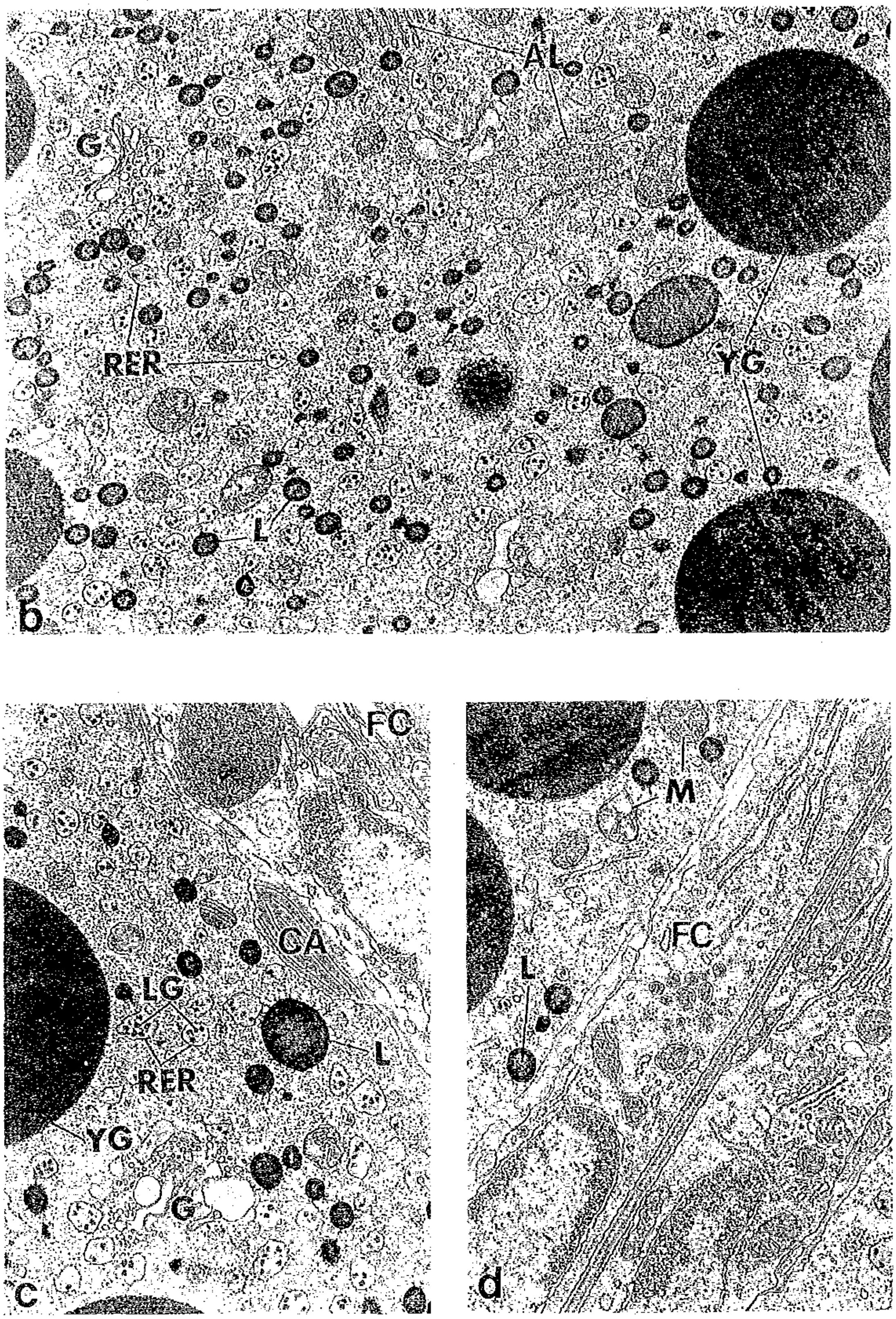

Fig. 21 b) RER remarkably reduced in volume. × 10,000 c) and d) Cortical alveoli located outside of the cytoplasm. × 10,000 (*P. japonicus*)

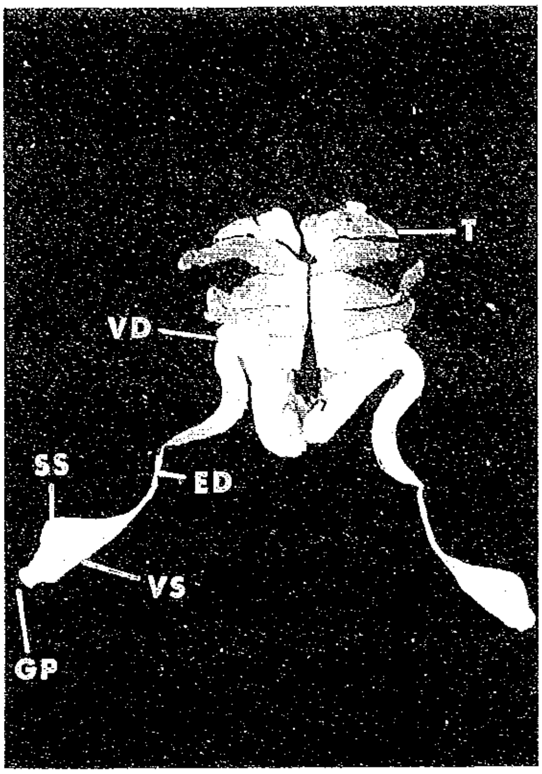

Fig. 22 Schematic representation of genital organs of male prawn. T, testis; VD, vas deferens; ED, ejaculatory duct; VS, vesicular seminalis; SS, sperm sac; GP, genital pore. × 5 (*P. japonicus*)

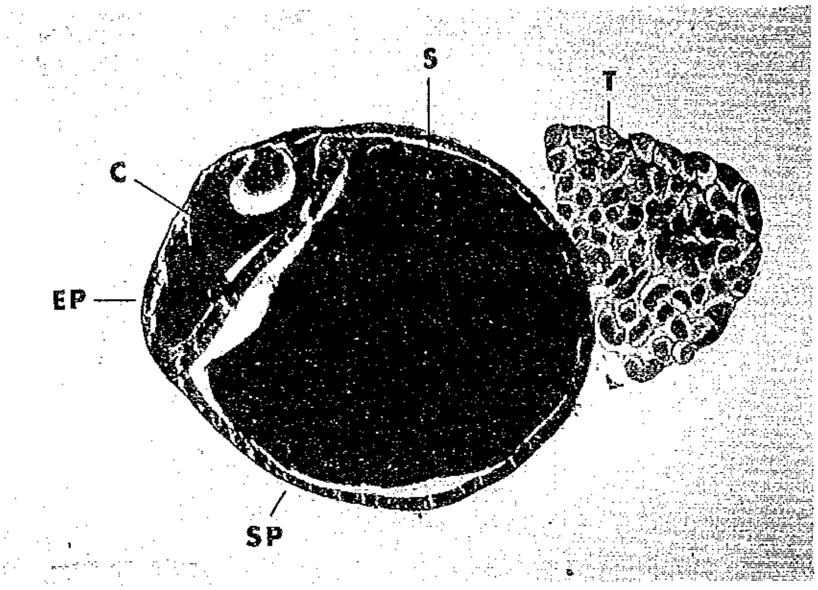

Fig. 23 Cross section of the vas deferens and testis, showing efferent part (EP) and secretory part (SP). C, chitin—like substance; S, sperm; T, testis. × 40 (*P. japonicus*)

