Chapter 7

http://en.wikipedia.org/wiki/Mollusca

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World capture fisheries and aquaculture production (FAO, 2014)
FAO: Food and Agriculture Organization of the United Nations

World aquaculture production: major species groups in 2008 (FAO)

What is cultivated?

Food requirements and constraints

Marine Invertebrate Zoology
Invertebrate Classification and Relationships
Why Study Invertebrates?

- Many diseases that effect humans and the animals we depend on are caused by invertebrates
- Invertebrates are the base of most food webs
- Invertebrates are the base of many medical studies:
  - Control of gene expression
  - Aging, cell death, fertilization and chemoreception
  - Transmission of nerve impulses, biochemical basis of learning and memory
  - Genetic basis for the predisposition for major diseases (i.e. type II diabetes)
  - Isolating unique chemicals for biomedical reasons
  - Using invertebrates as indicators in monitoring aquatic systems for pollutants

Invertebrates and the Marine Environment

<table>
<thead>
<tr>
<th>Property</th>
<th>Water</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Sensory器官</td>
<td>Simple</td>
<td>Simple</td>
</tr>
<tr>
<td>Respiration</td>
<td>Liquefied</td>
<td>Liquefied</td>
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<tr>
<td>Excretion of waste products</td>
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<td>Low</td>
</tr>
<tr>
<td>Osmotic regulation</td>
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<td>Simple</td>
</tr>
<tr>
<td>Photosynthesis</td>
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<td>No</td>
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<tr>
<td>Light sensitivity</td>
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<td>Simple</td>
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<tr>
<td>Temperature stability</td>
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<td>High</td>
</tr>
<tr>
<td>Oxygen stability</td>
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<td>High</td>
</tr>
<tr>
<td>Respiration</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Osmotic pressure</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Nutrient concentration</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Light intensity</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Light penetration</td>
<td>Simple</td>
<td>Simple</td>
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</tbody>
</table>

Molluscan characteristics: the unique features
- radula 齒舌
- mantle 外套膜
- mantle cavity 外套腔
- foot 足部

Primitive mollusc: slow moving, bilateral symmetry, low coil shell, flat broad foot, posterior mantle cavity, paired gills, grazer with radula, simple reproductive tract and external fertilization.

Classification of mollusca

- Class Aplacophora 无板纲
  - Subclass Solenogastres 滴腹亚纲
  - Subclass Caudofoveata 尾腔亚纲
- Class Polyplacophora 多板纲
- Class Monoplacophora 单板纲
- Class Gastropoda 腹足纲
  - Class Bivalvia 双壳纲
- Class Scaphopoda 掘足纲
- Class Cephalopoda 头足纲
Introduction to the phylum of Mollusca

Study purpose:
- to increase knowledge of a large and diverse invertebrate group whose members are important ecologically in marine, freshwater and terrestrial ecosystems
- to know the local molluscan fauna; study economically important species (e.g. +: shellfish; -: wood boring bivalves).

軟體動物:
- invertebrates, body without segments, body divided into head, foot, visceraous, mantle and shell.
- 2nd largest animal phylum (85,000 described – 110,000 estimated spp.);
- largest phylum: Arthropoda
- Geological literature: Molluscs are thought to have evolved from non-segmented worms at Precambrian (ca. 650 mya). Fossilized molluscs shells of diverse forms appear suddenly.

Conchology: study shells
Malacology: study shells and soft parts.

Binominal name:

*Cypraea tigris* Linnaeus, 1758 黑星寶螺
*Lambis lambis* (Linnaeus, 1758) 蜘蛛螺
(with revised genus by the person)
*Conus (Virroconus亚属) ebraeus*

History of Molluscs study in Taiwan

日據時代: records in the Bulletin of the Malacological Society of China (貝類學會誌 vol. 1 - 2; 1974 - 1975)

林朝棨 – seashell; 王雨卿; 藍子樵 姜祝山
at present: 巫文隆、吳錫圭、賴景陽、邱郁文、姜玲、薛美莉等

Spell “mollusk” in the USA; the spelling "mollusc" is preferred by some authors.

