

Marine pollution and sexual confusion in dog whelks

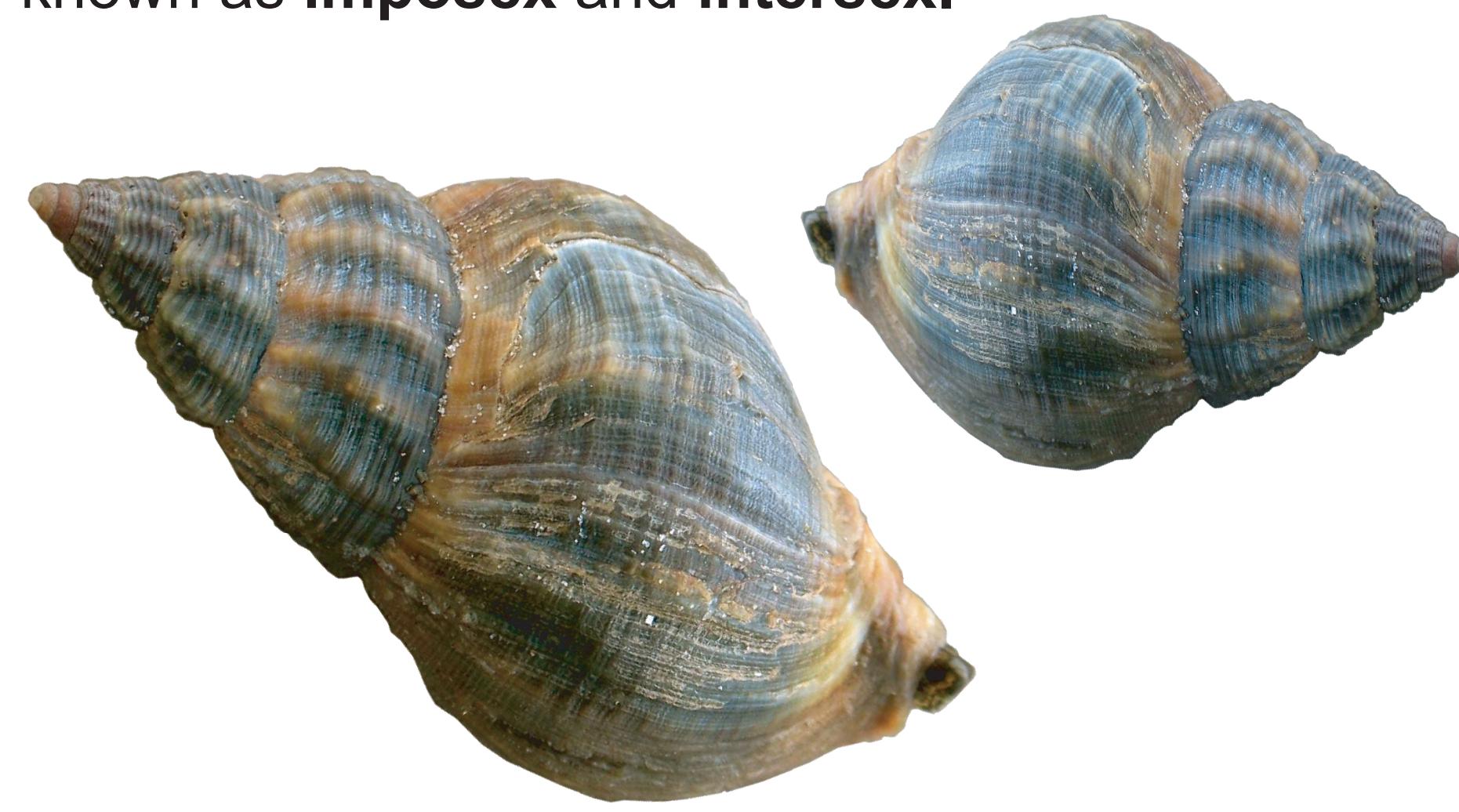
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Introduction

Chemical pollutants can have many damaging effects on marine life. One common way they cause harm is by disrupting an organism's reproductive processes. Gastropod molluscs are prone to such effects, notably the common dog whelk *Nucella lapillus*. Dog whelk populations all over the world have been damaged or destroyed by chemically-induced sexual dysfunctions known as **imposex** and **intersex**.