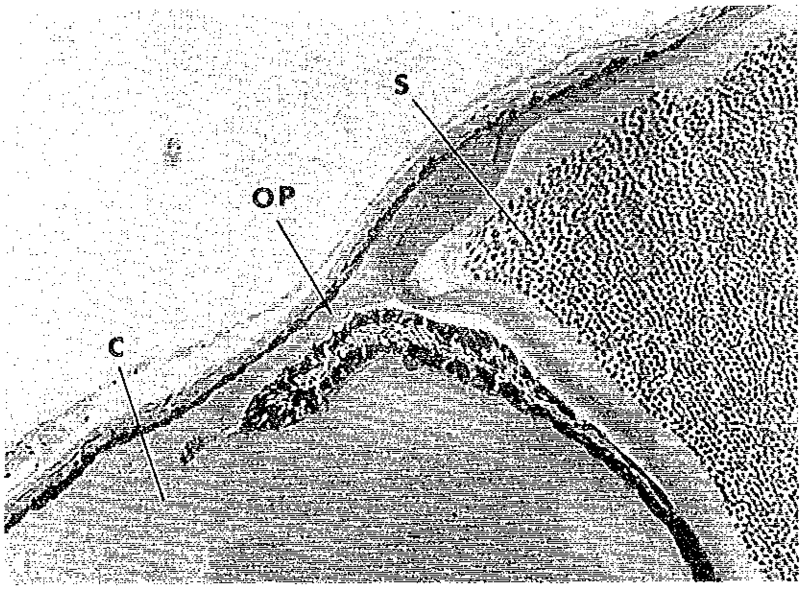

Fig. 24 Cross section of the vas deferens, showing a opening passage (OP) between the efferent part and secretory part. C, chitin—like substance; S, sperm. × 40 (*P. japonicus*)

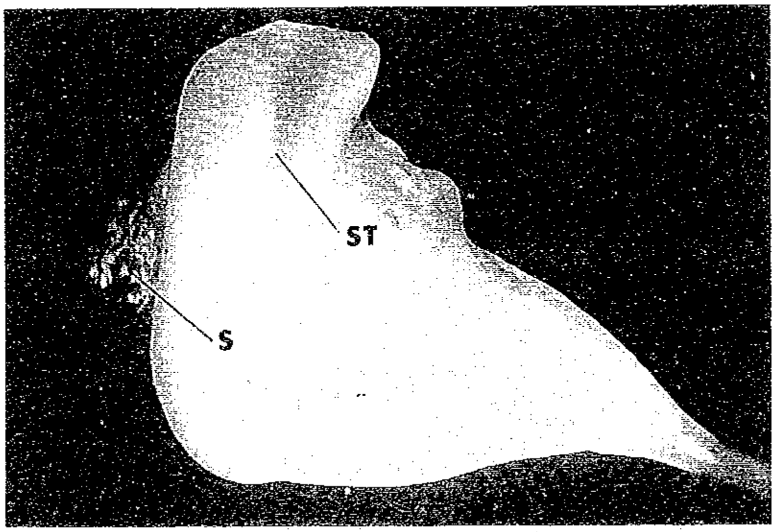

Fig. 25 External appearance of the vesicular seminalis. S, sperm sac; ST, original structure which will be a stopper in female's thelycum after copulation. × 40 (*P. japonicus*)

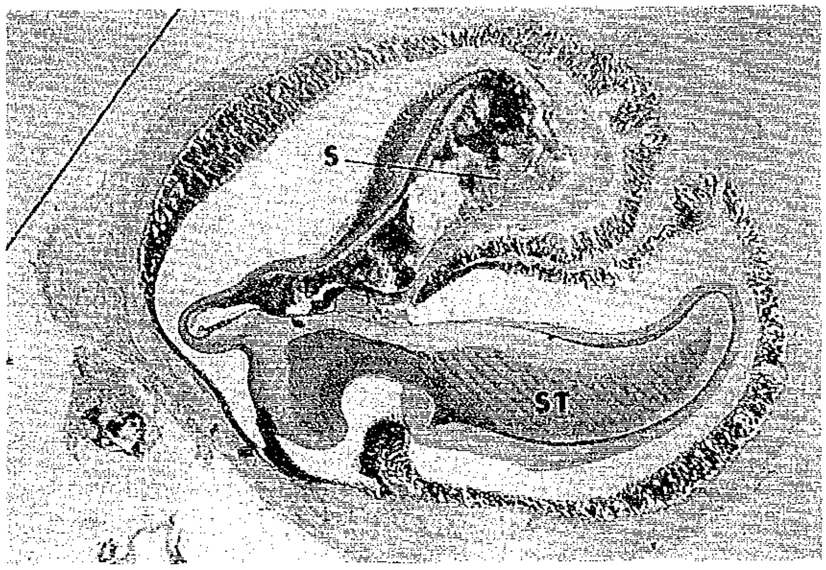

Fig. 26 Cross section of the vesicular seminalis, showing a part of stopper (ST) and sperm sac (S). × 40 (*P. japonicus*)

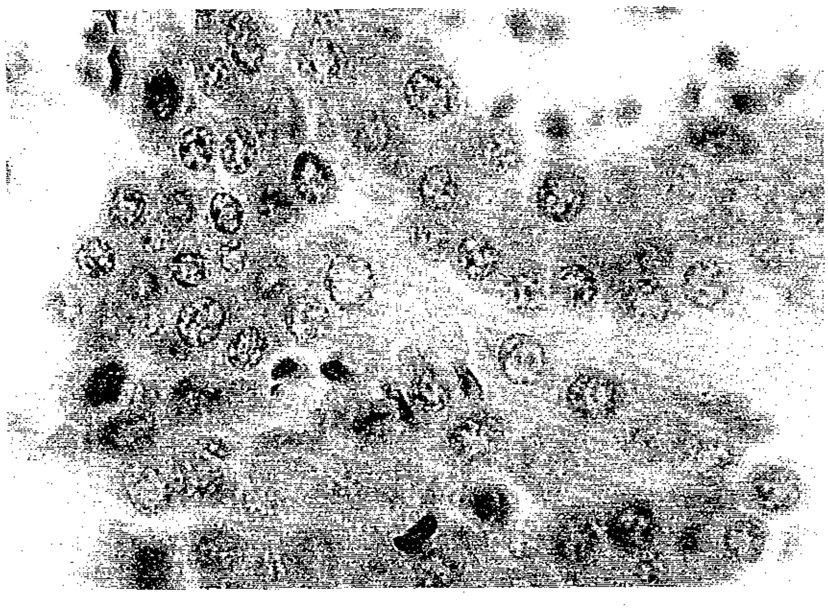

Fig. 27 Spermatogonia in the germinal epithelium. × 900 (*P. japonicus*)

