

冬眠中华鳖雌、雄生殖道的精子储存

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摘要:应用光镜和电镜技术,系统观察冬眠中华鳖(*Trionyx sinensis*)雌、雄生殖道的精子储存情况,显示与精子储存相关的形态结构和细胞特征。结果表明,中华鳖在冬眠期生精活动处于相对静止状态,仅有1~3层精原细胞排列在睾丸曲细精管基膜附近,其余生精细胞排列松散而紊乱,生精上皮中未见有各级细胞规律性排列,不能形成完整的管壁。附睾管腔增大,腔中储存有大量精子。附睾上皮及附睾管腔中见有PAS反应阳性物质。附睾上皮主要由主细胞、亮细胞和基细胞组成。超微结构显示,附睾上皮细胞中含有大量分泌颗粒,内质网膨大。储存在附睾中的精子结构完整,精子中段由35~40个同心圆状线粒体构成线粒体鞘,中段胞质中含有大量糖原颗粒。雌性输卵管分布着数量不等的精子,尤其狭部最多。狭部黏膜皱襞高度融合,形成大量纵行于输卵管的储精细管。在细管中含有大量精子,精子头部嵌入上皮细胞纤毛中。蛋白部和子宫部也有少量精子存在,但在这些部位不能形成明显的储精细管。PAS反应显示,输卵管狭部储精细管上皮分泌有糖蛋白类物质。储精细管上皮下固有层中分布有大量的管状腺,通过腺导管与输卵管管腔相通。雌、雄中华鳖隔离4个月(12月初至来年3月底)后,在雌性输卵管峡部的储精细管中仍可观察到大量结构完整的精子,表明中华鳖精子在输卵管中至少可以储存120 d。以上结果显示,在冬眠期,雄性附睾和雌性输卵管中有大量精子储存,储存的精子能够渡过漫长的冬季用于来年春天交配或受精,这一特殊的生殖策略对其成功繁殖具有重要意义。本研究还对中华鳖的繁殖特性进行了讨论。[中国水产科学,2007,14(5):705-713]

关键词:中华鳖;冬眠;精子储存;附睾;输卵管

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与哺乳动物和鸟类不同,许多爬行动物雄性精子发生与排放、雌性排卵以及雌、雄交配的时间相互错位^[1],如海龟 *Chrysemys picta* 精子发生始于6月,9~10月精子成熟并排放,而雌性排卵只发生在春季,但海龟一年才交配两次,分别在春季和秋季^[2]。这说明,对于秋季交配型而言,精子需要在输卵管中储存,直到第2年春季排卵时才能受精;而对于春季交配型而言,由于此时睾丸中没有成熟精子排放,射精需要的精子是附睾中上一年秋季排放的精子。所以,无论是秋季交配还是春季交配,都需要精子在雌性或雄性体内储存,而精子储存时间恰好选择在生殖活动相对较低的冬眠期,这是一个特殊的生殖现象。关于爬行动物精子储存,人们已在一些动物进行过观察。蛇精子储存时间短的11 d,长的为6~7 a^[3];蜥蜴精子储存一般在1个月^[4]到9个月^[5]之间;海龟精子储存期可达423 d^[6]。中华

鳖(*Trionyx sinensis*)属于龟鳖类的代表物种之一,具有典型的冬眠现象,是中国最主要的水产养殖爬行动物之一,具有很高的营养和药用价值。鳖的繁殖生理学研究对于中国养鳖业的发展具有重要意义,已经引起人们的重视。中国雌性中华鳖一般于春季开始交配,5月份开始排卵,一直持续到8月底^[7]。而雄性精子发生始于4、5月份,在8、9月份时正处于高峰期,直至11月末停止,然后精子一次性释放到附睾中储存起来^[8]。因此,中华鳖精子成熟的时间(9月份)与排卵时间(5月份)同样是相互错位的。作者所在实验室曾对中华鳖精子的形态结构及其与精子储存的关系进行过探讨^[9],发现精子线粒体为同心圆状结构,精子中糖原颗粒丰富,这些结构特点与精子储存具有一定关系。目前国内关于中华鳖精子储存这一特殊现象未见有明确阐释。本研究将在组织和细胞水平上对冬眠雌、雄中华鳖的

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精子储存现象及其相关结构进行探究,并对其生殖特性进行讨论,以期指导鳖的人工养殖,并为脊椎动物精子生物学研究提供实验模型。

