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CONGENITAL MALFORMATION OF THE SYSTEMIC HEART OF *SEPIA OFFICINALIS* L.: MORPHOLOGICAL, PHYLOGENETIC AND ECOTOXICOLOGICAL ASPECTS

R. SCHIPP and S. von BOLETZKY†*

Numerous preparations of the circulatory system of *Sepia officinalis* L. caught from the Bay of Arcachon (Atlantic Coast of France) in 1989 and 1996 showed an obvious congenital malformation of the systemic heart complex. The malformation consisted of a cord- or truncus-like structure at the left cranio-apical ventricle. It is interpreted as an atypical second root of the cephalic aorta reflecting an originally paired anlage of the heart in ancestral cephalopods. In considering possible causes of this atavistic abnormality, the high tributyltin (TBT) contamination recorded in the Bay at the time should not be overlooked.

During studies on the circulatory system of the cuttlefish *Sepia officinalis* L. in the autumn of 1989 and 1996, it was observed that many animals from the Bay of Arcachon (Atlantic Coast of France) showed an obvious malformation in the systemic heart complex. The malformation took the form of an atypical doubling in the rear of the root of the cephalic aorta. In all, 18 of 130 preparations in 1989 (13.9%), and 4 of 46 (8.3%) in 1996 had this malformation. During the period 1983–1988, not one of the animals caught in the Bay of Arcachon showed any malformation of this type. For the period 1990–1995, no observations are available for the area, but in the numerous heart preparations of *Sepia officinalis* made from 1976 to 1997 at the Observatoire Océanologique in Banyuls-sur-Mer (Mediterranean Coast), this type of malformation has not been found. Further, no malformation of this type has ever been observed in the numerous cuttlefish preparations made in the Biomedical Research Center at the University of Texas, Galveston, either (B. U. Budelmann pers. comm.).

The malformation consisted of a truncus- or cord-like structure that in most cases originated from a cone-like evagination on the left cranio-apical area of the heart ventricle. It joined the atypical elongated right apical part of the ventricle on the inner side just below the root of the aortic valve. The atypical truncus had a length and diameter different from a typical one and showed an open lumen circulated by the haemolymph as a by-pass; only in a few cases was the lumen totally closed. Further anomalies, visible macroscopically, concerned the right auricle and the origin of the renal and genital artery, which in some cases had shifted by 90° into a more ventral position, and the pancreatic appendages, which had shifted from the median position to the left side. The other organ systems showed no obvious anomalies and the animals' vitality did not seem to be impaired. In one case (animal 22/96) the genital artery ended within the gastral-arterial complex, and an atypical genital artery originating in this complex formed an atypical U-shaped loop running around the truncus-like malformation caudally to the testis (Fig. 1).

The congenital malformation reported here is interpreted as the full bilateral expression of a morphogenetic programme that is normally inhibited unilaterally. Naef (1909, 1910) showed that the normal embryonic development of *Loligo vulgaris* reflects the establishment of an originally paired structure during the early stages of systemic heart formation, and that the bilateral symmetry of this complex is only given up by the subsequent regression of the left root of the cephalic aorta. Based on his observations, he proposed a coleoid morphotype with a primitive systemic heart structure characterized by two antero-lateral issues leading to an unpaired cephalic aorta (Boletzky 1987). Although the bilateral symmetry is not perfect in the malformed heart complexes described here, the additional canal observed may reasonably be interpreted as an atavism, that is an expression of the supposedly morphogenetic programme envisaged by Naef (Alberch 1989). Therefore, the atypical truncus can be interpreted as a relic of the root of a left cephalic aorta which was possibly phenotypically present in ancestral cephalopods. On the other hand, it is possible that the left cephalic aorta of nautiloids is displayed in the phenotype

* Zoological Institute, Justus-Liebig University, D-35390 Giessen (Germany) and Laboratoire d'Océanographie Biologique, F-33120 Arcachon, France
† Observatoire Océanologique, F-66650 Banyuls-sur-Mer, France. Email: boletzky@oob-arago.univ-perp.fr