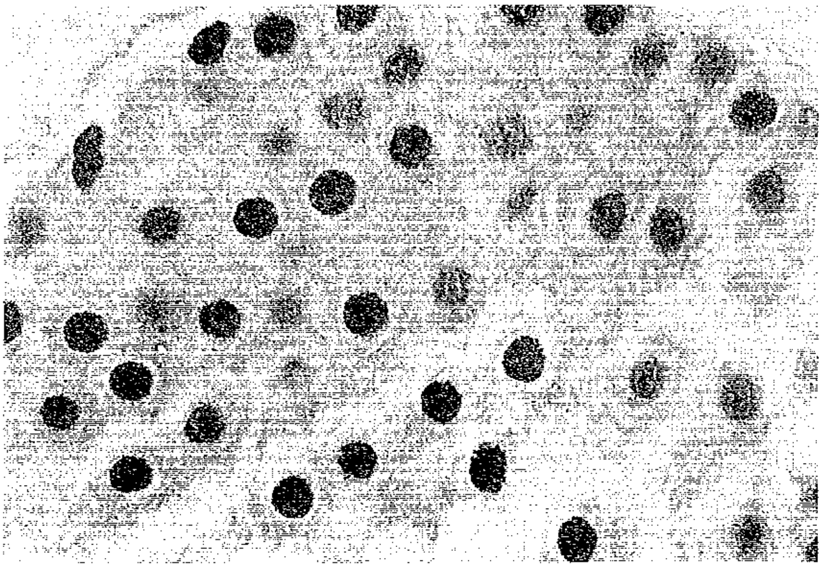

Fig. 28 Primary spermatocytes. × 900 (*P. japonicus*)

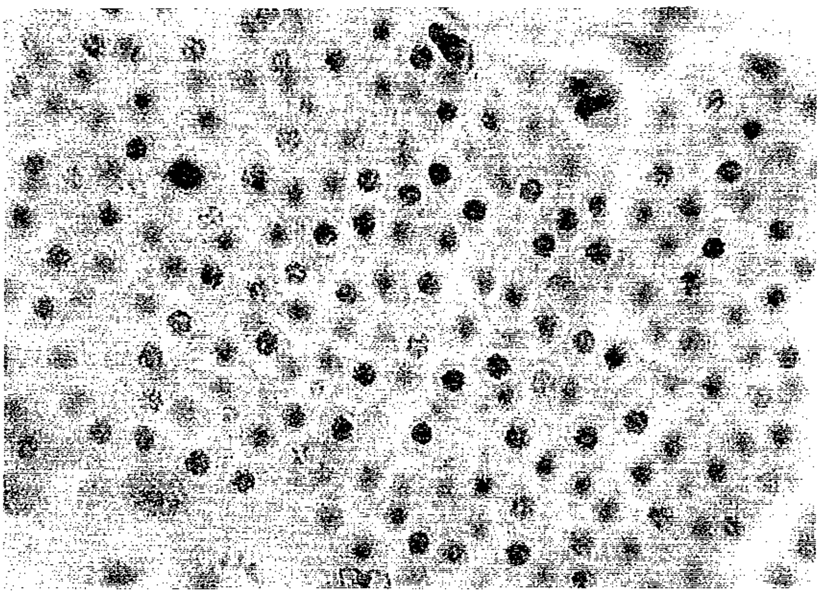

Fig. 29 Secondary spermatocytes. × 900 (*P. japonicus*)

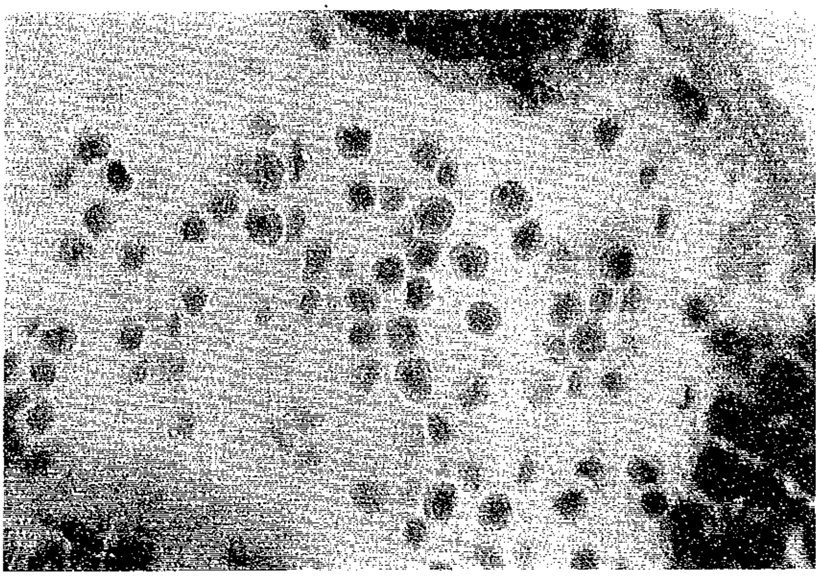

Fig. 30 Spermatids. × 900 (*P. japonicus*)

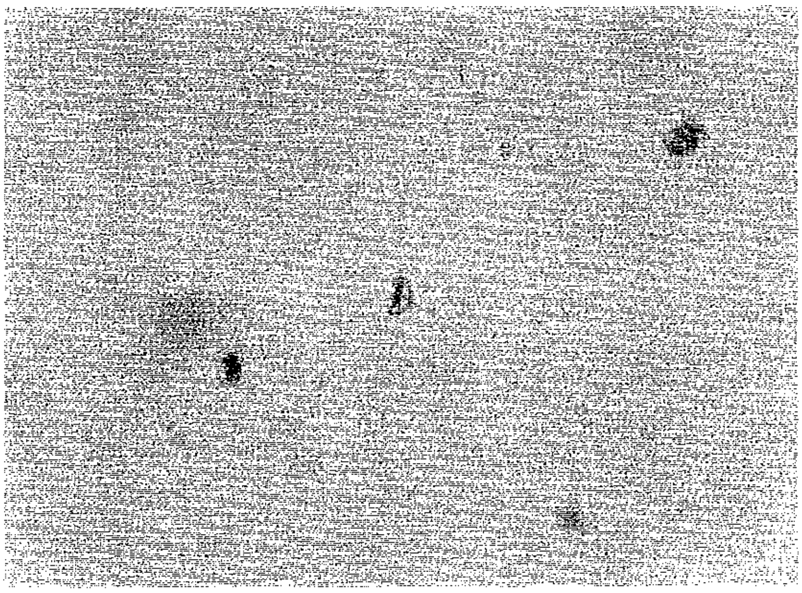

Fig. 31 Mature spermatozoa. × 900 (*P. japonicus*)