Class of Mollusca (Pechenik, 1996)

Major taxonomic divisions of the Phylum Mollusca

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Approximate number of described species</th>
<th>Adult habit</th>
<th>Benthic</th>
<th>Pelagic</th>
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<tbody>
<tr>
<td>Class Monoplaxapha</td>
<td>10</td>
<td>all</td>
<td>all</td>
<td></td>
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<td>Class Polyplaxapha</td>
<td>210</td>
<td>all</td>
<td></td>
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<tr>
<td>Class Ctenopoda</td>
<td>67,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subclass Poshenbrania</td>
<td>3,000*</td>
<td>most</td>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td>Subclass Quiasshanica</td>
<td>3,000*</td>
<td>most</td>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td>Class Bivalvia</td>
<td>31,000*</td>
<td>all</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Cephalopoda</td>
<td>1,000</td>
<td>some</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Scaphopoda</td>
<td>1,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>87,000</td>
<td>(105,000)</td>
<td>most</td>
<td>some</td>
</tr>
</tbody>
</table>

*From Kellogg, 1974.
*From Toonen, 1976.
*From Randell-Heune, 1980.
Freshwater molluscs

Class Bivalvia
  Order Schizodonta 裂齒
  Order Heterodonta 異齒

Class Gastropoda
  Subclass: Prosobranchia 前鰓
    Order Archaeogastropoda 原始腹足
    Order Mesogastropoda 中腹足
  Subclass Pulmonata 肺螺
    Order Basommatophora 基眼

Land molluscs

Class Gastropoda
  Subclass: Prosobranchia 前鰓
    Order Archaeogastropoda 原始腹足
    Order Mesogastropoda 中腹足
  Subclass Pulmonata 肺螺
    Order Systellomatophora 縮柄眼目
    Order Basommatophora 基眼目
    Order Stylommatophora 柄眼目


Yearly fisheries production of Taiwan (1995; 貝類學報 19:61-70)

What “Mollusca” is?

Molluscan characteristics:
  the unique features: radula, mantle cavity, foot, gills, external fertilization.

Primitive mollusc: slow moving, bilateral symmetry, low coil shell, flat broad foot, posterior mantle cavity, paired gills, grasper with radula, simple reproductive tract and external fertilization.

Yearly production of mollusks in Taiwan
1. Carbonate shell: external, internal or lost.
   Function: defense; prevent ambient changes e.g. 1°C, salinity, pH and etc. composed of calcium carbonate crystals interwoven between layers of organic matter.
   Gastropod-univalve, bivalves, no shell - parasitic species, slugs and etc.
2. Mantle (= pallium): part of the integument of molluscs; secretes the shell and forms a gill or gills in many species (known in molluscs as ctenidium or ctenidia, ctenae = comb-like).
3. Mantle cavity (pallial cavity): the space outside the body wall, bounded by the mantle or pallium, with gills for respiration, discharge wastes, eggs and sperm.
   Function of Mantle/mantle cavity: shell secretion, respiration (gills or lung cavity in terrestrial pulmonates, feeding, swimming expansion in some ophiuroids, brood chamber, locomotion with siphon in cephalopods, chemoreception, waste and gametes discharge, anti-predator secretions.
4. Head with tentacles and eyes: exceptions in chaetodermatids, solenogastres, bivalves and scaphopods.
5. Foot: formed by ventral body wall expansion, divergent evolution as their functions including - attachment in chitons or mussel, creeping locomotion, burrowing in scaphopods, swimming fin in pelagic snails, production of floats in pelagic snails, egg-laying, jet propulsion in cephalopods etc.
6. Radula: a ribbon-like band of teeth used in feeding. a few to numerous teeth per row, exception - bivalves, parasitic species, suction feeding species and some solenogastres.
7. Embryonic development: spiral cleavage development, with trochophore and veliger (most species) stages.
8. Circulatory system: open circulatory with hemocoel except cephalopods (close circulatory system).
Class Polyplacophora 多板綱
(= Placophora 有板, Amphineura 雙絨綱)

General biology:
- ca. 650 described species (石鱉)
- world-wide distribution;
- free living on hard substrata (except Notoplax in muddy sand); intertidal (most) to trench (5000m);
- herbivorous to carnivorous;
- life span 4 - 5 yrs (max. 16 yrs), sex maturity 1 - 2 yrs;
- predators including crabs, birds, elasmobranch fish, starfish;
- some have homing behavior, e.g. Acanthopleura gemmata with permanent home and moving range 20 - 60 cm (up to 200 cm)

Species diversity of chitons (石鱉)

California chiton, Placiphorella velata:
lateral view showing large head-flap raised in preparation for seizing animal prey (Yonge & Thompson, 1976).