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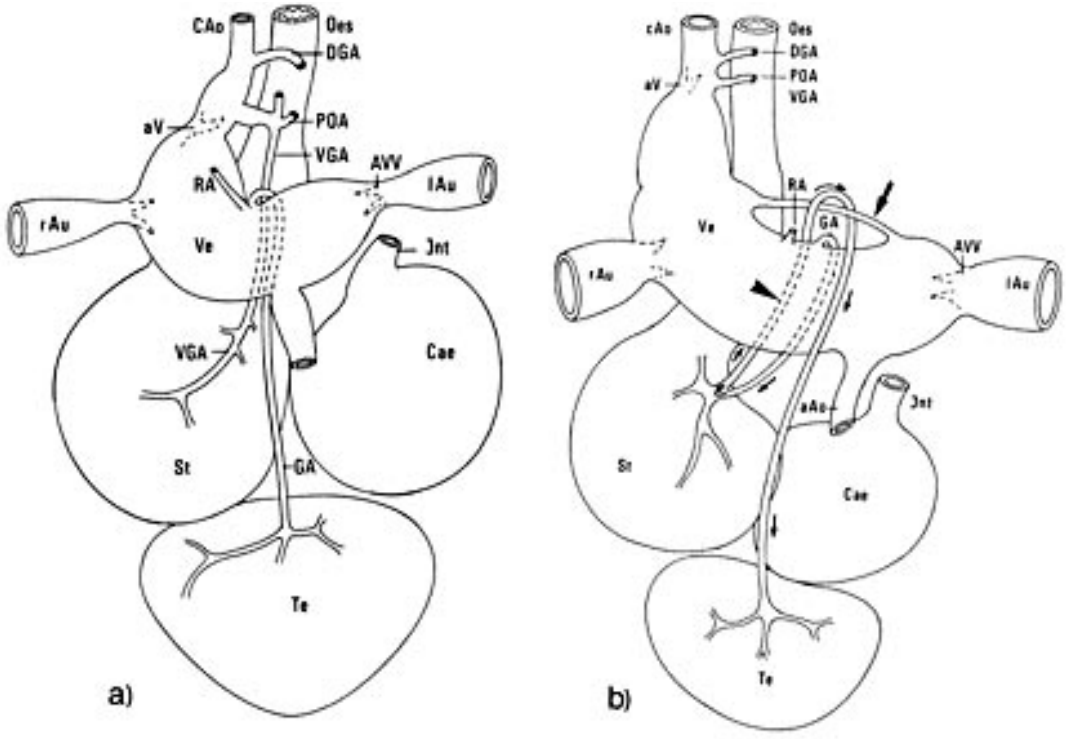

Fig. 1: (a) The normal systemic heart complex in *Sepia officinalis*; (b) a truncus-like malformation (large arrow) in the cranio-apical area of the systemic heart ventricle (Ve) of *Sepia officinalis* in ventral view (animal 22/96). Note: the genital artery (GA) runs via the gastric arteries, where an atypical genital artery originates (arrow head) forming a loop around the ventricular truncus-like malformation before running caudally to the testis (Te); the direction of blood flow from the ventricle to the testis is denoted by small arrows; cAo/aAo – cephalic and abdominal aorta, rAu/lAu – right and left auricle, AVV – atrio-ventricular valves, Cae – caecum, DGA/VGA – dorsal and ventral gastric artery, Int - intestine, Oes – oesophagus, POA – posterior oesophageal artery, RA – renal artery, St – stomach, (aV) – aortic valvae

whereas the right part of an originally paired heart vessel complex may possibly have been reduced in early evolution.

Concerning possible causes of the mutations reported here, it is significant that, in 1982 and 1985, a high tributyltin- (TBT) induced tin contamination was registered in the Bay of Arcachon around "La Vigne", where the malformed cuttlefish were caught. TBT in this area is apparently responsible for oyster shell anomalies (Alzieu *et al*. 1986) as well as toxic effects on molluscan larvae (His and Robert 1985). The teratogenic effect of the antifouling compound TBT on other marine molluscs has been demonstrated experimentally and is documented. In the prosobranchs *Nucella lapillus, Littorina littorea* and *Trivia arctica*, it induced obvious malformations of the genital tract, termed "imposex", characterized by the development (superimposition) of male sex organs (penis and/or ductus deferens) in females (Bryan *et al*. 1986, Stroben *et al*. 1992, Oehlmann *et al*. 1993, Bauer *et al*. 1995).

Clearly, the results presented here should be regarded as preliminary only. A more detailed analysis of the malformation is being undertaken and will be documented later.

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