1 材料与方法

1.1 材料

2005年12月初于南京下关水产市场买进20只健康性成熟中华鳖,雌雄各半,体质量650~800 g。购买后雌性与雄性立即隔离,饲养池铺以厚层细砂,置于安静环境下保持中华鳖持续进入冬眠状态。

1.2 样品前处理

将雄性鳖分别于2005年12月份和2006年3月底宰杀,观察冬眠期睾丸生精活动变化和附睾中精子储存情况。雌性鳖于2006年3月份宰杀,判定冬眠期精子在输卵管中的储存时间及储存部位。腹腔注射戊巴比妥钠(1 mL/ind)麻醉,颈部放血,掀开腹甲,摘取两侧睾丸、附睾和输卵管,切成适当大小组织块分别固定。

1.3 光镜样品制备与观察

睾丸、附睾和输卵管组织块用10%福尔马林固定24 h,上行梯度酒精脱水,二甲苯透明,石蜡包埋,用于常规HE染色。部分附睾和输卵管切片用Carnoy液固定,用于PAS反应。反应后组织切片Olympus显微镜观察并摄片。

1.4 透射电镜制样与观察

将附睾、输卵管组织修成1 mm³大小的组织块,固定于4℃预冷的2.5%戊二醛溶液中,1%锇酸后固定,梯度酒精脱水,丙酮置换,Epon812包埋,半薄切片(甲苯胺兰染色)定位后进行超薄切片,重金属双重染色。JEM-1200EX透射电镜观察并拍照。

1.5 扫描电镜制样与观察

取附睾中储存的精子,用2.5%戊二醛和1%锇酸双重固定,酒精梯度脱水,入丙酮、醋酸异戊酯,临界点干燥仪干燥,镀金后于S-520型扫描电镜观察和拍照。

2 结果与分析

2.1 冬眠期中华鳖睾丸生精活动情况

在冬眠期(12月份和来年3月份)分别取材观察睾丸曲细精管生精活动情况,结果显示睾丸曲细精管上皮生精活动在整个冬眠期都处于相对静止。管腔中分散分布着少量的精子,管壁上只有靠近基膜1~3层的精原细胞分布,其余生精细胞排列松散

而紊乱,不能形成完整的管壁,与腔内的精子和细胞团分界不明显。生精上皮中未见有各级细胞规律性排列,生精过程停止,管壁上未见精子形成(图版I-1)。

2.2 附睾的结构与精子储存

在冬眠期间不同时段(12月份和3月份)都能观察到大量精子储存于附睾管中。附睾管壁变薄,管腔增大(图版I-2)。附睾上皮细胞胞质以及管腔中见有PAS反应阳性分泌物(图版I-3)。

附睾上皮属于假复层柱状上皮,由主细胞、基细胞和亮细胞组成。主细胞数量多,细胞核椭圆形,在上皮的中上部排列成一层,核下方细胞狭窄,核上方胞质变宽(图版II-2)。相邻主细胞的胞质在腔面连接在一起,使得上皮腔面平滑整齐(图版I-2)。主细胞胞质顶端含有大量大小不等的空泡,有的空泡互相融合(图版II-2)。基细胞扁平,位于上皮基部,核扁而深染,在基底膜上排列成一层(图版I-2)。亮细胞较少,分布于主细胞之间,细胞核淡染,位于细胞中央,细胞质清亮(图版II-2)。亮细胞上方被主细胞封闭而不能与管腔接触(图版I-2、图版II-2)。

在透射电镜和扫描电镜下观察附睾中储存的精子,可见成熟中华鳖精子头部狭长,形似蚯蚓状,略弯曲。扫描电镜下,成熟精子具有典型的头部、中段和尾部3部分。精子结构完整(图版II-6)。透射电镜下可见在精子中段,由35~40个同心圆状线粒体构成线粒体鞘,中段胞质中含有大量的糖原颗粒(图版II-7)。附睾上皮细胞之间形成细胞连接复合体,主要由紧密连接、中间连接和桥粒连接构成(图版II-5)。附睾上皮细胞质中含有大量粗面内质网,细胞分泌活动旺盛,见有大量的分泌颗粒(图版II-5),内质网池因细胞代谢活动旺盛而显得更加膨大(图版II-4)。

