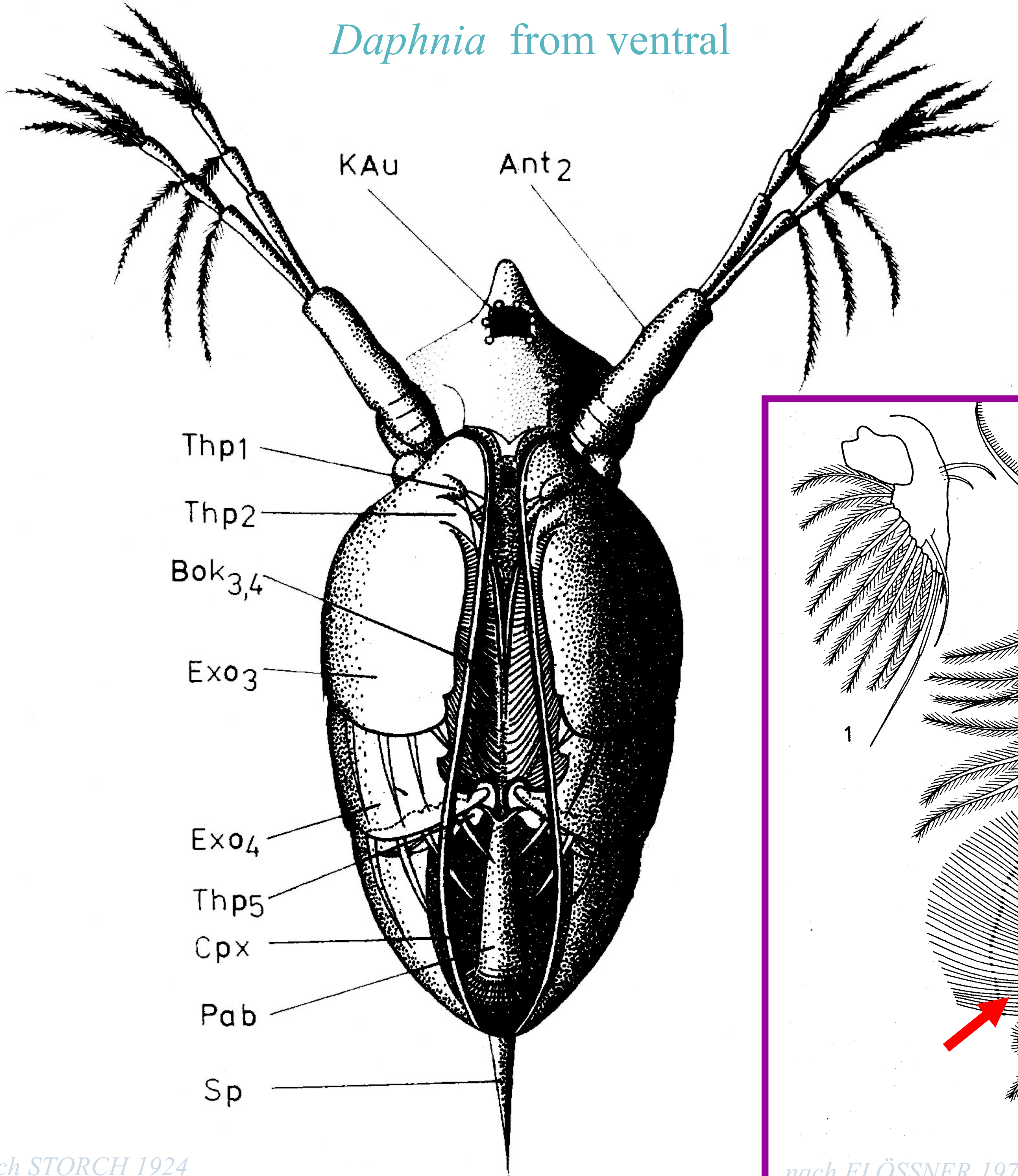


Abb.1: Stammbaum der Branchiopoda. Nach Waloßek (1993).

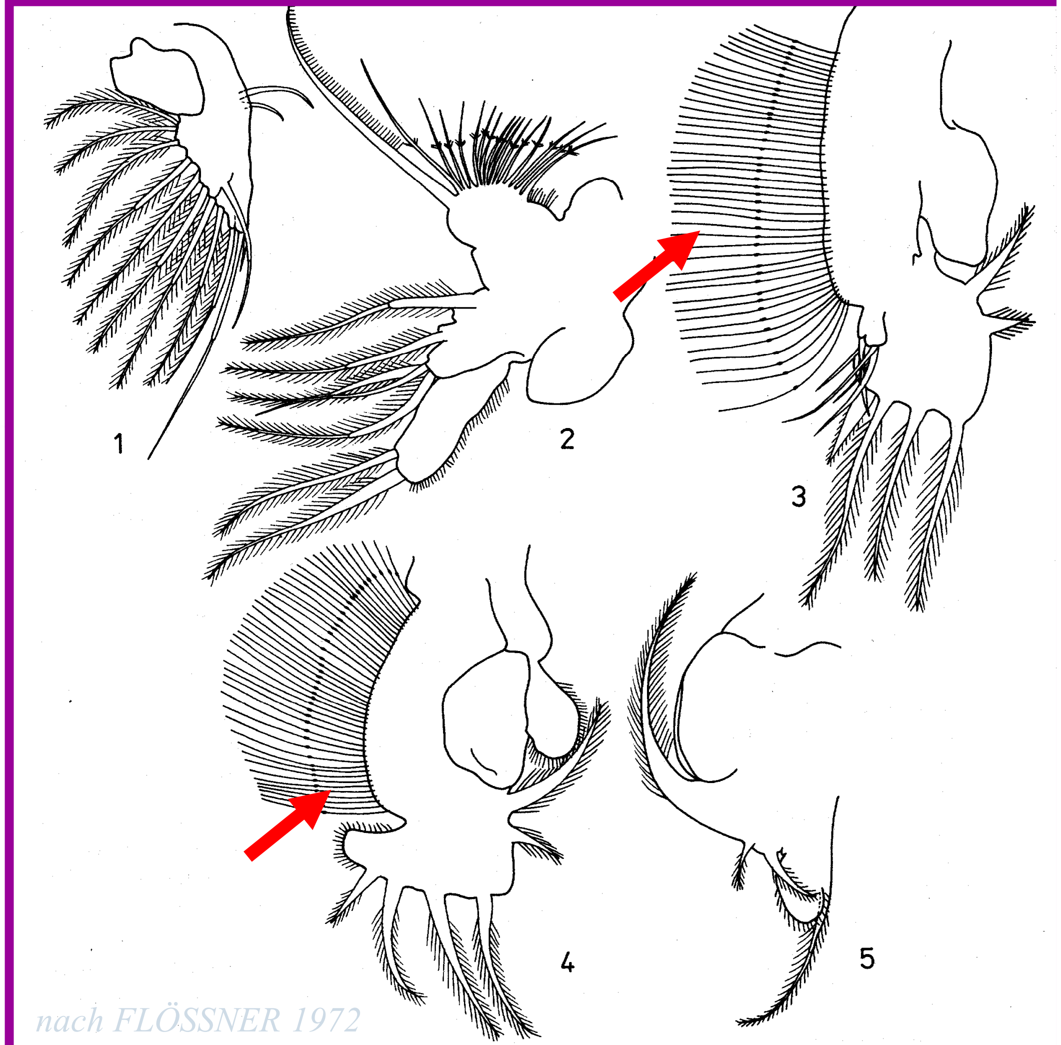


Compound eye with 22 ommatidia and black Pigment: basic vision and orientation
Eye muscle: 3 muscle pairs for eye movement
Second Antenna: locomotion
Ganglion opticus (= Lobus opticus)
Brain (= Cerebral ganglion)
Hepatic cecae (=Diverticulum): paired appendices; production of digestive fluids (?); sealed with membrane
Ocellus (= Nauplius eye)
Rostrum
Midgut with food: lined by an epithelium bearing microvilli
First Antenna (= antennule): sensory organ
Antennal muscles
Mouth and esophagus
Mandible: mechanical food processing
Heart: pump of open blood system
Shell gland: excreation? osmoregulation?
Paired ovary
5 thoracic appendages (= phyllo-pods) with filter setae form the filter apparatus: filtration, gas exchange?
Parthenogenetic oocyte cluster: 1 oocyte and 3 nurse cells
Brood chamber with 3 partheno-genetic embryos: here develop eggs and embryos
Carapace: exoskeleton, protection
Oviduct: release of eggs into brood chamber
Abdominal claw (=furca): paired claw, cleaning of filter apparatus, defence?
Caudal appendices (= abdominal pro-cesses): close brood chamber
Anus: excretion
Abdomen (=pleon)
Abdominal setae
Apical spine (= spina): defences,hydrodynamics?

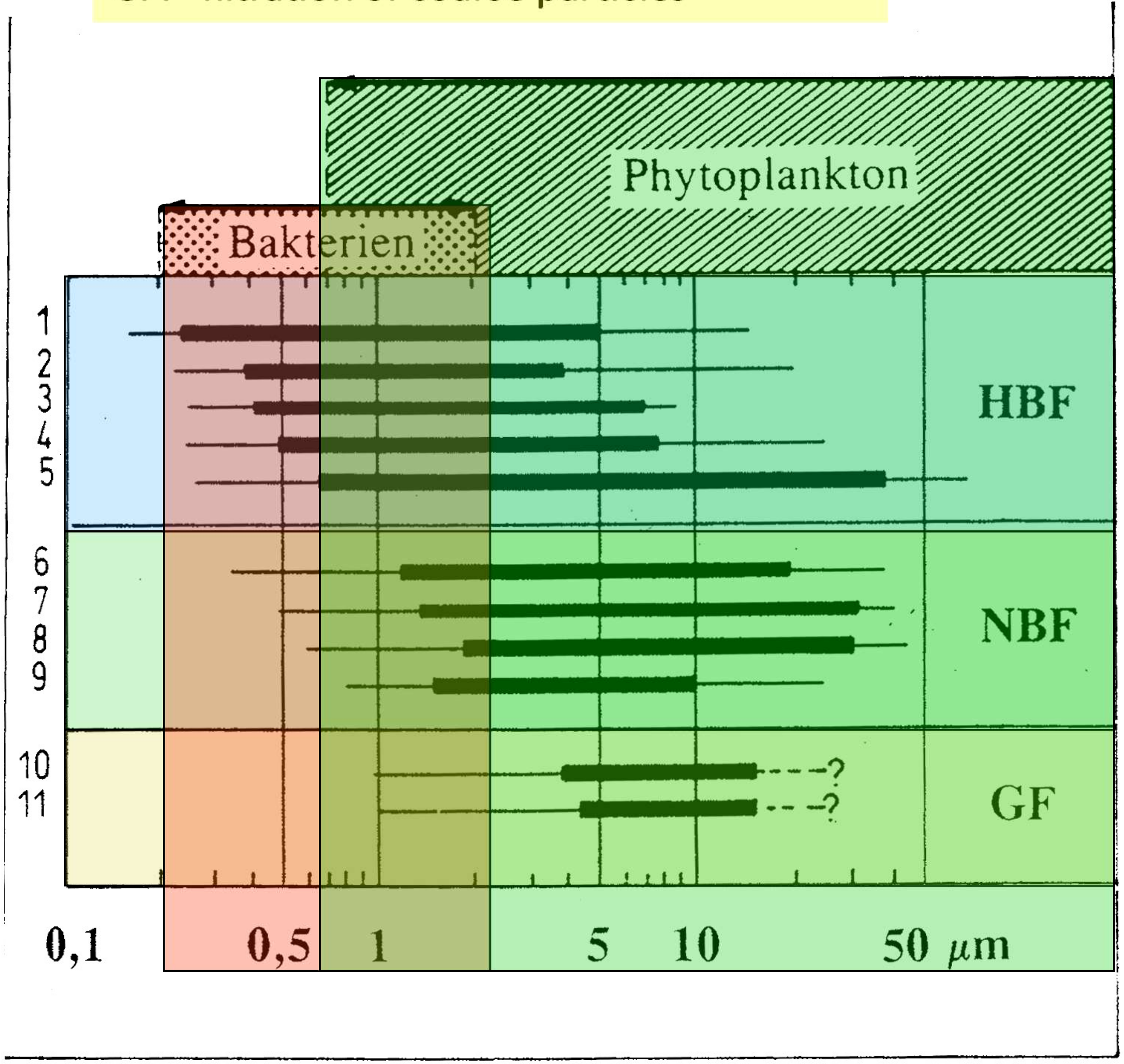
Filtering apparatus: consisting of phylopods