What are imposex and intersex?

Imposex is the more dramatic of the two conditions, referring to the development of sexual organs of the opposite sex in addition to the individual's own. It is also sometimes called **pseudohermaphroditism**. As applied to molluscs it invariably refers to the development of male organs by females and has been firmly linked to contamination by **tributyltin (TBT)**.

The 'imposed' genitalia – typically comprising a penis and vas deferens – in a few cases more than one! – are not normally fertile, but they occlude the vaginal opening, leading to sterility. More severe cases cause death as the individual is ruptured from within by a swelling mass of abortive egg capsules that have nowhere else to go.

Intersex is less catastrophic and is also common in other aquatic animals, notably several species of freshwater fish. It can occur in both sexes, though is more frequently found in males and that case is often singled out.

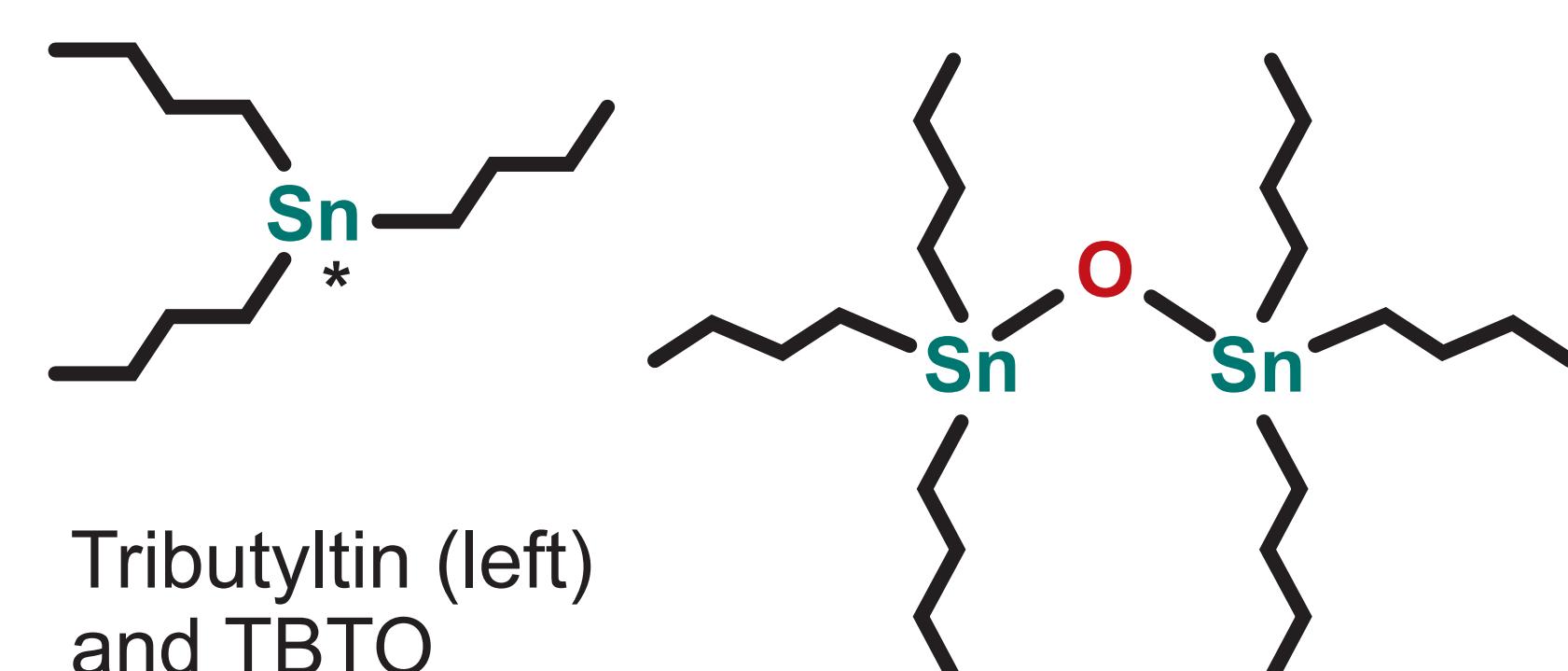
Intersex animals remain clearly their original sex, but develop some tissues associated with the opposite sex within their sexual organs. In the common male case, ovarian cells or even eggs occur within the testis, detracting from sperm production and reducing fertility.