2.3 输卵管的结构与精子储存

中华鳖输卵管左右各1条,每条由前向后依次分为漏斗部、蛋白部、峡部、子宫部和阴道部5段,每段管壁由内向外包括黏膜、肌层和外膜3层,其中黏膜层形成皱襞突向管腔。冬眠期输卵管的横切面上,峡部黏膜皱襞极其发达,皱襞长而有分支,相邻皱襞顶端相互融合(图版I-4),形成一系列纵行于输卵管的狭长封闭细管,为迷路样的储精细管(图版I-4)。漏斗部、蛋白分泌部、子宫部和阴道部也有发达的黏膜皱襞,但这些皱襞并不形成封闭的储精细管。

在输卵管蛋白分泌部、峡部和子宫部的皱襞之间及管腔内,储存着数量不同的精子。尤其在峡部的储精细管内精子成群分布(图版 I-5),数量巨大,即使将雌、雄鳖在 12 月初分离饲养到第 2 年 3 月底(大约 4 个月),仍能在储精细管中观察到大量精子储存。高倍镜下,可见精子头部插入到上皮顶端的纤毛之间,尾部游离于管腔(图版 I-6)。

储精小管上皮由纤毛细胞、分泌细胞组成(图版 II-1)。纤毛细胞顶部较宽,分布有大量的纤毛,细胞核位于上皮的中上部。分泌细胞核靠近基底膜,胞质深染(图版 II-1)。固有膜内分布着发达的腺体,为单管状腺(图版 I-5、图版 II-1)。管状腺通过导管与输卵管管腔相通(图版 II-1)。靠近上皮的固有层结缔组织中平行排列一层血管(图版 I-5、图版 II-1)。储精细管黏膜上皮 PAS 反应呈阳性(图版 II-3)。

3 讨论

3.1 冬眠期中华鳖睾丸曲细精管生精活动相对静止

哺乳类和鸟类精子的发生遵循一定的空间模式,在曲细精管壁上存在着周期性的生精上皮波,各级生精细胞有规律地分布在曲细精管壁上,使得动物在繁殖期生成的精子多次连续不断地释放到附睾中。与此不同,龟鳖类精子发生有明显季节性变化。Kevin 等^[10]通过对海龟 *Trachemys scripta* 生精规律研究发现,海龟精子发生是按着明显的时间模式进行的。海龟精子发生始于 5、6 月份,9 月份达到高峰,11 月份左右精子释放到附睾中。在冬眠期间生精活动停止。本实验观察到中华鳖在冬眠期间生精活动不活跃,生精上皮仅剩 1~3 层精原细胞,上皮管壁未见有其他发育阶段的生精细胞和成熟精子。因此,作者推测中华鳖在进入冬眠期间,精子全部释放到附睾中,其生精活动同样按着一定的时间模式进行。曲细精管中散在的精子可能是进入冬眠前剩余的部分精子。

3.2 冬眠期中华鳖附睾储存精子

正是由于龟鳖类配子成熟、排放和交配不是同时发生的,这就需要几个过程相互协调,才能达到正常受精的目的。这种协调策略在其他爬行动物主要是通过精子的储存来实现的。海龟成熟精子的排放一次性地发生于秋季,但它们的交配期一年两次,分

别在春季和秋季,但雌性排卵只发生在春季一次^[1]。所以,对于秋季交配海龟而言,曲细精管排放的精子需要在雌性输卵管中储存,直到第二年春季排卵才能受精^[2];对于春季交配者而言,则要求精子在雄性附睾中储存并渡过漫长的冬季才能受精^[11]。即,海龟要完成受精,无论是秋季交配还是春季交配,都需要一定时间的精子储存。Gist 等^[12]研究发现,海龟 *Chrysemys picta* 和 *Trachemys scripta* 精子在附睾中可以储存 1 年以上。有些蛇如 *Crotalus durissus terrificus* 在新一轮精子发生开始时,附睾中仍能发现储存有精子,这些精子至少是上一年生成的^[13]。本实验在形态上观察到,冬眠期间附睾管腔明显变大,腔中含有大量的精子。超微结构显示附睾中精子大部分结构完整,具有正常受精的结构基础。另外,附睾上皮细胞中分布着大量的分泌颗粒,内质网几乎分布于整个胞质中,由于上皮细胞分泌活动旺盛,内质网池明显变得膨大。附睾上皮 PAS 反应呈阳性,附睾管腔中同样也含有 PAS 阳性反应分泌物,这些分泌物可以营养储存的精子。附睾上皮之间构成的细胞连接复合体,在稳定附睾管腔的微环境中发挥重要的作用。这些结构表明,在冬眠期间,中华鳖附睾可以储存精子并能为精子提供一定的营养,以保证精子能渡过漫长的冬季。中华鳖精子由睾丸一次性排放到附睾中发生于秋末冬初(10~11 月),进入冬眠期后曲细精管上不再有精子发生,也没有成熟精子的排放,但冬眠结束时(3 月)附睾中仍有大量精子。因此作者推测,与蛇类及其他爬行动物相似^[12-14],无论当年交配与否,本实验观察到附睾中储存的精子,部分可能是当年交配时未完全射出而遗留下来的,甚至也包括了上年生成的部分精子。精子在中华鳖附睾中至少可以储存一个冬眠期间,而且这些精子结构完整,具备受精的结构要求。