phylopods 1-5



HBF: highly efficient filtration of bacteria
NBF: less efficient filtration of bacteria
GF: filtration of coarse particles



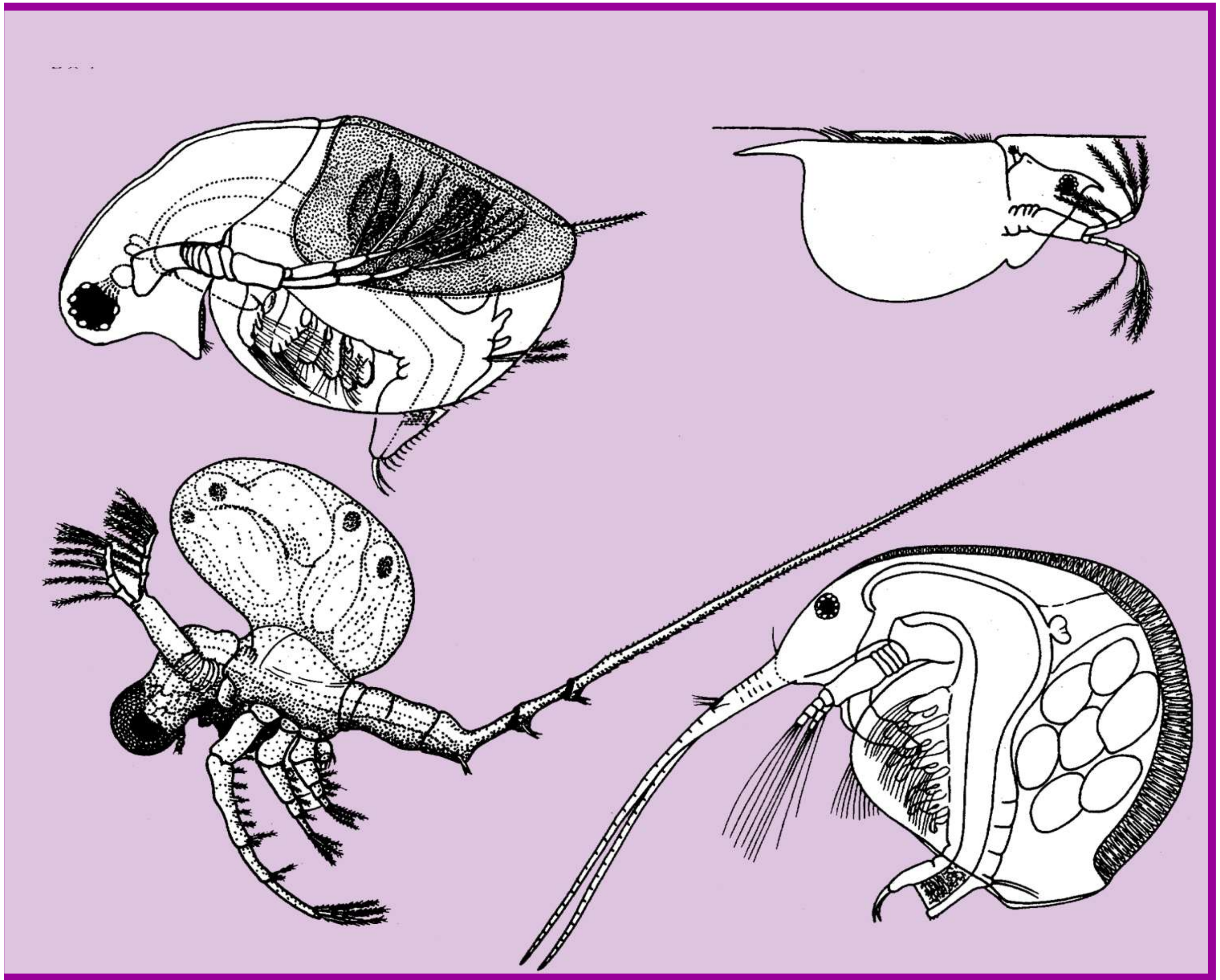
Size dimensions of food particles for cladocerans

HBF Hocheffiziente Bakterienfiltrierer: *1 Diaphanosoma brachyurum, 2 Chydorus sphaericus, 3 Ceriodaphnia quadrangula, 4 Daphnia cucculata, 5 Daphnia magna; NBF* Niedrigeffiziente Bakterienfiltrierer: *6 Daphnia galeata, 7 Daphnia pulicaria, 8 Daphnia hyalina, 9 Bosmina coregoni; GF* Grobfiltrierer: *10 Holopedium gibberum, 11 Sida cristallina.* (Nach Abb. 5 aus Geller und Müller 1981)

Cladocera

Daphnia longispina
(Langdorn-Wasserfloh)

Scapholeberis mucronata
(Kahnfahrer)



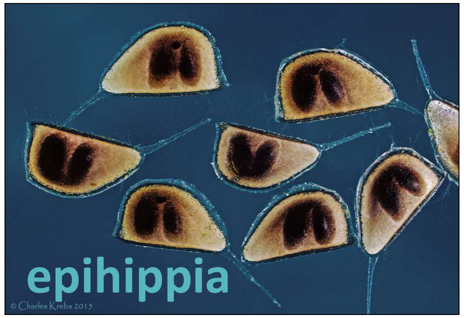
Bythotrephes longimanus
(Langschwanzkrebschen)

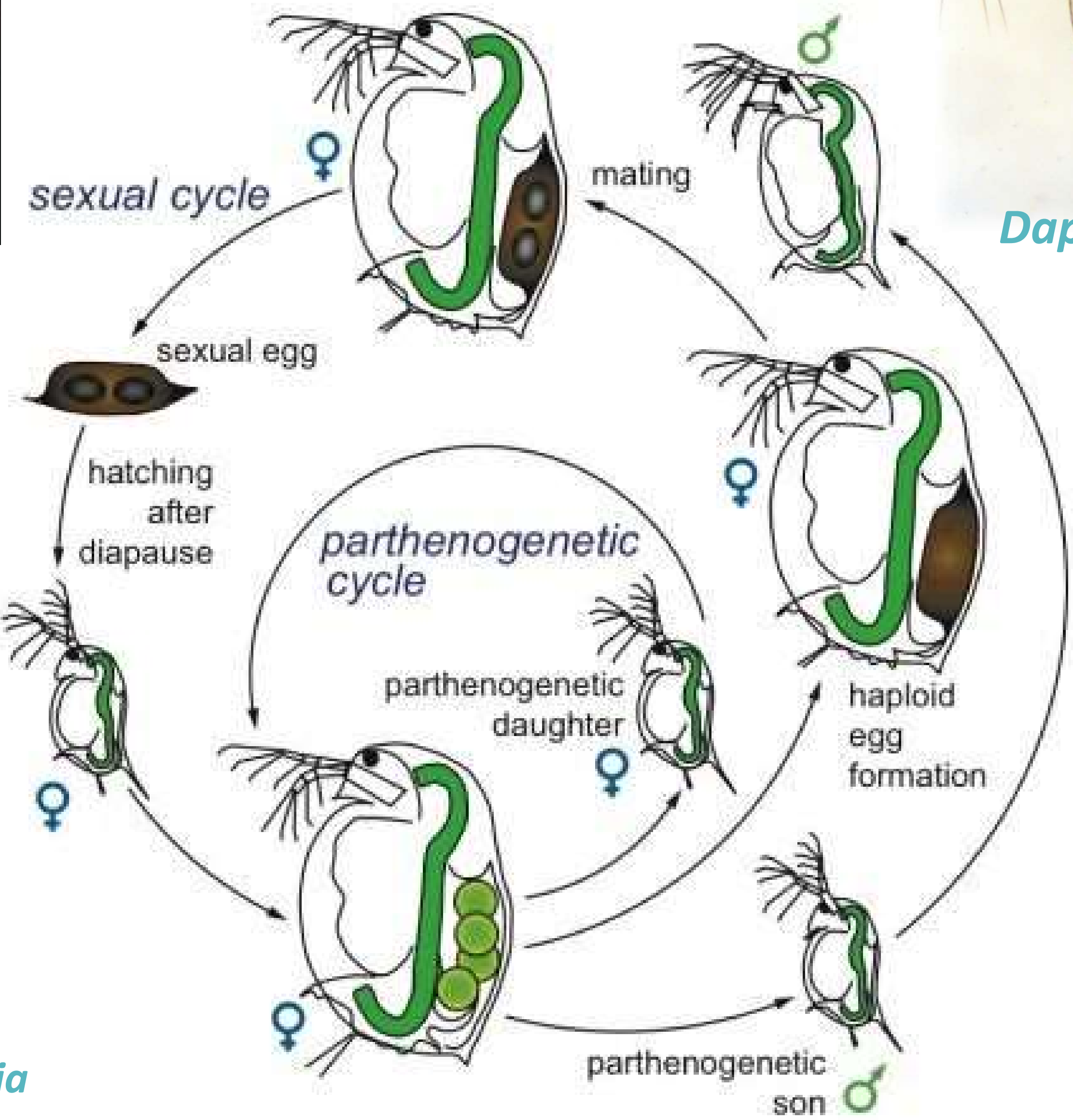
Bosmina coregoni
(See-Rüsselkrebs)