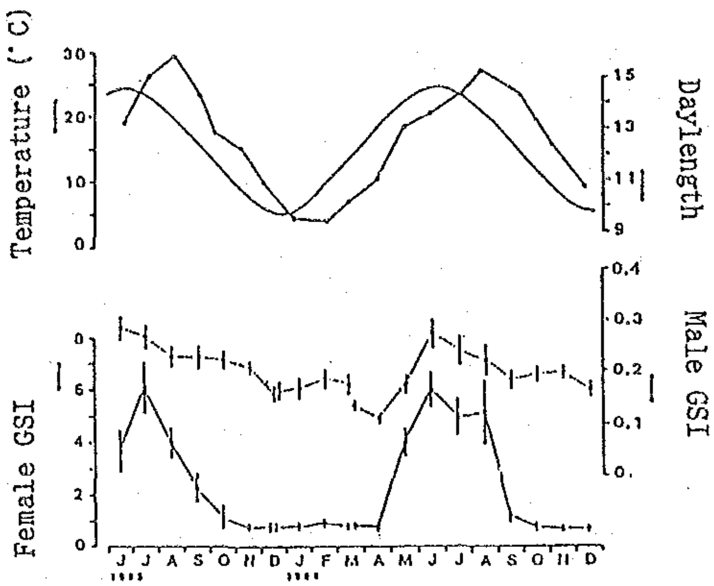

Fig. 32 Seasonal GSI chages in *M. nipponense* native to Lake Kasumigaura (Han, 1988). "Temperature" at top left indicates changes in water temperature.

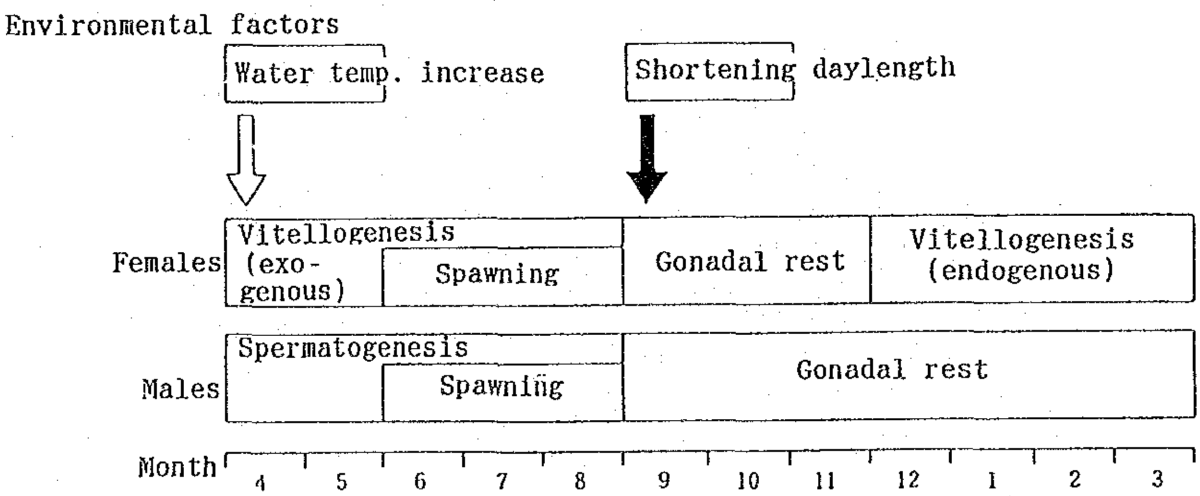

Fig. 33 Annual reproductive rhythms in Lake Kasumigaura *M. nipponense* and their regulating factors.

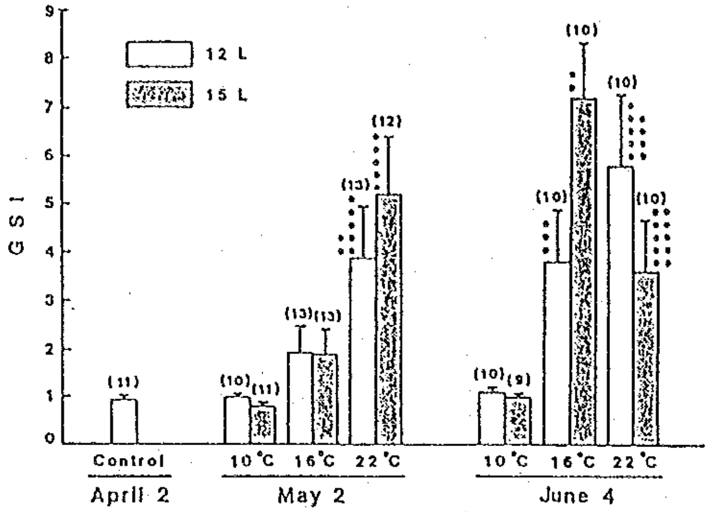

Fig. 34 Effects of water temperature and daylength on the induction of ovarian development in *M. nipponense*. Female *M. nipponense* were reared from April to June under six combinations of water temperature (10, 16, 22℃) and daylength (12, 15L); changes in GSI and numbers of spawned individuals were observed. Asterisk * : number of spawned individuals; Parentheses ( ) : number of experimental individuals (Han, 1988).

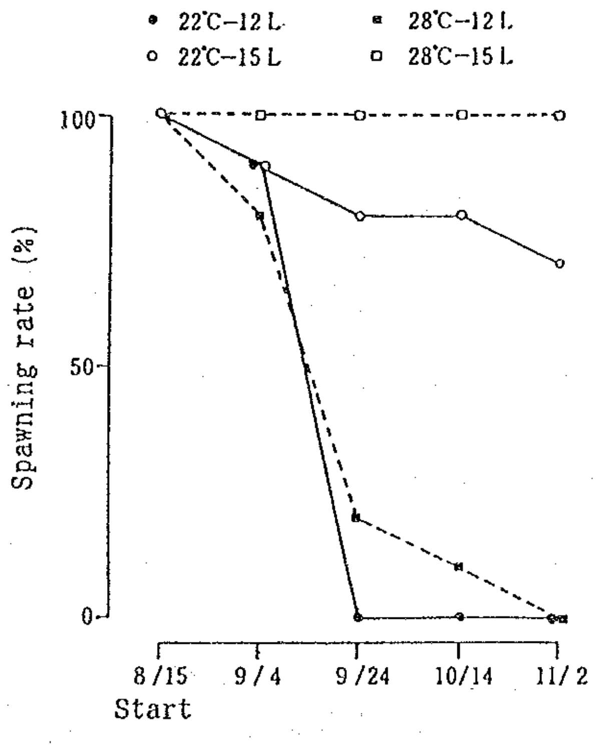

Fig. 35 Effects of daylength and water temperature on the termination of spawning in *M. nipponense*. Female *M. nipponense* were reared from August to November under four combinations of daylength (12L, 15L) and temperature (22, 28℃). Spawning rate is expressed in terms of numbers of individuals which continued to spawn.