3.3 冬眠期中华鳖输卵管储存精子

关于脊椎动物精子的储存,除了在雄性附睾进行外,在雌性生殖道也发生一定的精子储存。哺乳动物中有些蝙蝠精子可在雌性体内储存 5~9 个月^[15-16]。王^[17]发现雌性大足鼠耳蝙蝠可储存精子 40 d。在禽类,雌火鸡储存长达 72 d,母鸡 32 d^[20]。爬行动物中海龟、蛇和蜥蜴等都有雌性体内储存精子现象^[11]。Adams 等^[18]人发现,雌性蜥蜴 *Holbrookia propinqua* 在与雄性长期分离后,仍能连续产卵繁殖后代,甚至有些蛇如 *Acrochordus*

javanicus 在与雄性分离 7 年后,仍能继续繁殖^[19]。关于雌性体内精子储存部位在不同的动物有所不同。哺乳动物大鼠耳的精子储存在子宫中^[17];禽类储存精子的部位主要是在输卵管子宫-阴道交界处的储精腺(Sperm-host gland)内^[21];爬行动物蛇类精子储存部位因交配时间而异,夏季交配的精子储存于阴道的黏膜皱襞之间,而春季交配的精子主要储存在漏斗部^[22];另一种爬行动物海龟,交配后精子主要储存在输卵管峡部的储精细管,排卵前漏斗部也有少量精子^[6],但在海龟的输卵管蛋白分泌部和子宫部也发现了储精细管^[11],其结构与峡部的储精细管十分相似^[23]。关于储精细管的结构,Gist 等^[24]对海龟 *Terrapene carolina* 研究发现,这些细管由 6~8 个分泌细胞构成,分泌细胞表面含有大量的微绒毛,储精细管通过狭窄的开口与输卵管管腔相通。本实验将雌、雄中华鳖于冬眠期(上一年 12 月至下一年 3 月)隔离饲养,禁止交配,结果发现,在输卵管中分布着数量不同的精子,其中,峡部数量最多,蛋白分泌部次之,子宫部也有少量精子存在,精子形态和结构正常。冬眠期间峡部黏膜皱襞高度融合,形成大量纵行于输卵管的细管。但与 Gist 不同的是,本实验观察到储精细管由纤毛细胞和分泌细胞两种细胞构成,构成细管的细胞数量没有明显的数量限制。在一些切面上可见有黏膜的融合部位。这些形态表明,雌性中华鳖输卵管在冬眠期(约 4 个月)具有储存精子的功能,尤以峡部储精细管储量最多。构成储精细管细胞类型的差异可能是由于动物种类的不同所致。虽然本实验并未测定冬眠前雌性中华鳖是否在当年春季或秋季发生过交配,但根据 Adams 和 Mangusson 等人通过对蜥蜴和蛇的研究结果^[18-19],作者认为储存在输卵管中的精子即使在未发生交配的情况下,仍能继续用于繁殖下一代。本实验证明了中华鳖精子在输卵管中储存时间至少超过 120 d,甚至可能包括往年储存的部分精子。