Class Monoplacophora 單板綱

General biology:
- most fossil species (Devonian泥盆紀, 350 - 500 mya), living species found in 1952 by the Danish Galathea expedition（海神號）from 3750 m off the Pacific coast of Costa Rica (10 complete specimens and 3 shells); 11 - 15 living species, all deep sea, e.g. Neopilina galatheae新蝶貝; deposit feeders

General characters:
1. limpet like shell (univalve) with apex far forward than limpet;
- shell thin and fragile; 8 pairs muscle scars on the inside of the shell
2. 1.5 - 40 mm in length; bilateral symmetry;
- foot flat
3. reduced head with eyes and tentacles
4. mouth surrounded by oral tentacles to gather food
5. reproductive organs 2 pairs; diecious;
- development largely unknown
The evolution of torsion in the visceral mass and its consequences for the overall anatomy. (A) hypothetical anatomy of a primitive mollusk, (B) hypothetical intermediate development, (C) archaeogastropod, (D) mesogastropods and neogastropods, (E) opisthobranchia, (F) pulmonate system. 1-mouth, 2-tentacles, 3-eyes, 4-radula, 5-cerebral ganglion, 6-pleural ganglion, 7-pedal ganglion, 8-foot, 9-operculum, 10-parietal ganglion, 11-visceral ganglion, 12-gonad, 13-excretory organ, 14-gut, 15-anus, 16-pericardium, 17-ventricle, 18-atrium, 19-gill, 20-asphradium, 21-lung, 22-pallial chamber, 23-copulatory organ (Feinberg, 1979).

The evolution of torsion in the visceral mass and its consequences for the overall anatomy. (D) mesogastropods and neogastropods, (E) opisthobranchia, (F) pulmonate system. 1-mouth, 2-tentacles, 3-eyes, 4-radula, 5-cerebral ganglion, 6-pleural ganglion, 7-pedal ganglion, 8-foot, 9-operculum, 10-parietal ganglion, 11-visceral ganglion, 12-gonad, 13-excretory organ, 14-gut, 15-anus, 16-pericardium, 17-ventricle, 18-atrium, 19-gill, 20-asphradium, 21-lung, 22-pallial chamber, 23-copulatory organ (Feinberg, 1979).

Torsion
Definition of Torsion: a 180° anticlockwise (or clockwise) movement of the viscera, mantle and shell with respect to the head and foot; this is a unique character in animal kingdom.

The anatomical features on the twisting of the nerve cord and digestive tract into “8”

torsion starts at veliger stage: formed by contraction of an asymmetric retractor muscle attached to shell and left side of foot

巴西蝸牛

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Subclass Opisthobranchia 後鰓亞綱（sea slugs）
Greek opistho-, behind; brankhia, gills

General features and specimen preservation
1. almost all marine species, about 3000 described species, morphology highly diverse but physiologically conservative
2. usually without operculum external shell reduction → internalization → complete loss; then mobility increase; size (0.3 to 80 cm)
3. Detorsion
4. Feeding: mostly specialized herbivores or carnivores with radula and jaws; some suction feeding without radula
5. hermaphroditic; eggs (a few to million)
6. indirect (free-swimming veliger) or direct development
Subclass Pulmonata 肺螺亞綱
1. Mainly freshwater or land inhabitants; few marine species are from land or freshwater (2nd invasion)
2. no ctenidium, with mantle cavity vascularized to function as a lung in terrestrial species. The cavity is closed except for a rhythmically opening aperture (pneumostome 肺孔) on the right side. Aquatic species generally have neomorphic folded “gills” for respiration
3. detorsion usually incomplete; traces of torsion are found in the anterior and forward-facing mantle cavity
4. nerve system very concentrated
5. hermaphroditism
6. Basommatophora 基眼目 - a single pair of noninvaginable tentacles with eyes at base, most are aquatic.
   Stylommatophora 柄眼目 - two pairs of invaginable tentacles with eyes on ends of posterior pair, most terrestrial and slugs