Bosmina longirostris
(Weiher-Rüsselkrebs)

Polyphemus pediculus
(Raubwasserfloh)

Life cycle of *Daphna pulex*





Daphnia longispina

newly hatched *Daphnia* embryo

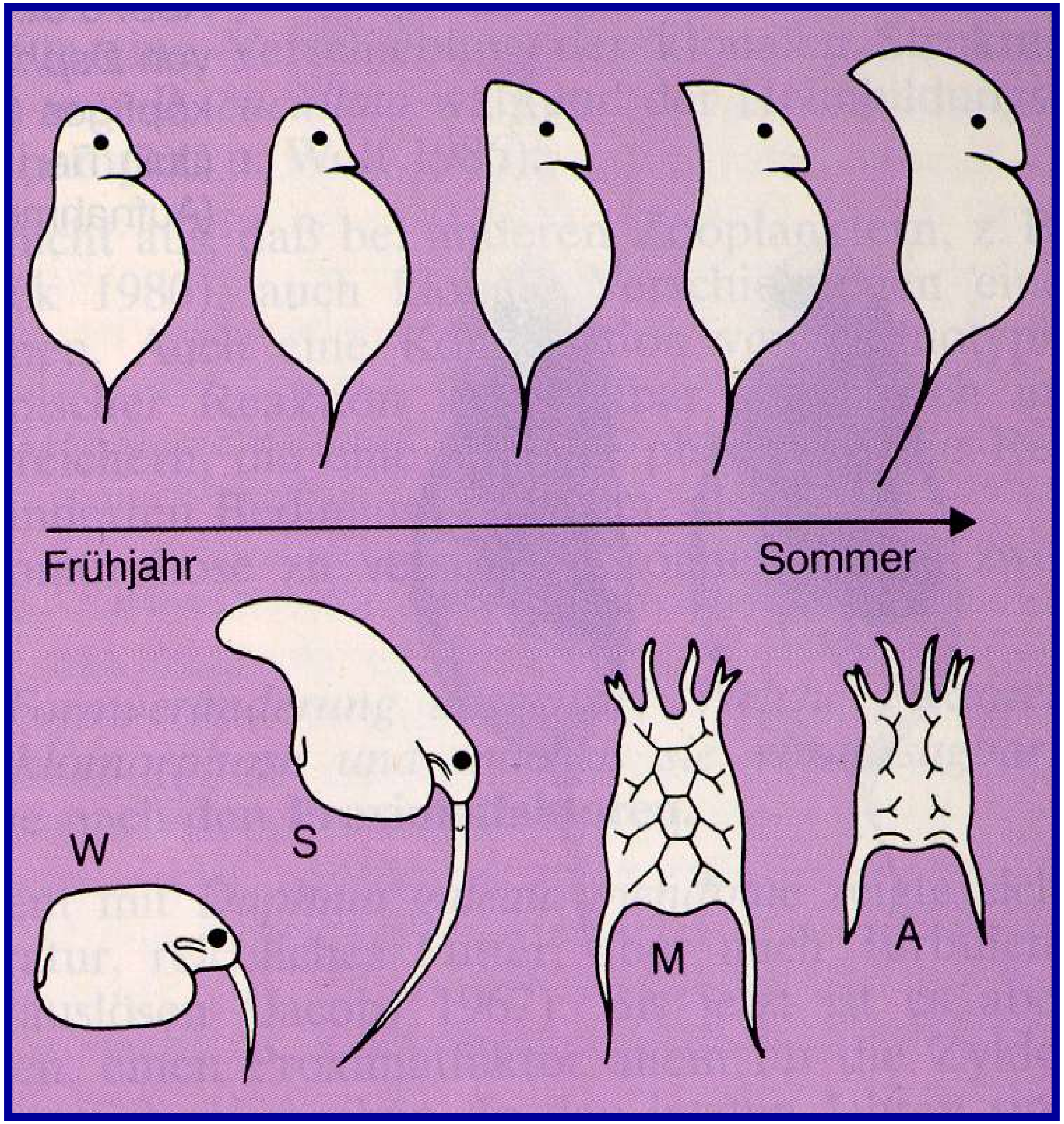
[Introduction to Daphnia Biology - Ecology, Epidemiology, and Evolution of Parasitism in Daphnia - NCBI Bookshelf (nih.gov)]

Cladocera

Modifications of heterogony

- No bisexual reproduction (in very large lakes)
- monocyclic: 1 bisexual reproduction/year (lakes)
- Dicyclic: 2x/year (small ponds)
- Polycyclic: frequently/year (astatic pools)
- No parthenogenesis (arctic waterbodies)

Cyclomorphosis in zooplankton

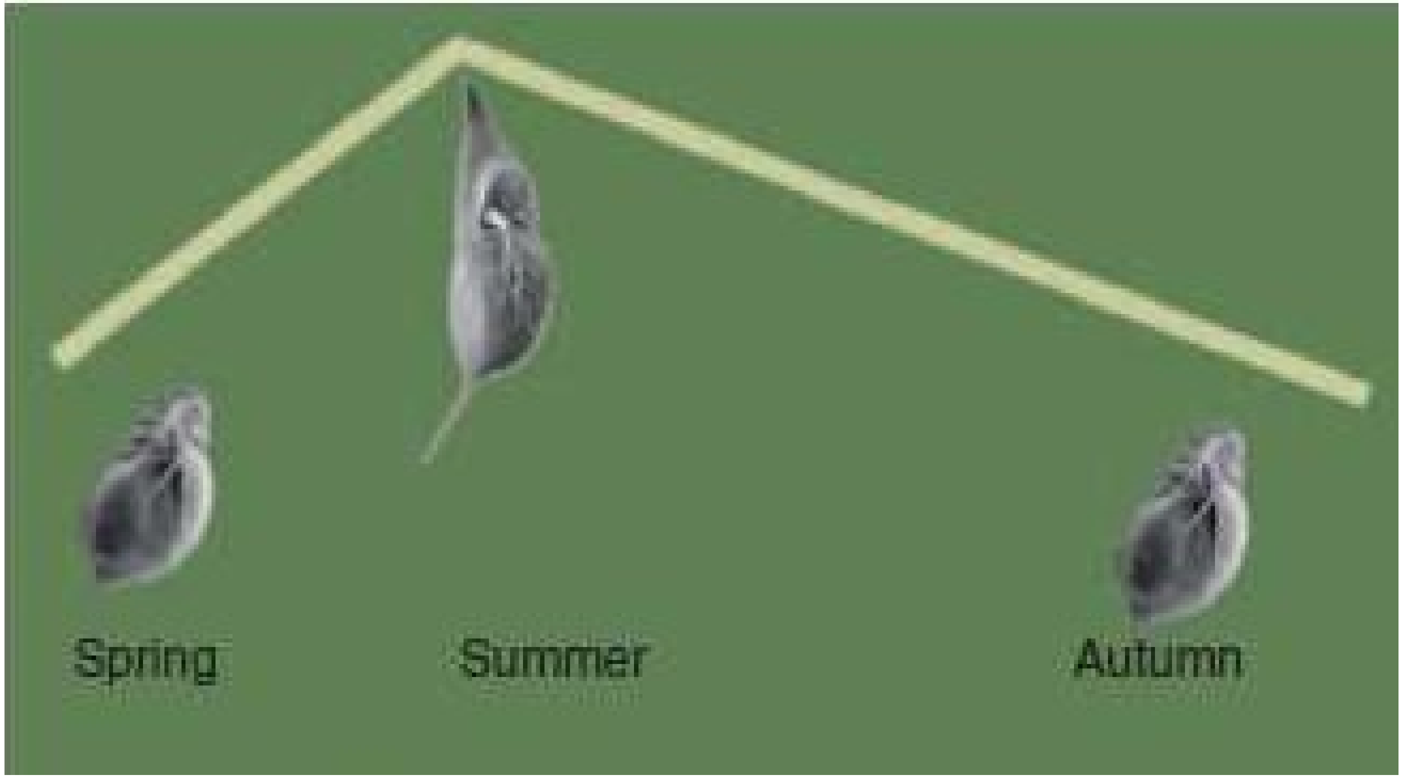


Daphnia retrocurva

Keratella quadrata
(May/August)

Bosmina coregoni
(winter/summer phenotypes)

LAMPERT & SOMMER 1999



Graphics: Laforsch & Tollrian 2004

Cyclomorphosis in *Daphnia cucullata*

Photo: Laforsch 2009

Triggers for cyclomorphosis:

- Higher temperatures
- Food availability
- Water turbulences
- Kairomones (= chemical signals produced by predators)

Adaptive value of cyclomorphosis:

- (reduced sinking rate in warmer water)
- Defence against predators: improved swimming performance, spines and helmets prevent ingestion (handling procedure of predators impeded)