封闭的储精细管可为储存的精子提供一个稳定的内环境,并能从上皮细胞中获取营养,保证其正常越冬。由于哺乳动物精子获能主要发生在输卵管峡部^[25],所以 Gist^[6]认为爬行动物的这些储精细管也可能具有精子获能的作用。通过对输卵管精子储存器官构成细胞的组织化学研究表明,蝙蝠子宫上皮细胞含有 PAS 反应阳性物质^[16],蛇输卵管精子储存器官细胞内也发现了糖原^[26],鸡的输卵管精子腺细胞胞浆内含有糖原颗粒,且糖原含量与腺腔内有

无精子密切相关^[27],而鸭精子腺细胞内不含糖原颗粒^[28]。本实验在高倍镜下观察到,精子头部嵌入到构成细管的上皮纤毛中,而且这些上皮细胞含有 PAS 反应阳性物质。在固有层中靠近上皮基底部平行排列着一层丰富的血管,为各种营养物质的交换提供了便利。另外,大量的管状腺通过腺管与输卵管管腔相通,其分泌物质可以进入到管腔中。由此可推测储存精子的营养来源可能是构成储存器官的上皮细胞和发达的腺体,这与其他爬行动物的报道相似^[22,29-33]。

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Sperm storage in male and female soft-shelled turtles, *Trionyx sinensis* in hibernation

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Abstract: Sperm production, mating and ovulation are out of phase with one another in numerous species. In turtles, spermatogenesis is an episodic event, commencing in early summer (June). Sperm leaves the testis and enters the epididymis in autumn (September October). Although oogenesis is initiated at about the same time as spermatogenesis, ovulation does not occur until the following spring. Thus, for autumn breeding turtles, sperm may be stored over winter in the oviductal glands of females, or, for spring-breeding turtles, in the epididymis of the male. Soft-shelled turtle, *Trionyx sinensis* are distributed widely in China and this species is famous for commercial and pharmacological value. This species exhibits an unusual reproductive cycle whose spermatogenesis and ovulation are out of phase with each other. Therefore the sperm is obligated to be stored in males or females, which is similar to other reptiles. Reproductive ducts of male and female soft-shelled turtle, *Trionyx sinensis* were examined in hibernation (December to next March) under light and electron microscopes (SEM and TEM) to determine the location and histomorphological characteristics of sperm storage structure. In male, spermiogenesis was inactive in winter, only 1–3 layers of resting sper-

matogonia are arranged closely to the base membrane. A few sperm dispose themselves loosely in the lumen of the seminiferous tubule, which are remnant germ cells from the previous year. The seminiferous epithelium is quiescent and there is no consistent cellular association or process of spermiogenesis at this stage. Epididymis duct becomes large and a large number of spermatozoa are stored. Cells comprising the pseudostratified epithelium of the epididymis are principal cell, base cell and clear cell. The PAS-positive materials secreted from the epithelium of the epididymis were observed, which might have the function of nourishment for the sperm to survive longer. The rough endoplasmic reticulum (RER) presented in the whole cytoplasm and the cisternae of RER are inflated due to the fallness of the secretory materials. Sperms stored in the epididymis are integrated which have 35 – 40 concentric mitochondria forming the mitochondrial sheath in the middle piece of the spermatozoon. The concentric cristae mitochondriales and lots of glycogens in the cytoplasm of the middle piece show the relationship to the vitality maintaining during long-time storage of the spermatozoon in the turtle. Various quantities of spermatozoa were observed in the cavity of the oviduct including tuba uterina, isthmus and uterus. However, most spermatozoa were distributed in the sperm storage tubules (SST) in the isthmus. The mucosa of isthmus shows extensive foldings and convolutions. A majority of mucosa fused into sperm storage tubules orientated toward the longitudinal axes of the oviduct. These tubules developed either by folding or fusion of the oviductal mucosal folds and were lined by both ciliated and secretory epithelial cells. Tubular glands distribute in the inner mucosa. They communicate with the oviduct lumen via short openings composed of invaginations of the epithelium. PAS-positive materials secreted from the epithelium were observed in sperm storage tubules of the isthmus. Sperm might get nutrition from the epithelium of the sperm storage tube and the gland in the inner mucosa. After being separated for 4 months (December to March next year), the sperms were observed in the tubules of the isthmus, most of which housed themselves with the head orientating toward epithelium in the SST, even some spermatozoa embed their head in the cilia of the ciliated cells and kept their tails towards to the cavity of the SST. Although we do not know whether these females have finished mating in spring or autumn, the sperm can be stored in the oviduct of the female at least 120 d. In conclusion, sperm can be stored both in the epididymis of the male and the sperm storage tubules in the isthmus of the oviduct in hibernation. This strategy is necessary for the turtles to breed successfully. We also discuss the reproductive characters of the soft-shelled turtle, *Trionyx sinensis* in the study. [Journal of Fishery Sciences of China, 2007, 14 (5): 705 – 713]