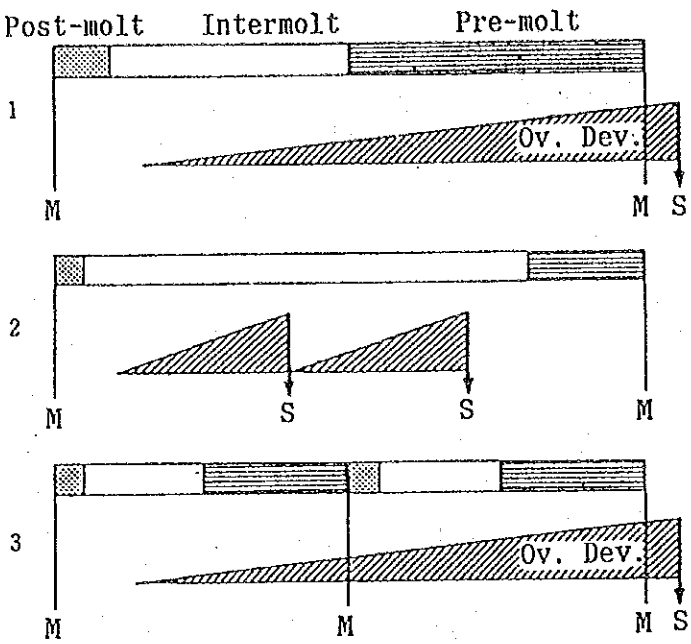

Fig. 36 Relationship of spawning rhythms to the molt cycle. 1) *M. nipponense* and related species; isopods, etc. 2) Crabs: in species exhibiting lengthy molt cycles, ovarian development/spawning/brooding occurs one or more times between successive moltings. 3) In barnacles, and similar animals, the molting period duration is extremely short; therefore, ovarian development occurs over several molt cycles. Immediately after molting, individuals spawn and brood. Ov. Dev: ovarian development, M: molting, S: spawning.

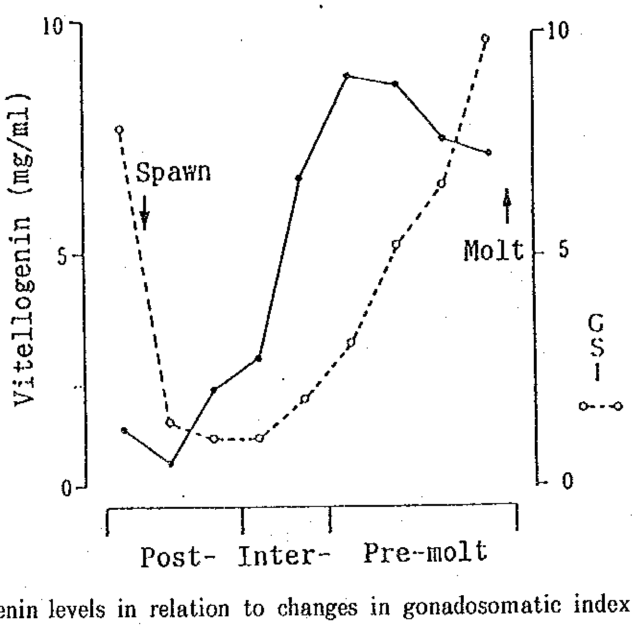

Fig. 37 Vitellogenin levels in relation to changes in gonadosomatic index (GSI) during the molt cycle in female *M. nipponense*.

Amino Acid Sequences of CHH-Family Peptides in the Eyestalk

```
                                   1               10          20                  30                40
Cam-CHH (shore crab)              pE I Y D T S C K G V Y   D R A L F N D L E H V C D D C Y N L Y R T S Y V A S A C R
Orl-CHH (crayfish)                 - V F - Q A - - - I -   - - - I - K K - D R - - E - - - - - - - - K P - - - T T - -
Prb-CHH-I (crayfish)               - V F - Q A - - - I -   - - - I - K K - D R - - E - - - - - - - - K P - - - T T - -
Hoa-CHH-A (lobster)                - V F - Q A - - - - -   - - N - - K K - D R - - E - - - - Y L - K P F - - T T - -
Hoa-CHH-B (lobster)                - V F - Q A - - - - -   - - N - - K K - N R - - E - - - - - L - K P F I V T T - -
Arv-CHH (woodlice)                 R I F - - - - - - F -   - - G - - A Q - D R - - E - - - - - - - - K P H - - A E - -
Pej-CHH (kuruma prawn)             S L F - P A - T - I -   - - Q - L R K - G R L - - - - - - V F - E P K - - T G - -
Hoa-MIH/CHH (lobster)              - V F - Q A - - - - -   - - N - - K K - D R - - E - - - - - - - - K P F - - T T - -
Pev-MIH-like (white shrimp)        D T F - H - - - - I -   - - E - - R K - D R - - E - - - - V F - E P K - - T E - K
Cam-MIH (shore crab)               R V I N E D - P N L I G N - D - Y K K V - W I - E - - - - I F - K T G M - - L - -
Hoa-VIH (lobster)            A S A W F T N D E - P - - M G N - D - Y E K V A W - - N - - S - I F - N N D - G V M - K

                41                  50                  60                  70
Cam-CHH         S N C Y S N L V F R Q C M D D L L M M D E F D Q Y A R K V Q M V (amide)
Orl-CHH         Q - - - A - S - - - - - - L - - - - L I - V L - E - I S G - - T - (amide)
Prb-CHH-I       Q - - - A - S - - - - - - L - - - - L I - V V - E - I S G - - T - (amide)
Hoa-CHH-A       Q - - - - - W - - - - - - L - - - - L S - V I - E - V S N - - - - (amide)
Hoa-CHH-B       E - - - - - R - - - - - - L - - - - - I - V I - E - - S N - - - - (amide)
Arv-CHH         R D - - T G E - - E S - L K - - M - H - F I N E - K E M A L - - S (amide)
Pej-CHH         - - - - H - - I - L D - L E Y - I P S H L Q E E H M A A M - T V (amide)
Hoa-MIH/CHH     E - - - - - W - - - - - - L - - - - L S N V I - E - V S N - - - - (amide)
Pev-MIH-like    - - - F V - K R - N V - V A - - R H D V S R F L K M A N S A L S
Cam-MIH         R - - F F - E D - V W - V H A T E R S E - L R D L E E W - G I L G A G R D
Hoa-VIH         K D - F H T M W - L W - V Y A T E R H G - I D - F R K W - S I L R
```

CHH, crustacean hyperglycemic hormone; MIH, molt-inhibiting hormone; VIH, vitellogenesis-inhibiting hormone.

<Common Chemical Features>

1. Homologous sequence (6 Cys residues).
2. Total amino acid residues: 72-78 (Molecular weight: 8300-9300).
3. Intramolecular 3 disulfide bonds (Cys7-Cys43, Cys23-Cys39, Cys26-Cys52).

Fig. 38 Amino acid sequences of crustacean hyperglycemic hormone (CHH) family peptides in the eyestalk.