Morphological changes induced by predator-released kairomones

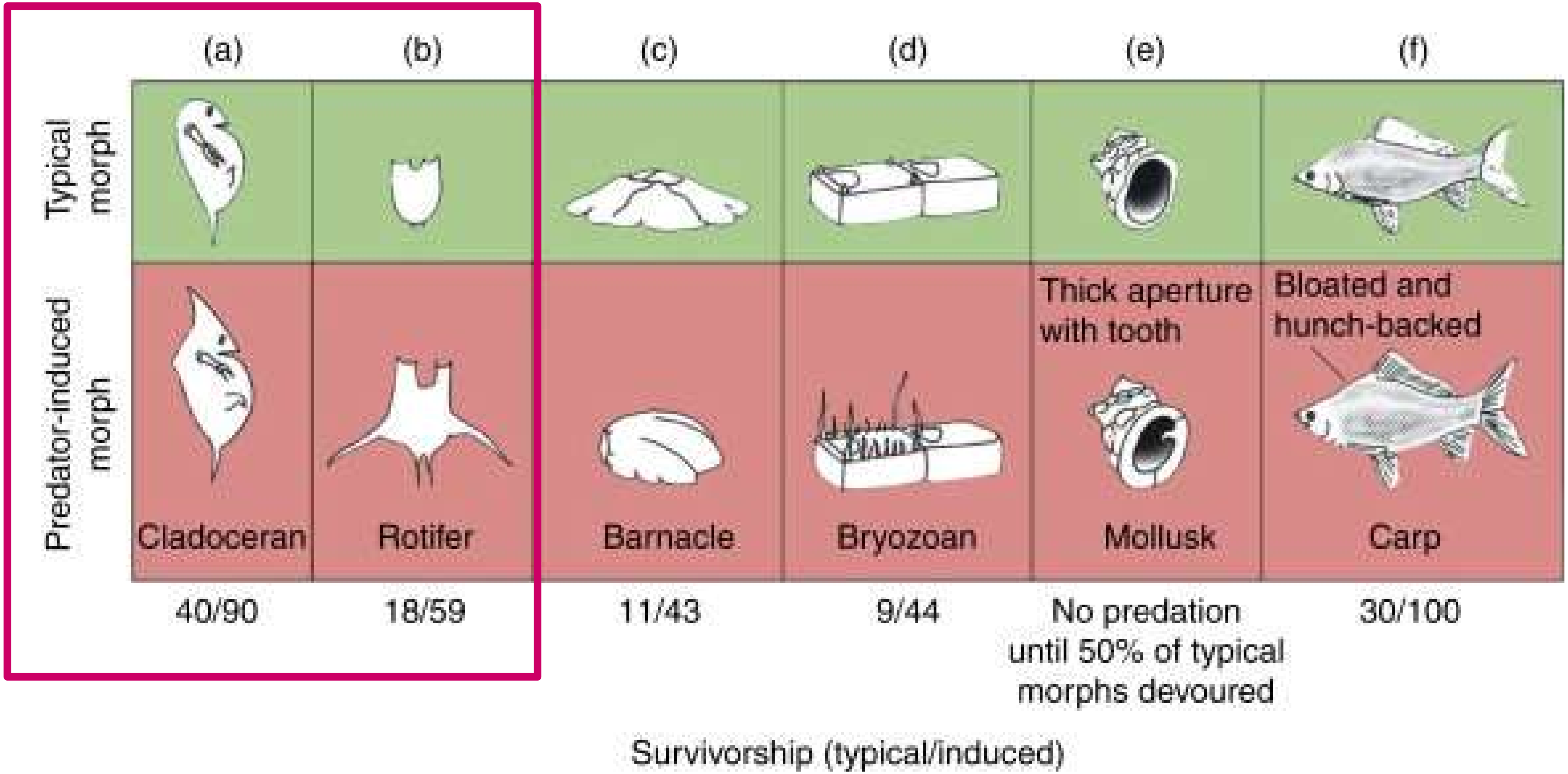


Figure 10. Predator-induced polyphenisms. Shown are typical (green) and predator-induced (red) morphologies of various organisms. Numbers beneath each column represent the percentage of organisms surviving predation when both induced and uninduced individuals were presented to predators. (a) Cladocerans (e.g., *Daphnia* sp.) develop neckteeth and enlarged crests (helmets). (b) Rotifers (e.g., *Keratella slacki*) produce spined progeny in response to predator-derived kairomones. (c) Exposed to predatory gastropods, barnacles (e.g., *Chthalamus* sp.) develop asymmetrically, making it more difficult for the gastropod to open the opercular plates. (d) Bryozoans (*Membranipora* sp.) rapidly grow spines when exposed to waterborne cues from predatory nudibranchs. (e) The mollusk *Thais lamellosa* develops a thickened shell and a ‘tooth’ on its aperture when exposed to carps. (f) The carp *Carassius carasius* responds to piscivorous pike that has already eaten fish by growing into a hunchbacked morph that will not fit into the pike’s jaw.

Disadvantages of cyclomorphosis:

- Smaller breeding pouches in some species, e.g *Daphnia catawba* – lower reproductive rates
- Energetically expensive (swimming, slower development, etc.)
- BUT during summer food availability is low

Cyclomorphosis optimizes fitness: maximal reproduction rates with the round-headed form in spring, when food levels are high and predation pressure is low, minimal mortality during summer.

Copepoda

Approx. 13,000 species globally, 2,800 of them in fresh waters.

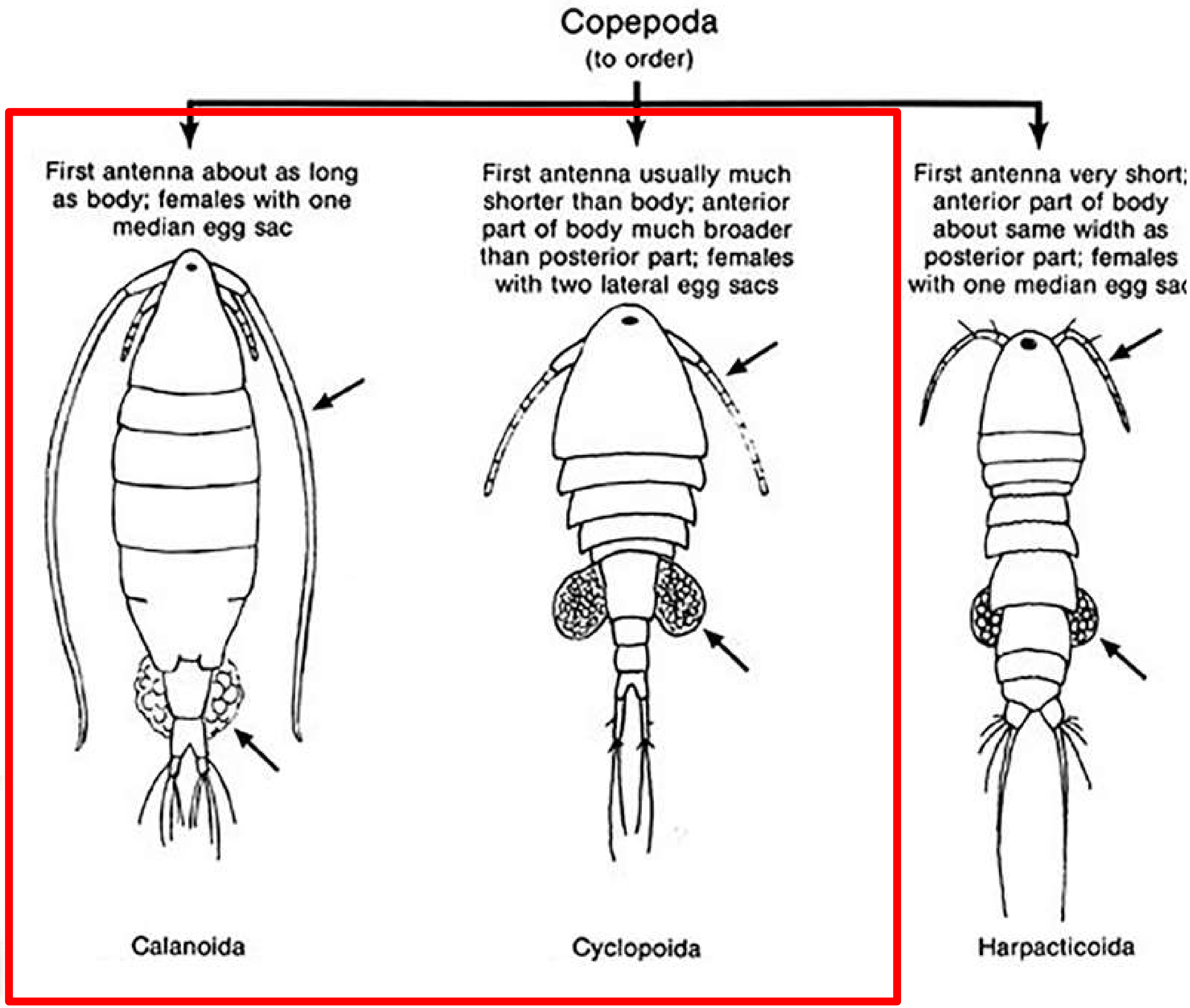
Cyclops as one of the most common genera comprised over 400 species.

Веслоногие ракообразные разных видов - Copepod – Wikipedia

Copepoda

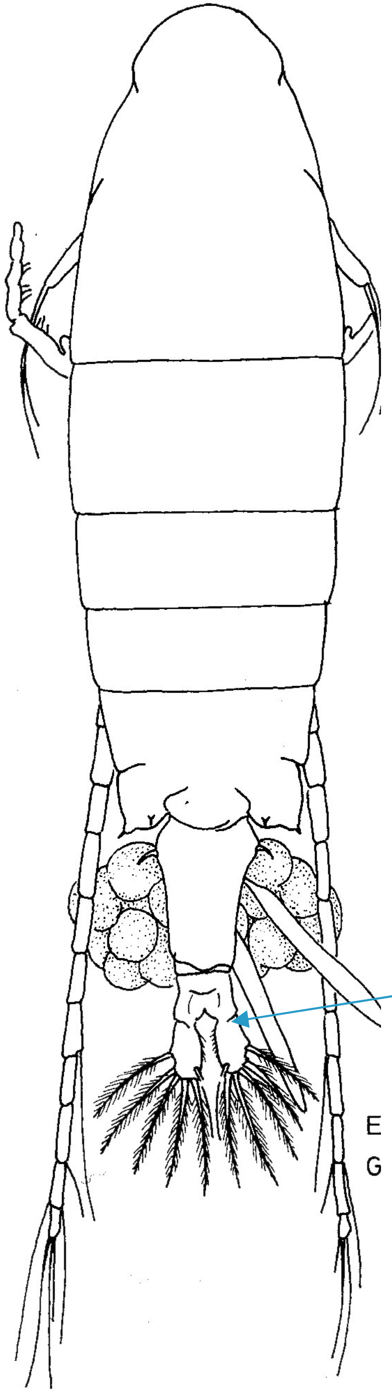
Cyclops strenuus
(Gemeiner Hüpferling)

Eudiaptomus gracilis
(Farbloser Schwebekrebs)



The Canadian Nature Photographer Robert Walsh Australian Waterlife

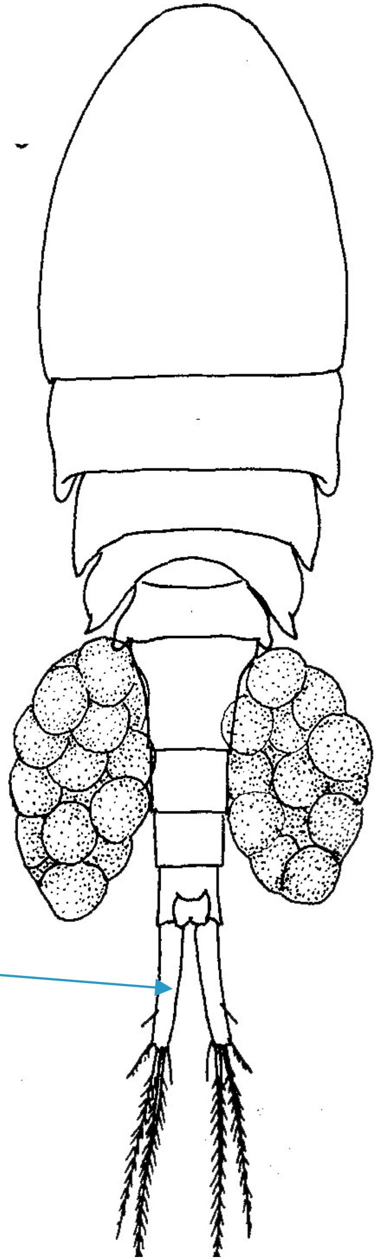
Cephalothorax formed of the head fused with the first thoracic segment (carries antennae, mouth parts, 1.pair of legs)