Key words: soft-shelled turtle, *trionyx sinensis*; hibernation; sperm storage; epididymis; oviduct

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图版说明

图版 I

Fig.1: 冬眠期间中华鳖睾丸曲细精管,靠近基底部仅有1~3层精原细胞排列(◀),曲细精管管腔内散在有少量精子和大小不同的圆形细胞(→),管壁未见有精子生成过程,HE,×40.

Fig.2: 冬眠期附睾管腔变大,腔中储存大量精子(★),基细胞核扁平(→),亮泡细胞(←),主细胞(←)顶端相互连接,管壁表面平整,HE,×10.

Fig.3: 冬眠期附睾上皮PAS反应(↓),管腔中分泌的PAS阳性物质(→),×20.

Fig.4: 冬眠期输卵管狭部,切面上可见大量形状不规则的细管(★),黏膜上皮相互融合部位(↓),HE,×4.

Fig.5: 冬眠期输卵管狭部储精细管中储存大量精子(←),腺层与黏膜上皮之间分布一层血管(▼),固有层中分布有大量单管状腺,HE,×10.

Fig.6: 精子头部嵌入到储精细管上皮纤毛中(↑),HE,×100.

图版 II

Fig.1: 输卵管上皮由纤毛细胞(→)和分泌细胞(→)构成,示血管(★),腺导管(↙),精子头部横切面(→),甲苯胺兰染色,×100.

Fig.2: 附睾上皮,亮细胞(←)和主细胞(↖),甲苯胺兰染色,×100.

Fig.3: 储精细管上皮细胞分泌PAS反应阳性物质(→),PAS反应,×10.

Fig.4: 附睾上皮细胞,内质网变得膨大(→),×20 000.

Fig.5: 附睾上皮细胞之间形成连接复合体.微绒毛(▼),紧密连接(↑),中间连接(↑),桥粒(↑),分泌颗粒(↘),×40 000.

Fig.6: 扫描电镜显示精子形态:精子由头部(HEAD),中段(MP),尾部(TAIL)组成,×1 400.

Fig.7: 精子细胞由完整的膜包围(↙),同心圆状线粒体(→),中段胞质中分布有大量糖原颗粒(↘),×25 000.

Explanation of Plate

Plate I

Fig.1 Cross-section of the seminiferous tubule of soft-shelled turtle, *Trionyx sinensis* in hibernation. Layers 1-3 of spermatogonia arranged closely to the base membrane (◀); a few of sperms and round spermatids dispose themselves loosely in the lumen of the seminiferous tubule (→), which are remnant germ cells from the previous year. HE, ×40.

Fig.2 Epididymis duct in hibernation. Full of spermatozoa (★), base cell (→), principal cell (←), clear cell (←). HE, ×10.

Fig.3 PAS-positive materials in epithelium cell (↓) and epididymis duct (→), ×20.

Fig.4 Cross section through the isthmus of the oviduct in hibernation. Sperm storage tubules with various shape (★). Inosculation of the two mucosal fold (↓) HE, ×4.

Fig.5 Sperm storage tubules are full of spermatozoa (←), one layer of blood vessel arranged under the epithelium (▼) HE, ×10.

Fig.6 The head of the spermatozoon embedded into the cilia of epithelium, the tail towards to the lumen of the isthmus (↑). HE, ×100.

Plate II

Fig.1 The epithelium of the oviduct. Cilia cell (→), secrete cell (→). Blood vessel (★), gland duct (↙), cross section of the spermatozoon (→), aniline blue stain, ×100.

Fig.2 Epithelium of the epididymis in hibernation. Principal cell (←), clear cell (↖). Aniline blue stain, ×100.

Fig.3 PAS-positive materials secret from the epithelium cell (→), HE, ×10.

Fig.4 Rough endoplasmic reticulum with inflated cisternae (→) in the epithelium cell of the epididymis ×20 000.