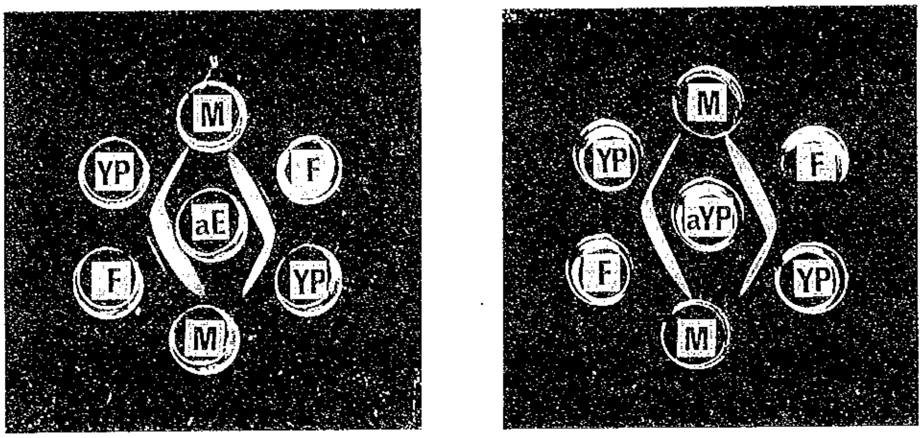

Fig. 39 Ouchterlony's immunodiffusion test for purified yolk protein and hemolymph of a mature male and female against the antisera to crude ovarian extract (A) and to purified yolk protein (B). aE, antiserum to crude ovarian extract; aYP, antiserum to purified yolk protein; F, mature female hemolymph; M, mature male hemolymph; YP, purified yolk protein.

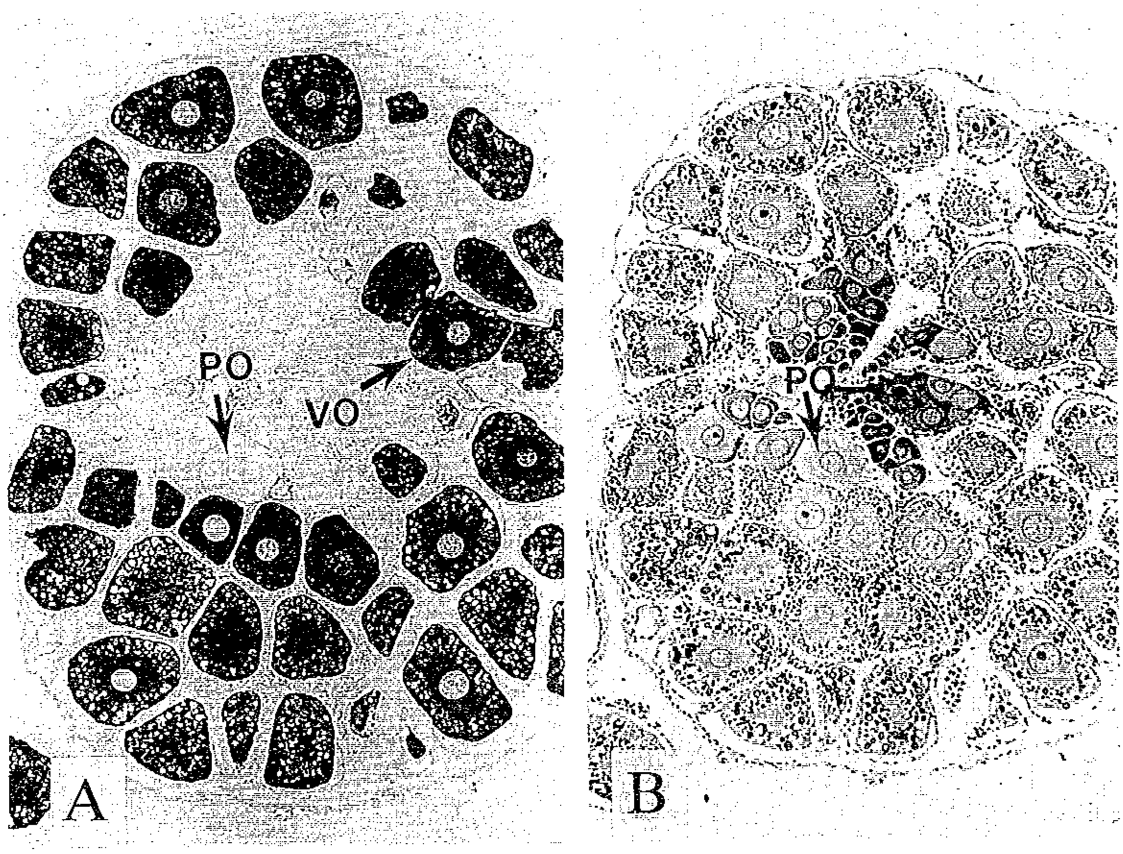

Fig. 40 Immunocytochemical staining using PAP (peroxidase anti-peroxidase) reaction (A), and hematoxylin-eosin staining (B) for adjacent sections of ovary. PO, previtellogenic and endogenous vitellogenic oocytes; VO, exogenous vitellogenic oocytes.