short

Furcal ramus

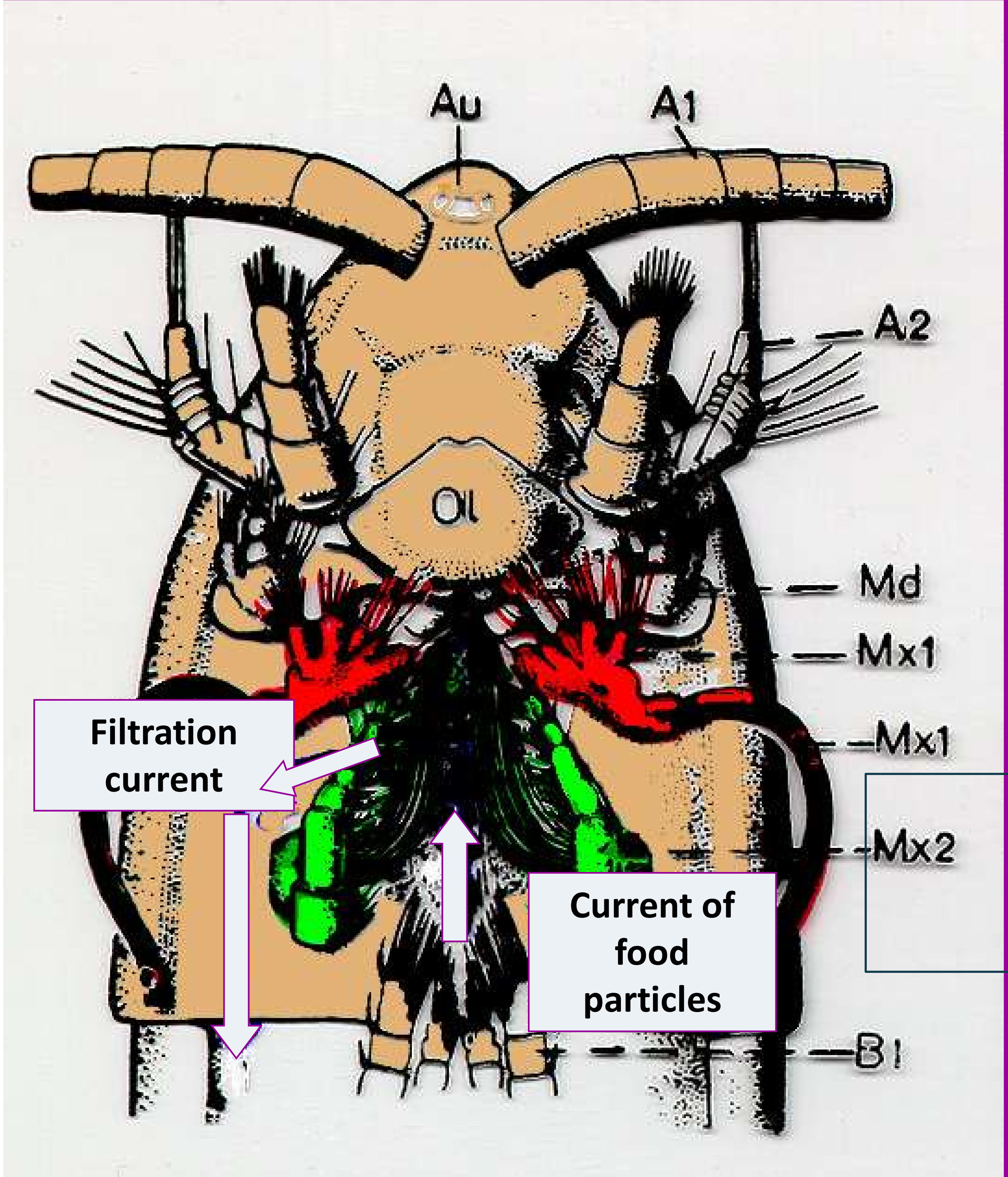
long



CALANOIDA

CYCLOPOIDA

Feeding procedure in *Diaptomus*

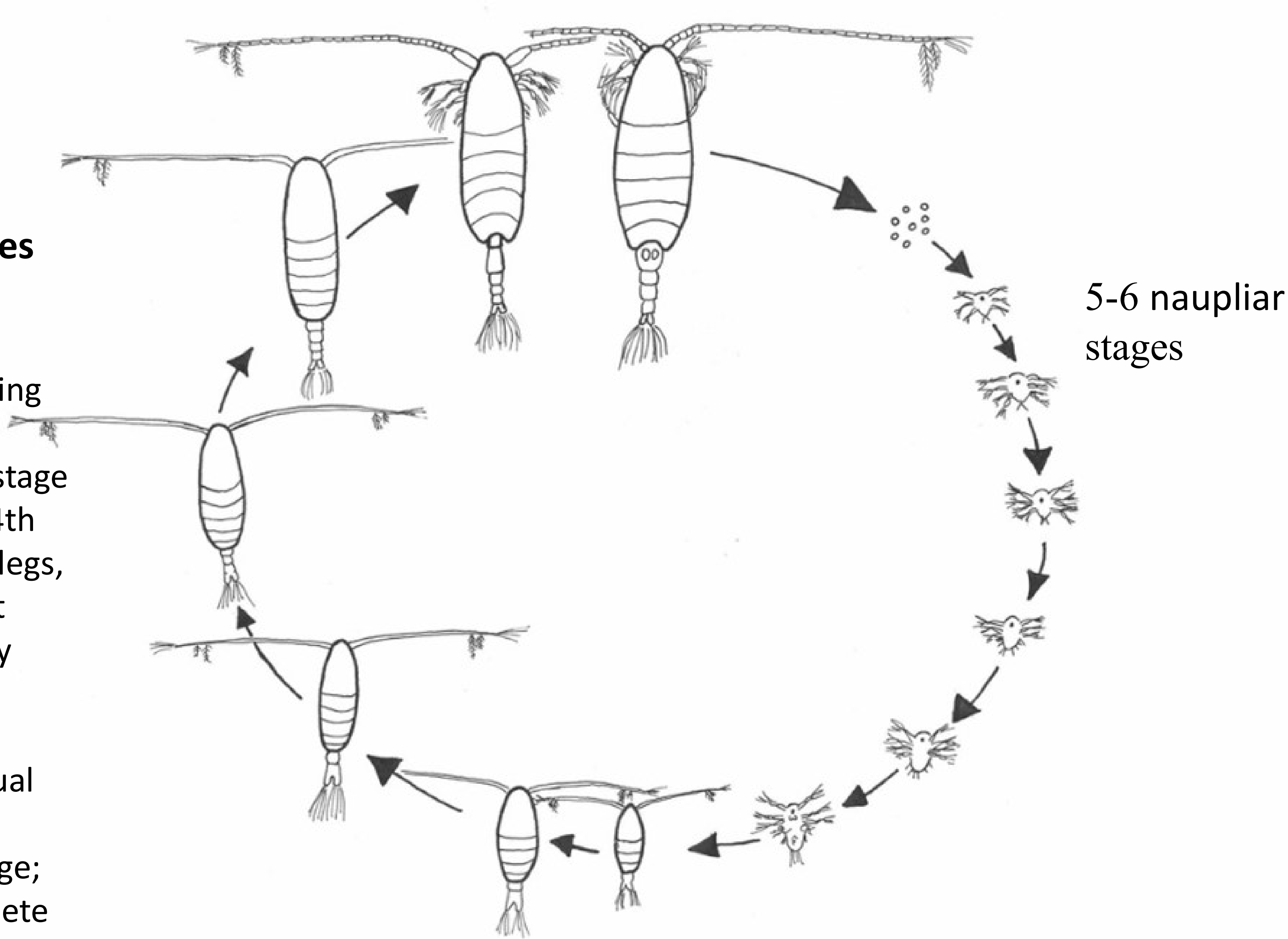


Filtering device of 2nd Maxillae

6 copepodite stages after the nauplius stage

1st stage = 2 swimming legs, 2nd stage = 3 swimming legs, 3rd stage = 4 swimming legs, 4th stage = 5 swimming legs, 5th stage = pre-adult stage; determined by enlargement of the urosome and development of sexual organs

6th stage = adult stage; 5th leg is fully complete



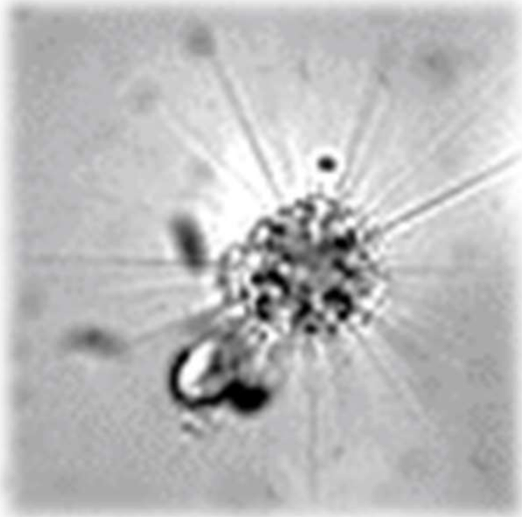
The Canadian Nature Photographer Robert Walsh Australian Waterlife

Nauplius-larva

Feeding in the pelagic zone

- **<u>Passive particle feeding</u>: „sticky traps“:** Heliozoa



- **<u>Filtration</u>**
  - **Directed towards mouth:** Rotatoria
  - **Directed towards filtration organes:** Ciliata, Cladocera

Feeding in the pelagic zone

- **Filtration by the 2.maxilla   or**

  particle grabbing: Calanoida, Cyclopida

Cyclops strenuus

Feeding in the pelagic zone

- **<u>Predators</u>: Rotatoria:** *Asplanchna, Ascomorpha*

Cyclopidae *Cyclops strenuus*

Feeding in the pelagic zone

- **Predators:**

Cladocera: *Leptodora kindtii*

http://www.psteinmann.net/bio_plankton.html

Polyphemus pediculus

Bythotrephes longimanus

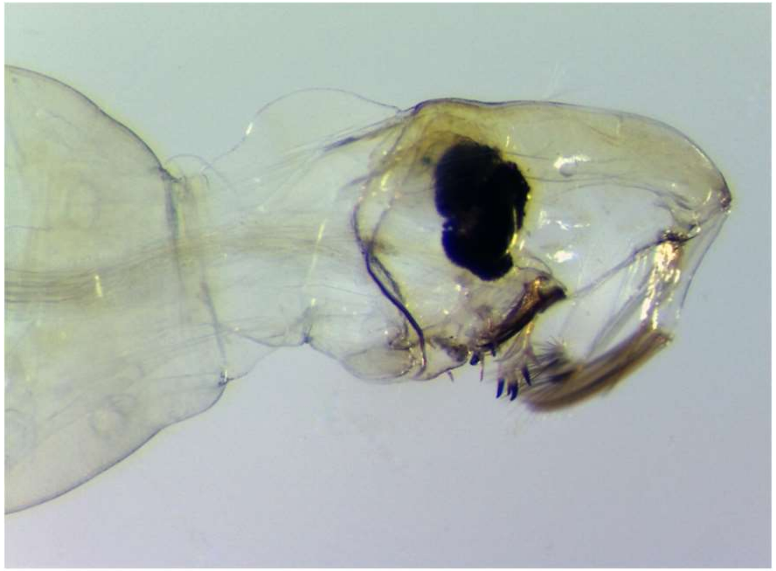
http://www.psteinmann.net/bio_plankton.html