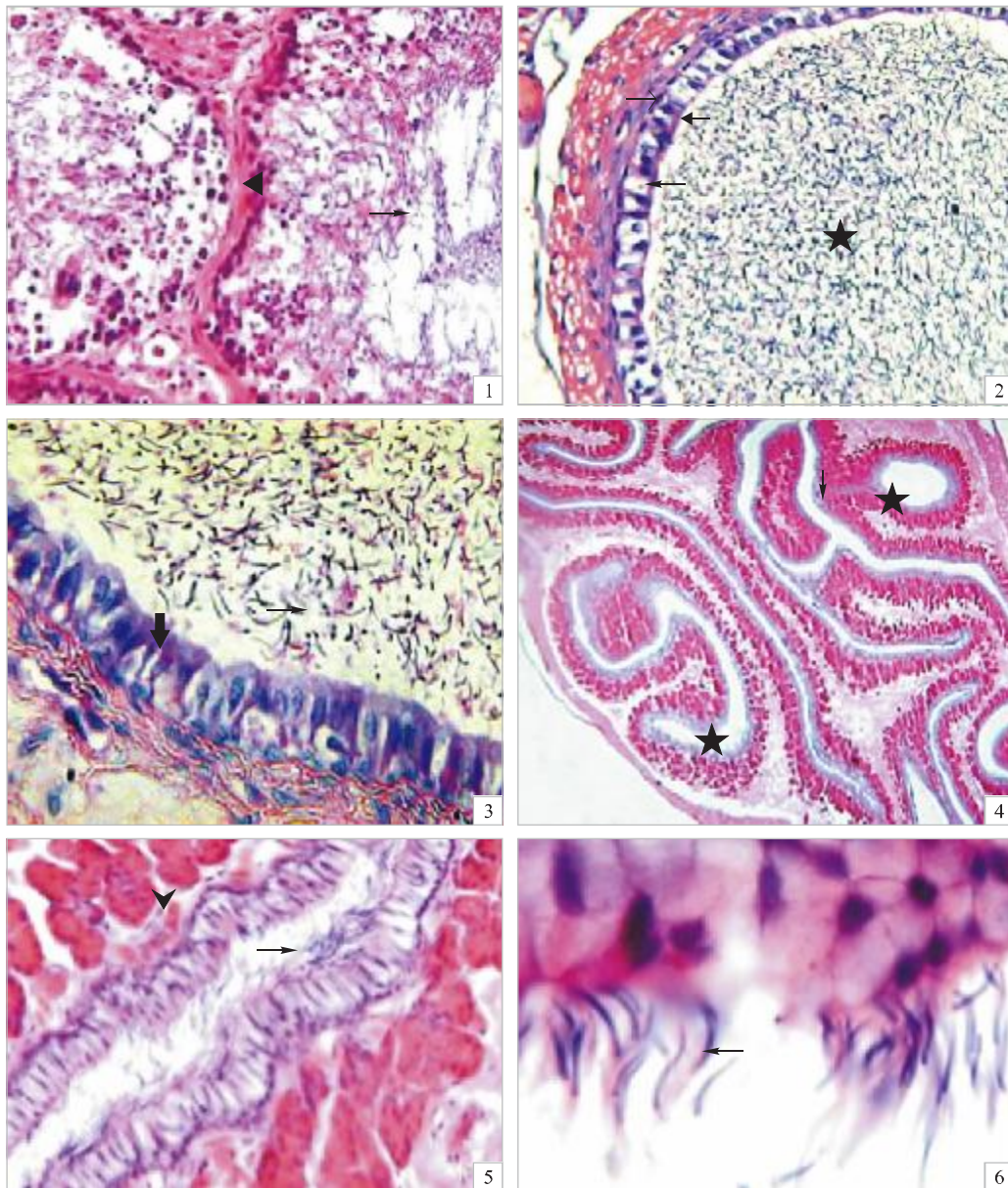
Fig.5 Cell junctions in the epithelium of the epididymis. Tight junction (▼), intermediate junction (↑), desmosome (↑), secretory granules (↑), microvilli (↘), ×40 000.

Fig.6 The mature sperm in the epididymis examined by SEM. Note that the mature sperm is vermiform in shape, which consists of: head (HEAD), middle piece (MP), tail (TAIL), ×1 400.