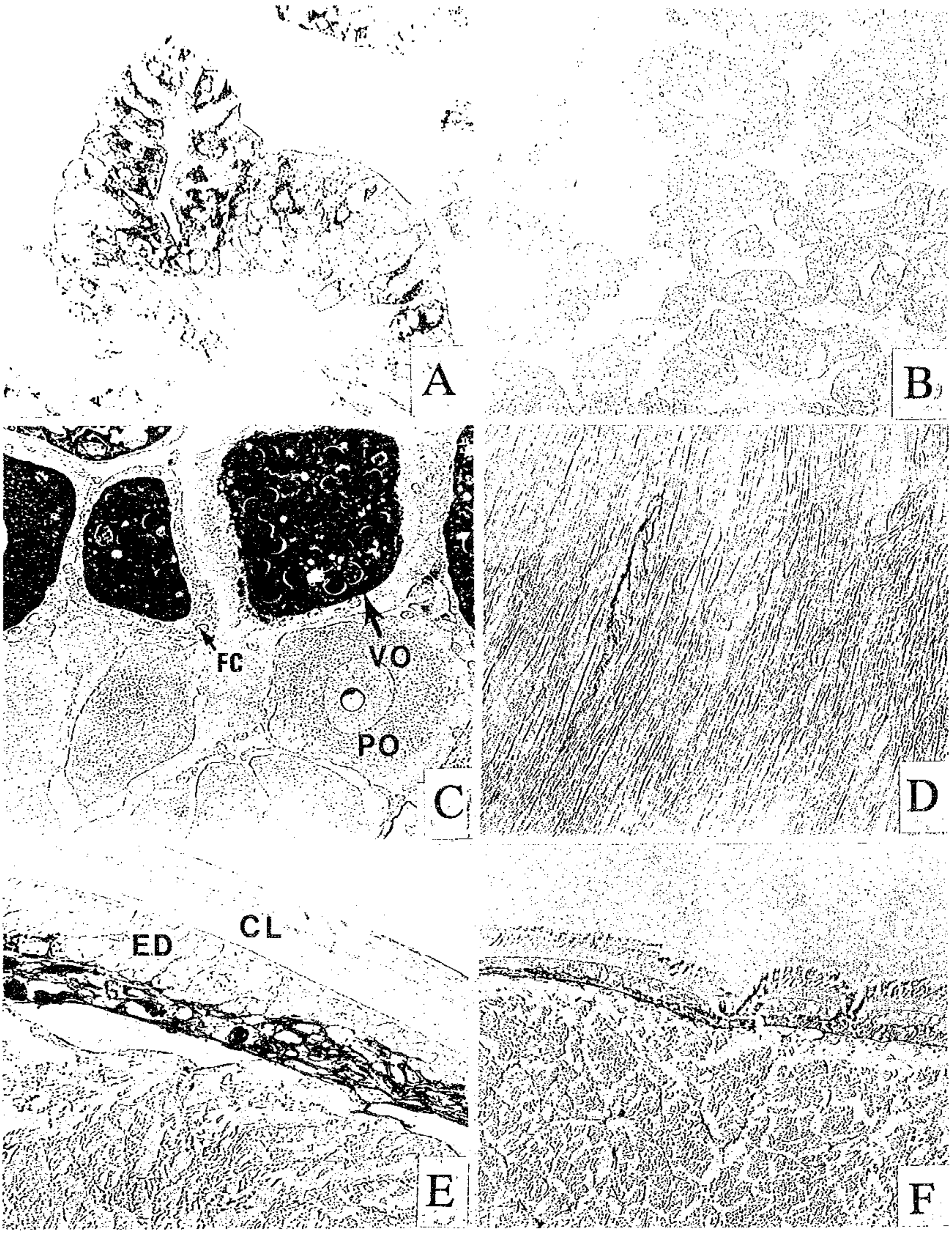

Fig. 41 PAP reaction of hepatopancreas of a mature female (A) and male (B), ovary (C), muscle (D) and sub-epidermal tissues-lateral (E) and dorsal (F) somites. FC, follicular cell; PO, previtellogenic and endogenous vitellogenic oocytes; VO, exogenous vitellogenic oocytes; CL, cuticle layer; ED, epidermis.

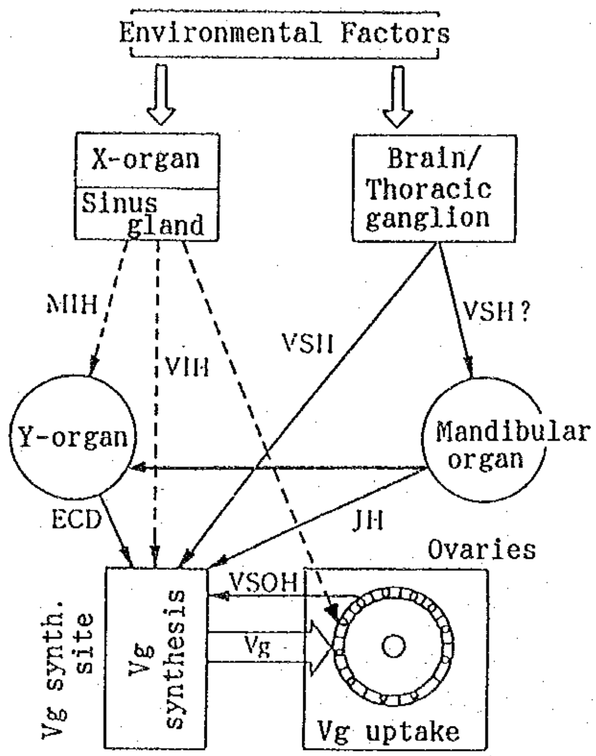

Fig. 42 Hormonal mechanisms controlling vitellogenesis in Crustacea. ECD: ecdysteroids, JH: juvenile hormone, MIH: molt-inhibiting hormone, Vg: vitellogenin, VIH: vitellogenesis-inhibiting hormone, VSH: vitellogenesis-stimulating hormone, VSOH: vitellogenesis-stimulating ovarian hormone.

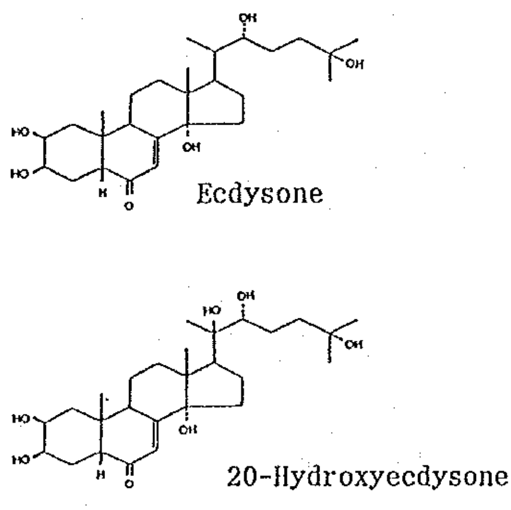

Fig. 43 Structures of ecdysone and 20-hydroxyecdysone.

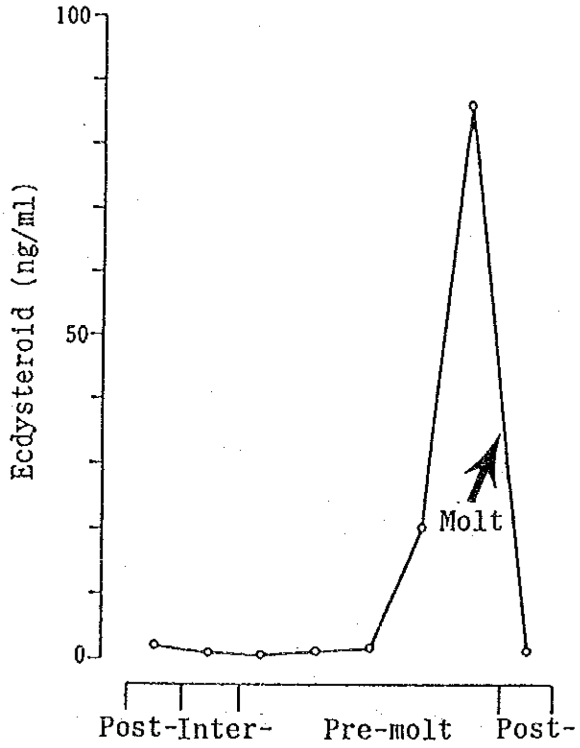

Fig. 44 Changes in hemolymph ecdysteroids during the molt cycle in female *M. nipponense*.