Feeding in the pelagic zone

- **Predators:**

  Diptera: *Chaoborus spp.*

Capturing organs: antennae



	Rotatoria	Cladocera	Copepoda, Diaptomidae
Filtration rate	1-10µl/h (max. 50µl)	10-150µl/h	100-800µl/h
Particle-size	4-17µm (*Keratella cochlearis:* 1µm) algae bacteria Important because of their high densities (200-1000 per liter), especially in oligotrophic lakes	mostly 0.16 - 4.2µm *Ceriodaphnia:* 0.2-0.6µm *D. galeata:* 0,5-1,5µm *Sida:* 2-4µm Max.: 20-50µm Species with fine mesh sizes: also bacteria *Holopedium, Sida:* lower limit: phytoplankton	max.: 50µm

Spatial distribution

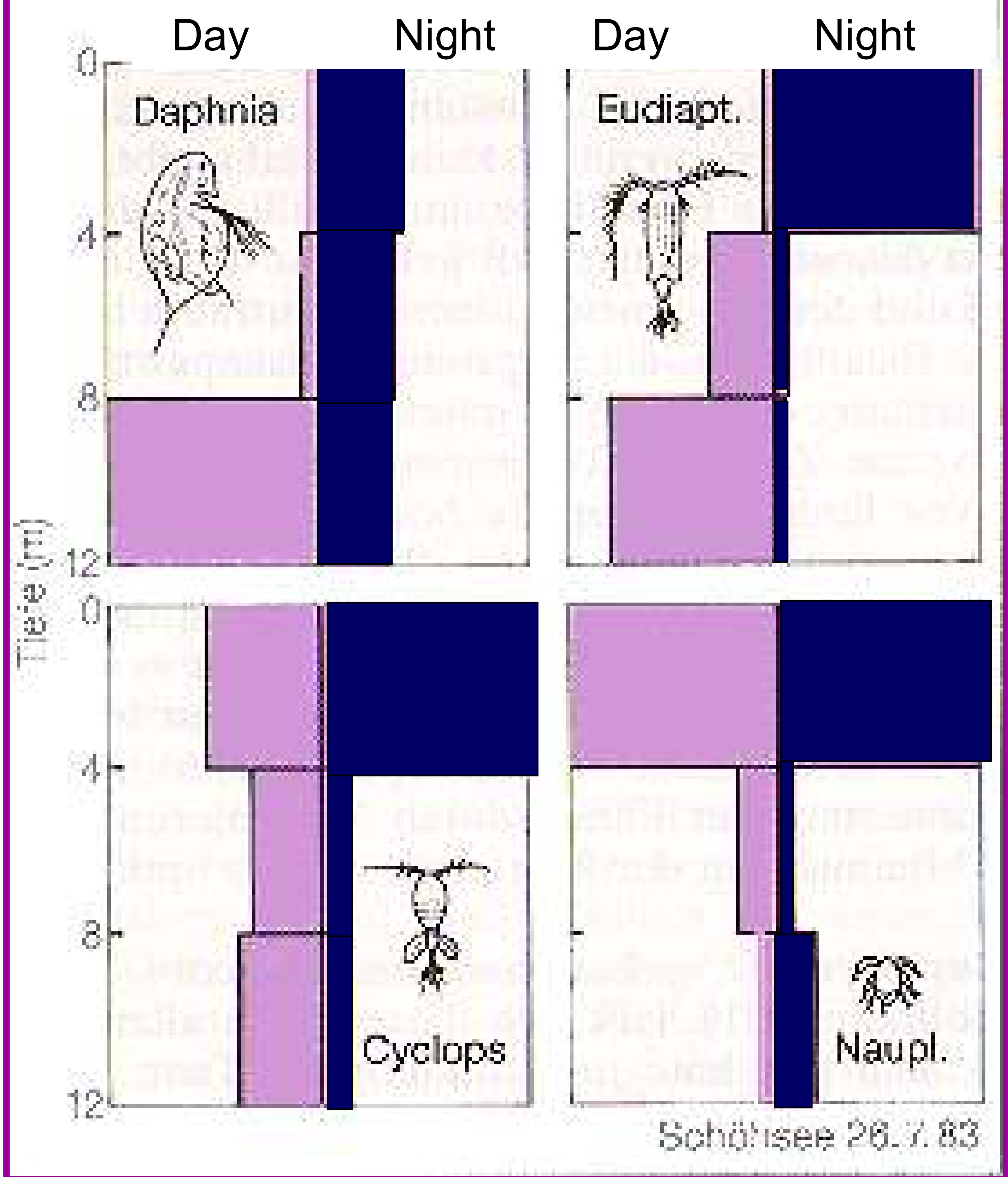
Zooplankton has only a minor mobility

in limnetic systems to max. 100 m depth

- **species specific vertical differences depending on floating mechanisms and mechanics**
- **seasonal differences depending on different water circulation processes**
- **diurnal vertical migrations**
- **horizontal migrations („Uferflucht“): navigation using light/dark fields indicating the skyline**

Spatial distribution depends on

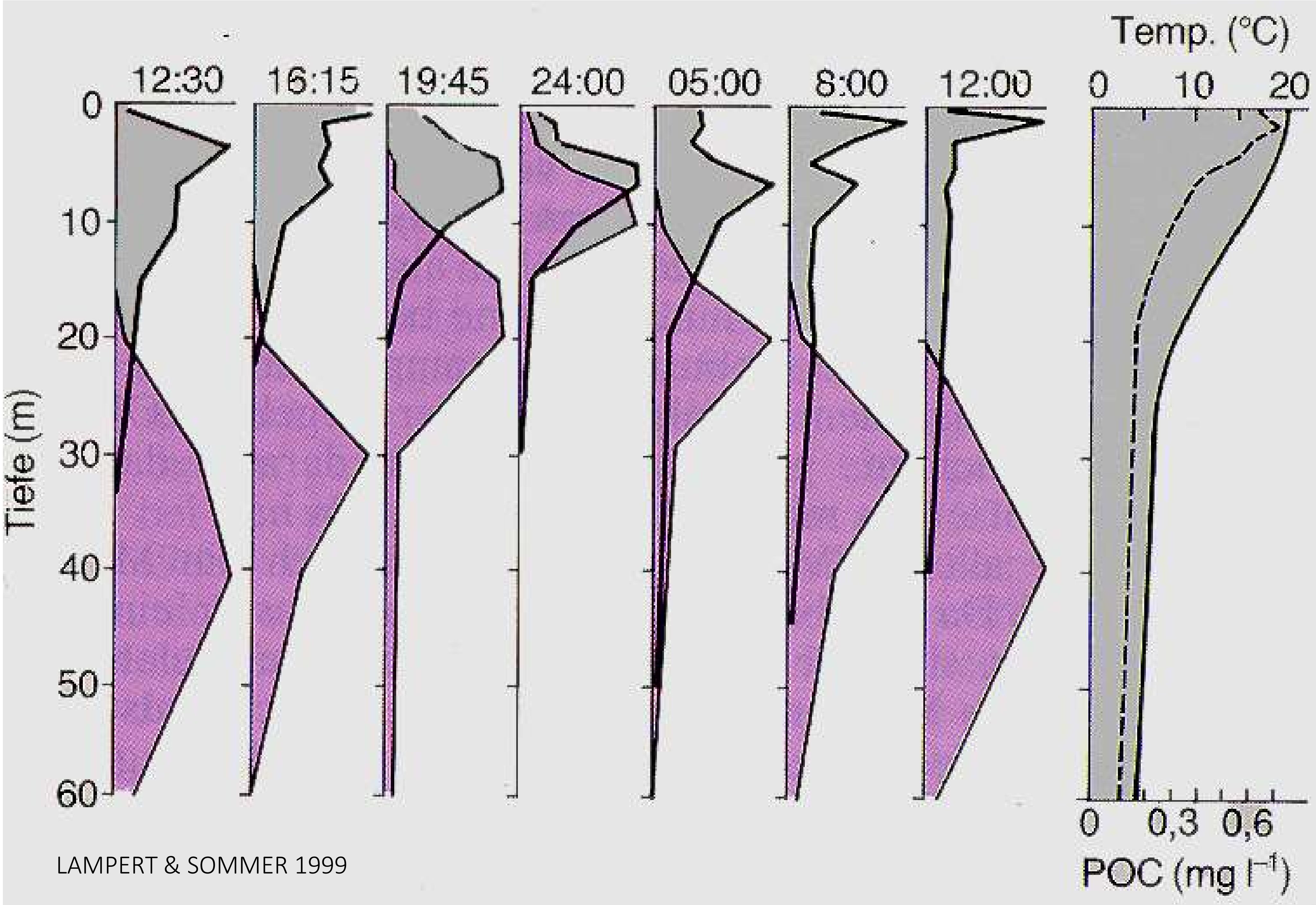
- water circulation patterns
- water currents in the lake
- internal seiches
- temperature
- light