Fig.7 The unique feature of the middle piece of the mature spermatozoon in epididymis. Cell membrane (↙), concentric mitochondria (→), glycogens (↘), ×25 000.

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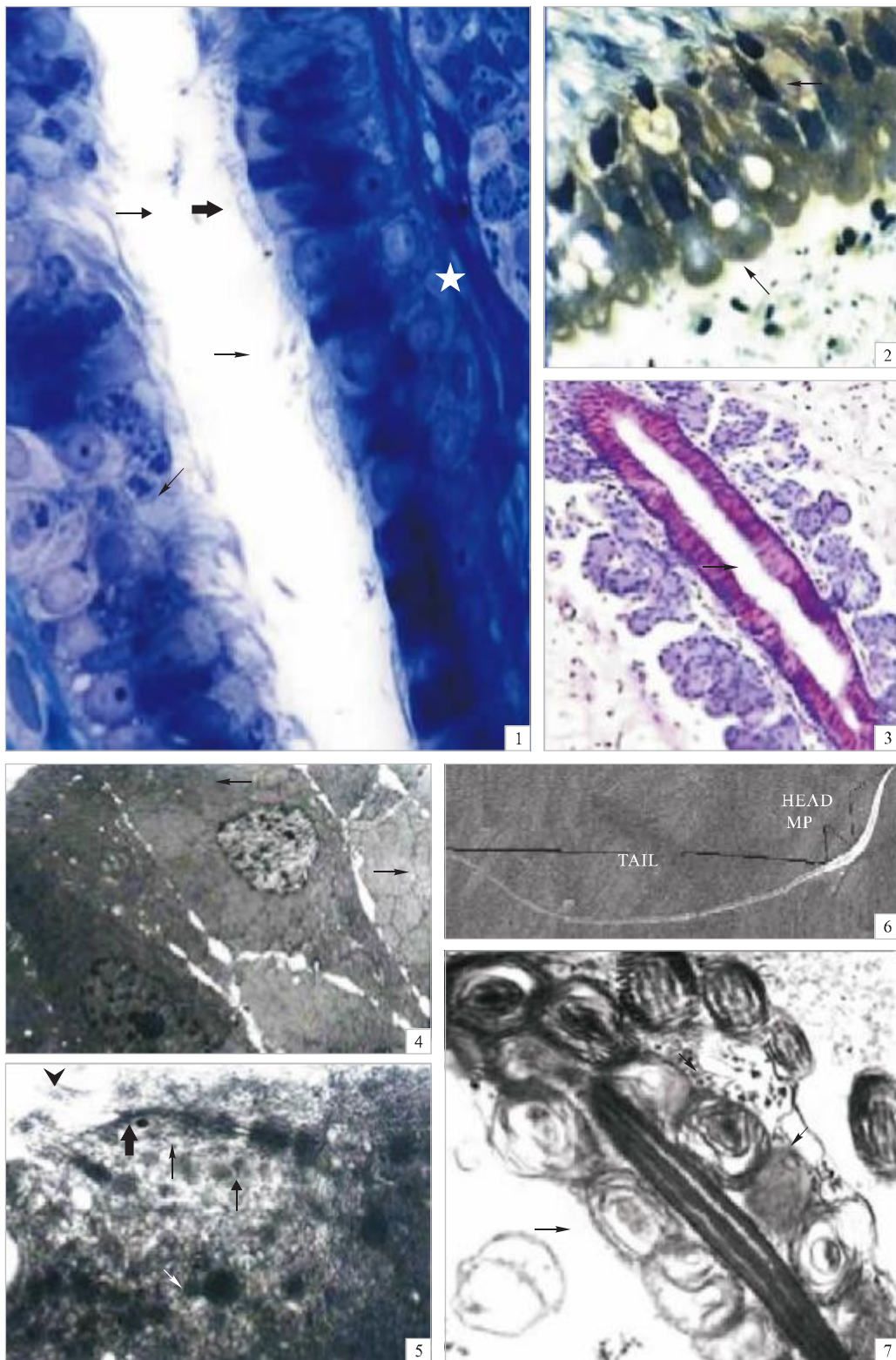


图版 I Plate I

(图版 I 说明见文末 Explanation of Plate I at the end of the text)

韩向琨等:冬眠中华鳖雌、雄生殖道的精子储存

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图版 II Plate II

(图版 II 说明见文末 Explanation of Plate II at the end of the text)