Class Scaphopoda 掘足綱
1. about 350 species with uniform structure and specialized infaunal habits
2. all are marine and infaunal (mud/sand), subtidal (most)
3. bilateral symmetry; mantle and shell (open both ends) are elongated and united ventrally to form a tapered tube at both ends
4. the foot is cylindrical and pointed with epipodial lobes
5. no ctenidia with 2nd gills, no heart and pericardium; twisted
6. the head is undifferentiated without eyes and sensory tentacles but surrounded by clusters of captacula (small, elongate, retractile tentacles about several hundreds) for feeding

Structure and habits of Scaphopods.
A. Dentalium sp.
B. stages of the “digging cycle”
C. stages in twisting motion during burrowing
D. terminal region of capitulum in D. conspicuum
E. D. pseudohexagonum shown in situ indicating extent of excavated feeding cavity
Class Bivalvia 双殼綱、斧足綱、瓣鰓綱
(=Acephala, Lamellibranchia, Pelecypoda, Conchifera)

1. About 7500 species with 3/4 marine species; about 600 in Taiwan
2. Without torsion
3. Body bilateral symmetry with laterally compressed
4. Head reduced or lost; no cephalic sense organs; sense organs locate on the mantle margin
5. Compressed foot adapted for burrowing
6. Diecious (96%) or hermaphroditic 4%, external fertilization
7. Most species with trophophore and veliger stages

Types of bivalve gills in transverse section. A. protobranch, B. filibranch, C. eulamellibranch, D. septibranch. (1) foot, (2) ctenidium, (3) branchial filaments, (4) suprabranchial chamber, (5) septum (Kasang, 1979).

Mussel

成熟貽貝有30–50條足絲,每條長約2–4cm, 直徑約0.1mm, 黏著處膨大成2–3mm. 足絲含有十種蛋白質,越近貽貝身體的足絲越有彈性,反之越堅硬。一萬隻貽貝只萃取出幾公克的足絲蛋白, 每次實驗至少要100mg足絲蛋白質,因此,生物黏膠的研究進展有材料不足的問題。

Cephalopoda (=Siphonopoda) 頭足綱

1. About 600 living species, 10000 fossil species (early Cambrian) all are marine and mostly pelagic
2. Giant squid Architeuthis 16m long (6m tentacles included) and 4m in diameter; giant octopods arms 10 – 15m long; smallest cuttlefish Idiosepius 1.5cm long (intertidal to subtidal)
3. Evolution trend: benthic to pelagic
   a. development gas-filled external chambered shell
   b. reduction and loss shell
4. Without torsion; bilateral symmetry; concentrated nervous system with brain; highly developed sense organs (e.g. eyes); nerve cord 5 pairs
5. Foot derived to tentacles (arms 腕足) and funnel (siphon 漏斗)
6. Circulatory system
7. Diecious
頭足綱:

鳥鵡螺亞綱（Nautiloidea）又稱四鰓亞綱 
鸚鵡螺目（Nautilida）：例如珍珠鸚鵡螺

蛸亞綱（Coleoidea）又稱二鰓亞綱 

d101x642]十腕總目（Decapodiformes）
例如烏賊、魷魚等。

烏賊目

耳烏賊目
管魷目 

八腕總目（Octopodiformes）
例如章魚、軟絲仔等。

如何辨別花枝、烏賊、魷魚、鎖管…等?

真烏賊（花枝）

真鎖管（透抽）

無針烏賊（墨賊）

鎖管（小管）

柔魚（軟翅仔）

魷魚

體呈扁平袋狀，兩側全緣有狹窄的鯺，外套內有舢舨形石灰質的內殼

體呈圓筒形，鯺自體中部至尾端，呈長菱形，後緣凹入，所有的腕皆有吸盤與齒環。

外型類似烏賊，但內殼後端無硬針突出，肉質較軟。

體型較小，較無似透抽的細長，鯺後端邊緣平直。

Cephalopod chromatophores contracted (A) and expanded (B).