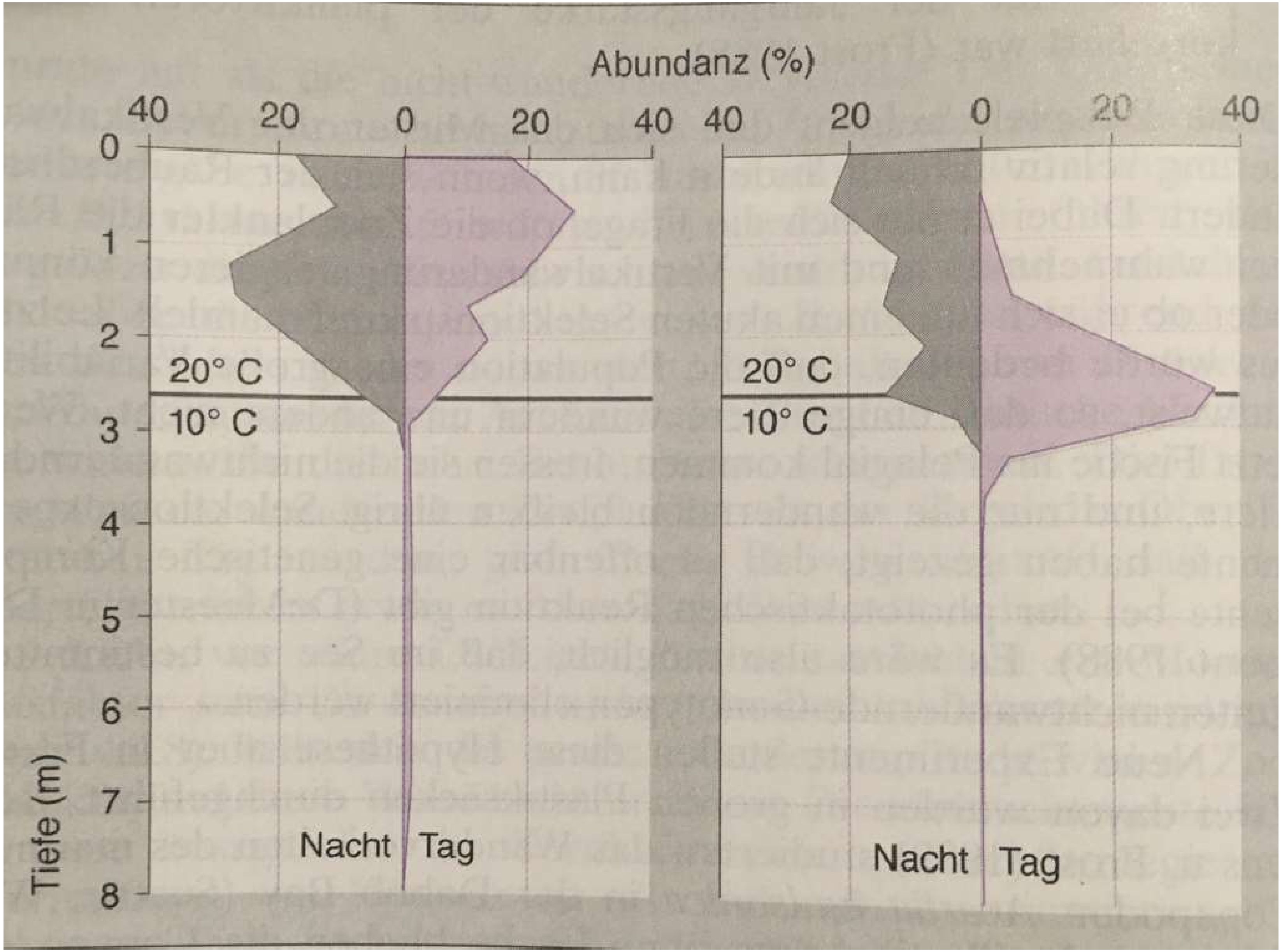
Diurnal vertical migration in Schöhsee

LAMPERT & SOMMER 1999

Vertical distribution of *Daphnia hyalina* and *D. galeata* in Bodensee



LAMPERT & SOMMER 1999

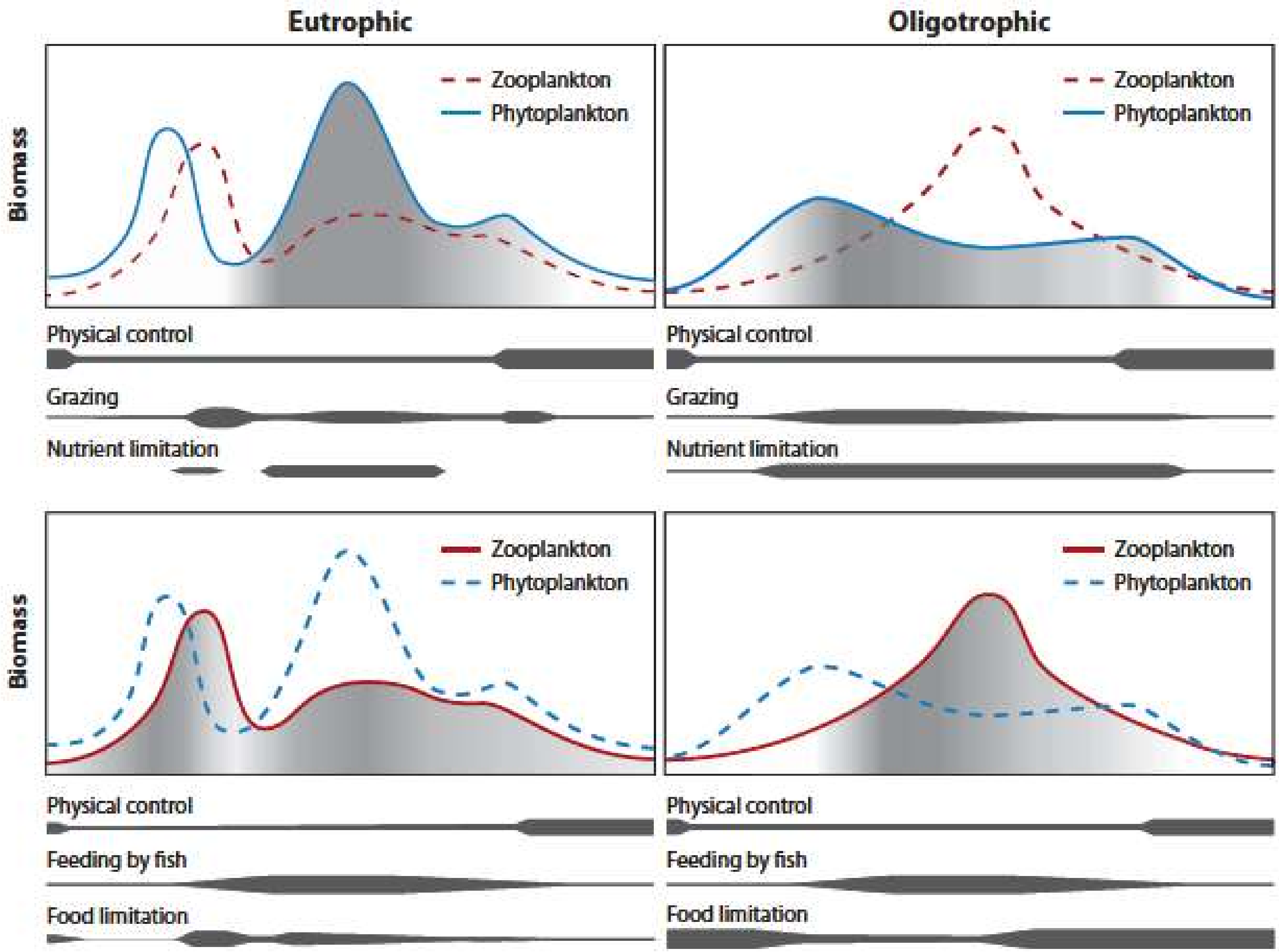


Verteilung von *Daphnia hyalina* bei Tage (hellrote Fläche) und nachts (graue Fläche) in Abwesenheit (links) und Anwesenheit (rechts) eines chemischen Signals von Fischen.

LAMPERT & SOMMER 1999

phytoplankton (*blue solid line*) (*dark shading*, inedible for zooplankton; *light shading*, edible for zooplankton).

zooplankton (*red solid line*) (*dark shading*, small herbivores; *light shading*, large herbivores)



PEG (plankton ecology group)-modell (SOMMER et al. 1986):
Seasonal (winter through autumn) biomass patterns in eutrophic (*left*) and oligotrophic (*right*) water bodies

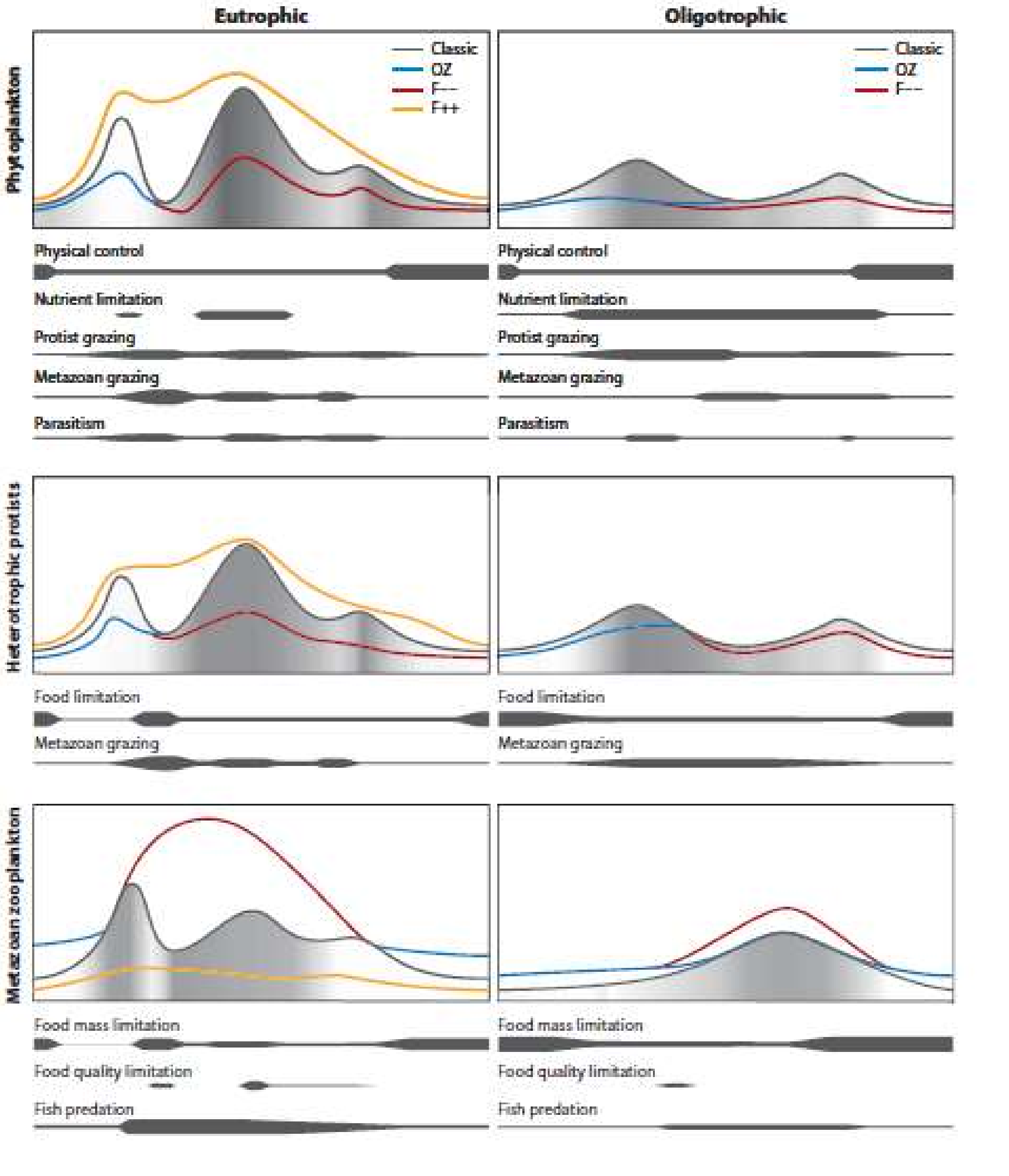
PEG (plankton ecology group)-modell extended version (SOMMER et al. 2012)

Classic szenario: moderate fish predation, overwintering of metazoan plankton unimportant

Fish predation high

No fish predation

Overwintering of metazoan plankton important



Seasonal (winter through autumn) biomass patterns of plankton in a eutrophic (*left*) and an oligotrophic (*right*) water body. (*Top*) Phytoplankton, (*middle*) heterotrophic protists, (*bottom*) metazoan plankton. Gray line, classic scenario (moderate fish predation, overwintering of metazoan plankton unimportant); blue line (OZ), overwintering zooplankton important; red line (F−−), high metazoan density in fishless water bodies; orange line (F++), metazoan plankton suppressed by high fish predation. Shading indicates the mean vulnerability of phytoplankton and protists against metazoan grazing and of metazoan zooplankton against fish predation in the classic scenario (*light*, low; *dark*, high). The thickness of the horizontal bars indicates the seasonal change in regard to the relative importance of physical factors such as grazing by protists and metazoa, nutrient limitation, fish predation, food mass limitation, and food quality limitation.