Intersex is not typically fatal, nor does it necessarily lead to outright sterility. Nevertheless, it is clearly bad for reproductive success. It is associated with a range of natural and synthetic **oestrogens**.

Where does the pollution come from?

Tributyltin, or TBT, well established as a primary cause of gastropod imposex, is a biocide that has been widely used since the 1960s in anti-foulant coatings for the hulls of ships and boats, buoys, lines, nets etc. Although TBT itself is unstable, it forms stable compounds such as bis(tributyltin) oxide (TBTO), able to persist for years both in hull paints – which is what makes them useful – and in the environment – which makes them a problem.

The negative effects of TBT on molluscs were noticed within a few years of the compound's widespread deployment: dog whelk imposex was first observed in 1970 and linked to pollution a decade later. In the 1980s and early 1990s, many countries introduced restrictions on the use of TBT for **small** vessels, assumed to be the main sources of contamination in inshore waters. These are now in place worldwide and significant improvements have been observed. There is, however, good evidence that TBT contamination remains a problem on major commercial shipping lanes – plied by vessels still using TBT – but progress towards a universal ban remains inconclusive.



Pollutants causing intersex include natural oestrogens such as **oestradiol**, synthetics such as **ethinyl oestradiol** – the main ingredient of the contraceptive pill – and also some non-hormones such as **nonylphenol**, a breakdown product of surfactants, that demonstrate oestrogenic effects in aquatic life. The major source for all these contaminants is believed to be outflows of (treated) sewage, although agricultural run-off may also contribute.