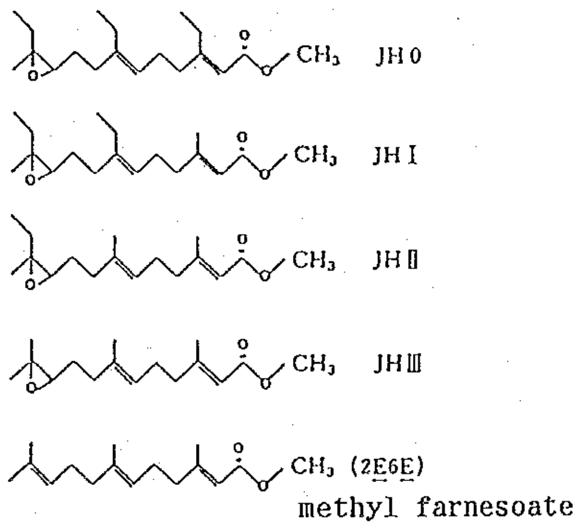

Fig. 45 Structures of the juvenile hormone (JH) family. JH 0, I, II, III are insect hormones. Methyl farnesoate (MF) has been discovered as the crustacean equivalent of juvenile hormone. methyl farnesoate.

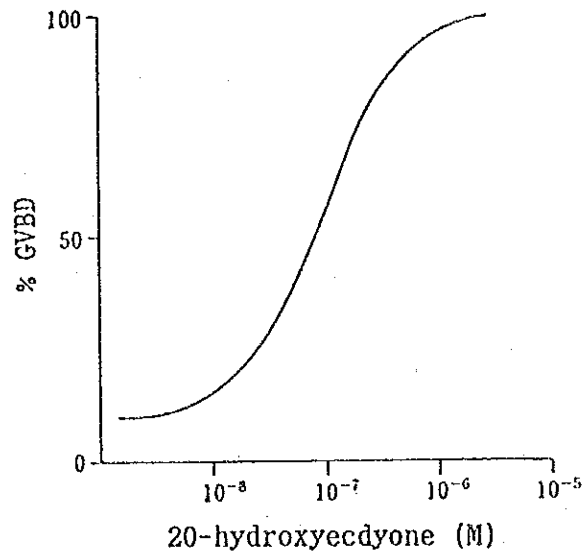

Fig. 46 Percent induction of germinal vesicle breakdown (GVBD) by 20-hydroxyecdysone in the grass shrimp, *Palaemon serratus*. Mature oocytes were dissected out, and incubated with varying concentrations of 20-hydroxyecdysone in tissue culture. Percentage of oocytes showing occurrence of GVBD was examined, and expressed in terms of percent.

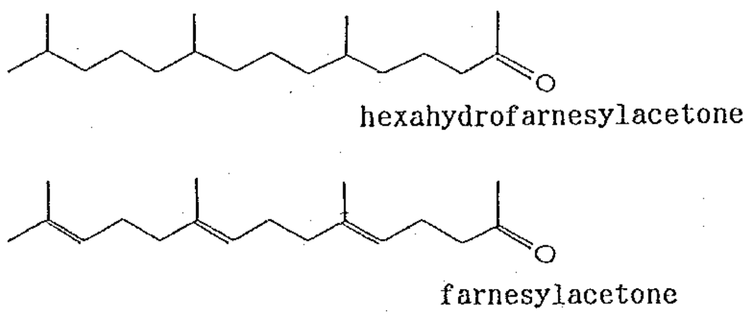

Fig. 47 Isoprenoid type androgenic gland hormone isolated from the androgenic glands of the crab, *Carcinus maenus*.

Table 1. Breeding seasonality in various crustacean species.

Species name	Habitat	Distribution	Breeding time
JAPAN			
(Prawns)			
Penaeus japonicus	Coastal	Tokyo Bay／Southward	Early May－Early Sept
Sergestes lucens	Deep sea	Tokyo, Sagami, Suruga Bays	June－August
Metapenaeus joyneri	Inland seas	Tokyo Bay／Southward	June－August
Macrobrachium nipponense	Freshwater	Honshu, Shikoku, Kyushu	June－August
(Crayfish)			
Procambarus clarkii	Freshwater	Honshu, Shikoku, Kyushu	Fall spawn／brood Spring hatchout
(Crabs)			
Paralithodes camtschatica	Deep sea	Japan, Ohotsuku Seas	Approx. May
Chionoecetes opilio	Deep sea	Japan, Ohotsuku Seas Inubozaki／Northward	Winter－Spring／ July－Sept
Sesarma haematocheir	Estuaries／beach areas	Iwate Pref.／Southward	July－Sept
Eriocheir japonicus	Rivers／estuaries	Sahalin／Southward	August－Oct, spawn Spring hatchout
(Mantis shrimp)			
Oratosquilla oratoria	Bays	Hokkaido to Kyushu	Mid-May to late July
MID TO UPPER LATITUDES			
(Crabs)			
Hemigraspus nudus *	Beach areas	Puget Sound, USA, 49° N Monterey Bay, USA, 36° －30° N	Jan－April Oct－May
Pachygraspus crassipes	Intertidal areas	Monterey Bay, USA, 36° －30° N	March－Aug
Helice crassa *	Mangrove areas	Avaon and Heathcote Estuary, (New Zealand), 43° －33° S Wellington, 41° S Dundein, 45° －50° S	August－March August－Jan Sept－Feb
(Krill)			
Euphasia * *superba*	0－900m	South Pole region	Jan－March
Thysanoessa raschii	0－200m	North Atlantic, 40° －75° N	Feb－May, Aug－Sept
LOWER LATITUDES			
(Crabs)			
Pachycheles tomentosus *	Intertidal areas	Karachi, Pakistan	Year-round
Clibanarius chapini *		Prampram, Ghana, 6° N	Year-round

* From Sastry, 1985

Table 2. The effects of light and temperature on crustacean reproduction

Species	Treatments and subsequent results	
(Amphipoda)		
Gammarus setosus	Short days	→Acceleration of reproductive cycle. However, cycle not completely controllable by photoperiod.
G. lawrencianus	Short days	→Inhibition of vitellogenesis.
(Isopoda)		
Armadillium vulgare	Long days	→Promotion of reproduction.
(Decapoda)		
Penaeus japonicus	Long days (13.5−16L) and high water tem. (24−26℃)	→Stimulation of breeding.
Macrobrachium nipponense	Increase in water temp.	→Commence breeding season.
	Shortened day length	→Terminate breeding.
Orconectes nais	Long days	→Inhibition of ovarian growth.
	Short days	→Acceleration of ovarian growth.
Pachygraspus marmoratus	Long photophase	→Animals undergo vitellogenesis if previously exposed to short photophase.
Scylla serrata	long days (14L)	→Promotion of vitellogenesis.

Table 3. Hatchout rates/effects of use of artificial copulatel fluid on efficacy of sperm receptacle implantation in the prawn, *Penaeus penicillatus*.

Treatment	No. Ind.	Hatching rate
I	6	30.7±6.2 [1]
II	8	47.4±9.1
III	5	25.6±7.3
IV	10	21.3±5.0

[1] Trypsin concentration = 62.5mg/mℓ seawater; exposure time, 5 min.

JICA