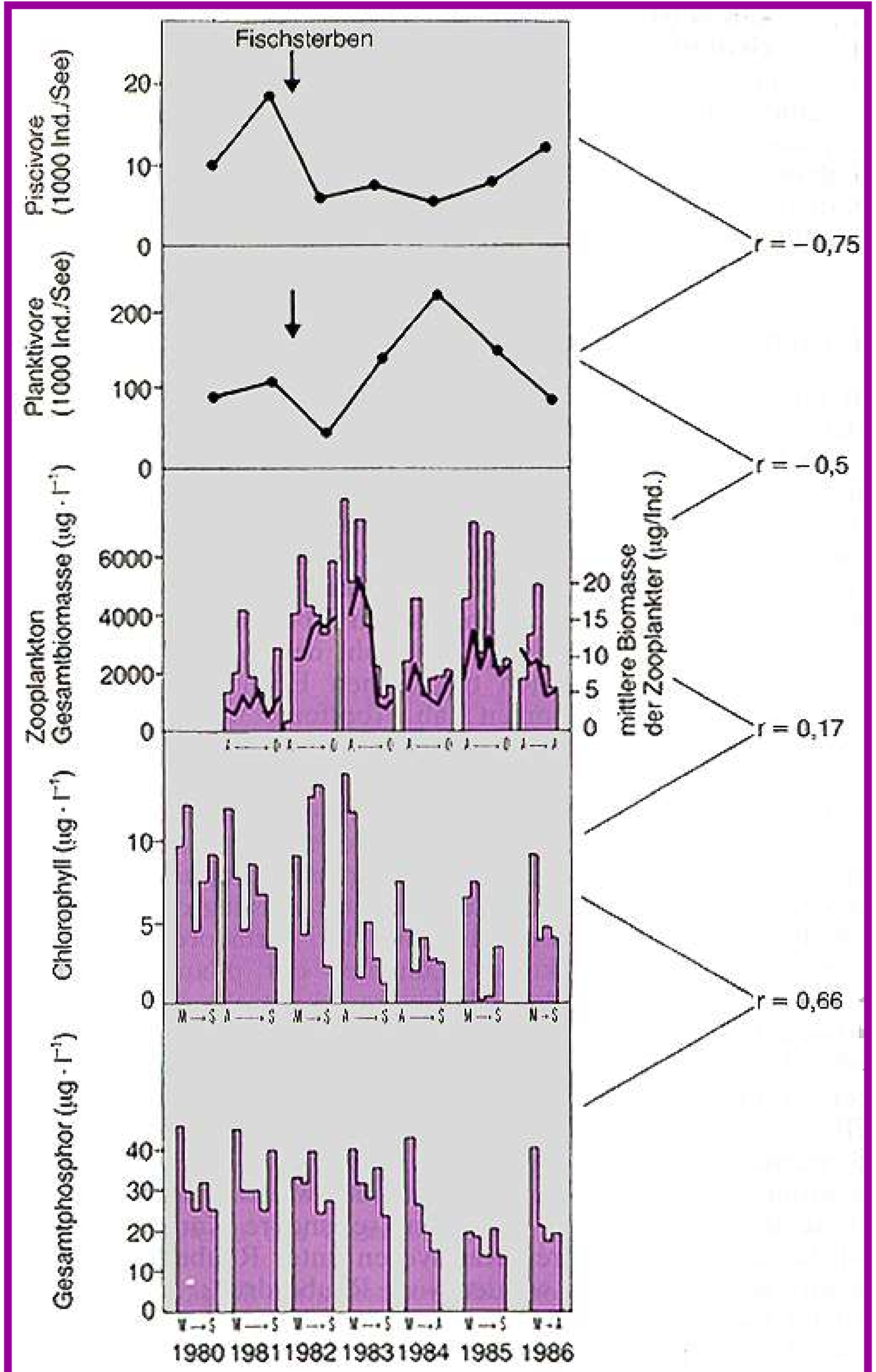
Bottom-up/Top-down-dispute:

Case study Lake St.George

(McQUEEN et al., 1989):

Top-down forces: strong at the top of the food web, weaken towards the bottom

Bottom-up forces: strong at the bottom and weaken towards the top



LAMPERT & SOMMER 1999

SEH

Size efficiency hypothesis

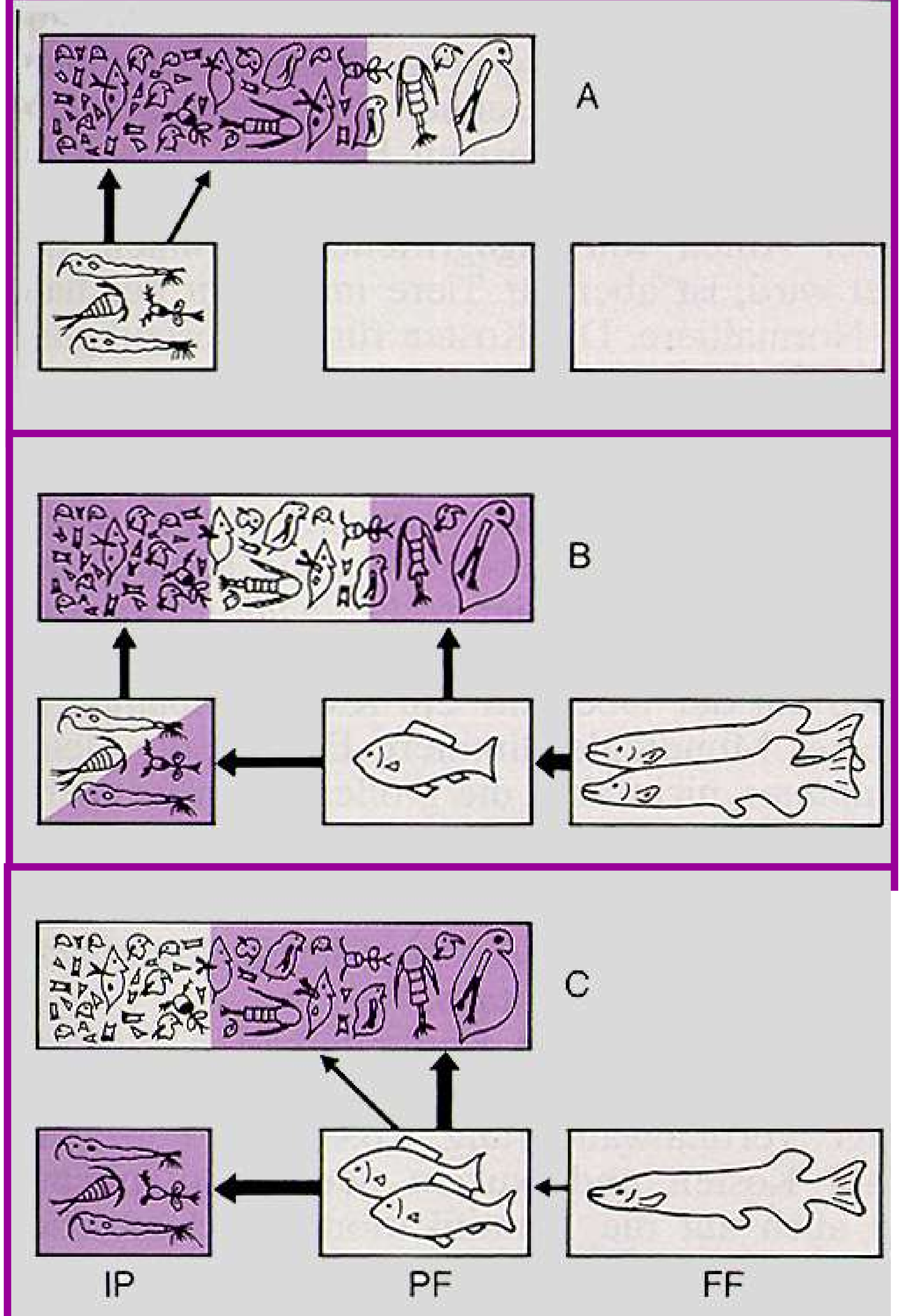
Effect of invertebrate and vertebrate predators on the size composition of zooplankton

A: no planktivorous fish -> large zooplankton species abundant

B: piscivorous fish -> reduced planktivorous fish -> medium size of zooplankton predominates

C: less piscivores -> abundant planktivorous fish -> small zooplankton

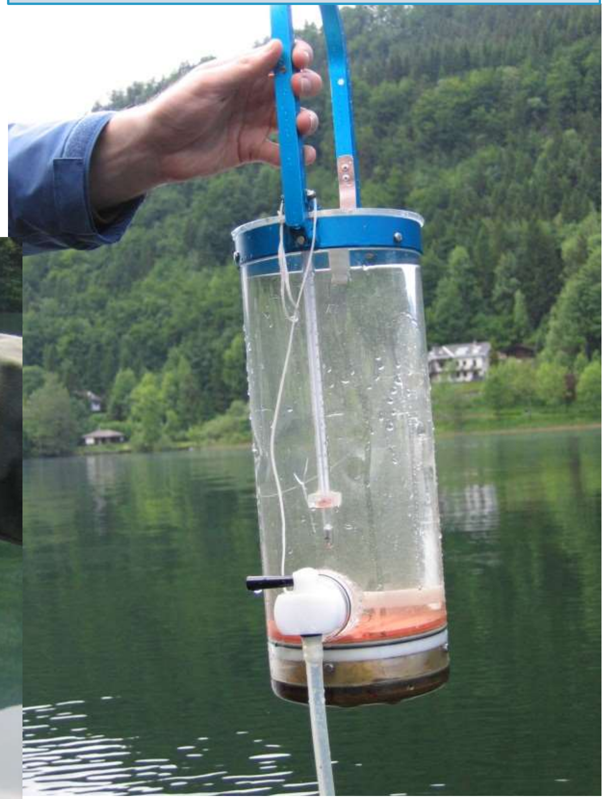
LAMPERT & SOMMER 1999



Sampling methods

Plankton net

Schindler Sampler



Ruttner Sampler