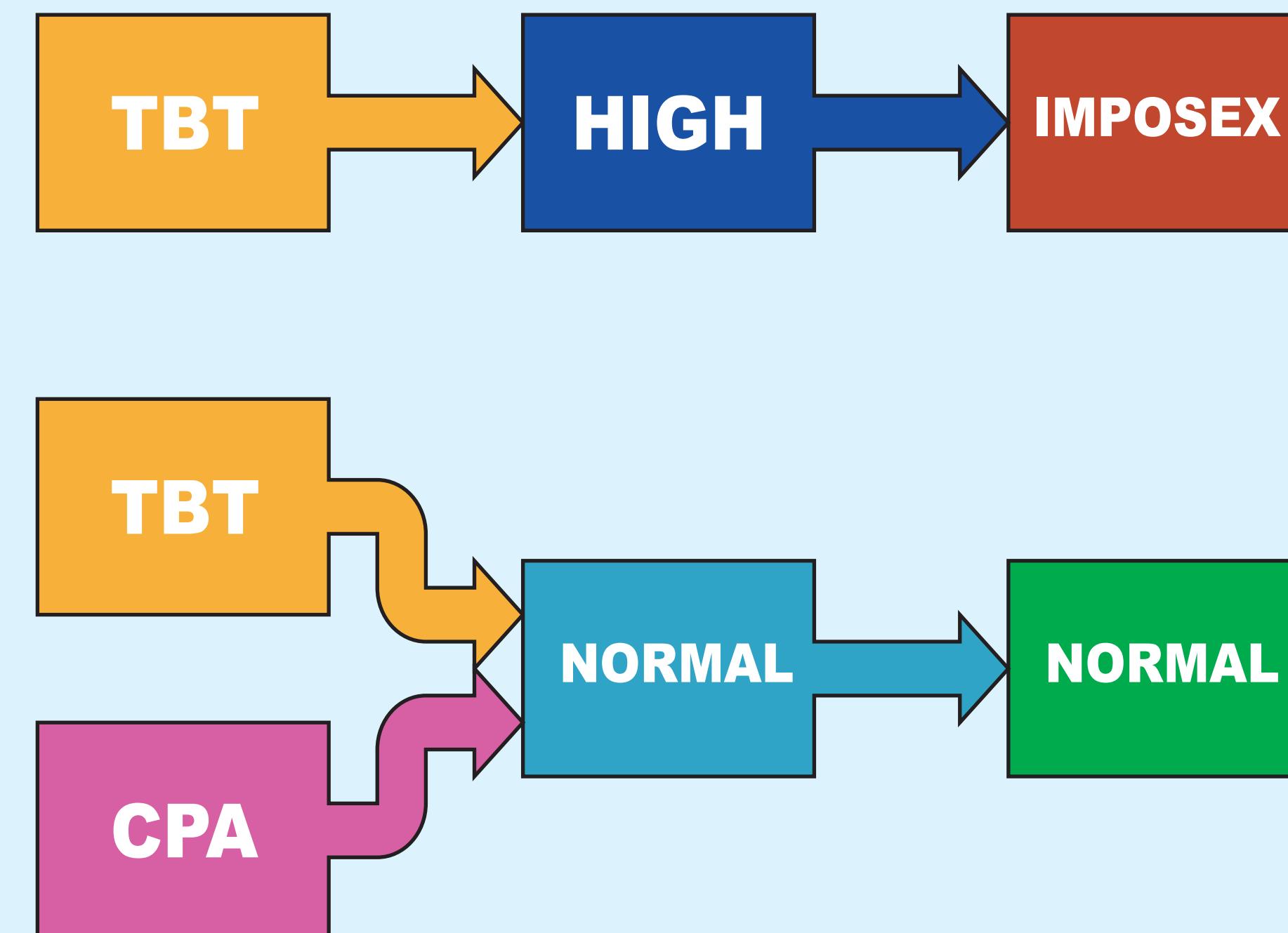
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How does TBT cause imposex?

The processes linking TBT to imposex are not well understood, but some details are known. TBT exposure leads to significantly elevated levels of testosterone in female whelks, suggesting this androgen is involved in promoting the development of male sexual characters. Furthermore, imposex can be prevented in TBT-exposed whelks by simultaneous application of an anti-androgen, cyproterone acetate (CPA), which seems to confirm the androgen's role.

However, no mollusc (nor even any invertebrate) has yet been shown to have androgen receptors, so it is not clear how the signal is transduced. Experiments with human prostate cancer cells have demonstrated that TBT can induce androgen-dependent transcription even in the presence of androgen receptor antagonists, suggesting a novel binding site. Whether this has any analogue in gastropods remains unknown.



Tributyltin increases testosterone, but CPA blocks its effects.



Does it matter?

In a world of competing ecological and economic concerns, the fate of the humble dog whelk may seem of questionable importance. They are not fished; nor are they a keystone species in their ecosystems. A local extinction would probably not by itself have a substantive impact on either biodiversity or human activities. Moreover, there is evidence from some sites that dog whelk populations may recover relatively quickly once contamination is removed – more so than would be expected for a species lacking a planktonic larval stage that can be carried into an area by the sea.

However, dog whelks constitute an important **indicator species**. Pollutants like TBT will ultimately affect many creatures, but whelks' sensitivity puts them on the front line. With imposex occurring at concentrations less than 1 ng/l, observations of *Nucella* populations give early warnings of trouble. Protecting the dog whelk will ultimately benefit the whole marine ecology.

Acknowledgements

Dog whelk photographs by Cherry Welsh, used with permission.

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