Pyura gangelion (Savigny, 1816) (Tunicata: Pyuridae) from the Persian Gulf

Amin Afzali[1,*], Majid Askari Hesni[1,*], Azad Teimori[1] and Thomas Stach[2]

[1]Department of Biology, Faculty of Sciences,
Shahid Bahonar University of Kerman, 76169-14111 Kerman, Iran
[2]Department of Molecular Parasitology,
Humboldt University of Berlin, 10115 Berlin, Germany

We report the occurrence of *Pyura gangelion* (Savigny, 1816) from two sites in the Persian Gulf and its morphological description is also provided. This species has a wide distribution in the Indian and Pacific oceans as well as the Red Sea region. However, no record is available on its distribution in the Persian Gulf. The species is distinguished from other species by characteristics such as individuals are solitary with leathery, brownish to reddish tunic, siphons not easily visible; both siphons are in upright position with four lobes, mantle thin and covers entire body, muscle bands are denser adjacent to the siphons, oral tentacles branched with different sizes, the branchial sac is folded with six folds on each side of the body. Both internal longitudinal and transverse vessels are present, there is only one hermaphroditic gonad on the right side, endocarps, conspicuous projections into the atrium are visible in both sides, a hepatic cecum is positioned on the left side with a close connection to the branchial basket.

Keywords: Geographic distribution, Persian Gulf, *Pyura gangelion*, Tunicata.

ASCIDIANS or sea squirts are the most diverse group of tunicates and are ecologically important due to their ability to live in nutrient-rich environments[1]. To date, approximately 2500 species have been described from the marine environments of coastal waters and deep seas around the world[1].

Based on the morphology of their adult branchial sacs, ascidians are classified into three orders namely, Aplousobranchiata, Phlebobranchiata and Stolidobranchiata[2], which is corresponding to the molecular phylogeny[1,3,4]. In addition, according to another classification based on the position of gonads and other morphological features[5], ascidians have been classified into two orders namely, Enterogona and Pleurogona[1,5]. Aplousobranchia and Phlebobranchia belong to Entrogona and Stolidobranchia belongs to Pleurogona[6].

Ascidians are dominated in tropical waters by colonial forms and solitary forms clearly increase in higher altitudes[7]. The ascidian fauna of the Persian Gulf is poorly known and little information is available on this animal group in this region, particularly in the Iranian waters of the Persian Gulf. Most of the records are from Bahrain or the nearest marine systems such as the Red Sea[8,9].

In our recent study on the ascidians of the Persian Gulf, we collected and identified samples of ascidians belonging to *Pyura gangelion* (Savigny, 1816). This species has not been previously recorded from the Persian Gulf. Therefore, we report here the occurrence of this species from the Persian Gulf, and provide its morphological description by using scanning electron microscopy (SEM) images.

The specimens were collected from Ramchah in Qeshm Island (26°53′58.74″N, 56°10′04.93″E) and from east of Kish Island (26°33′10″N, 54°01′25.44″E) with SCUBA diving and snorkeling equipment in depths ranging from 1 to 12 m (Figure 1). Photographs of the live animals were taken underwater by GOPRO HERO5.

For fixation and relaxation, the specimens were kept in sea water for 10 min and then $MgCl_2$ crystals were added slowly to the sea water and the animals were kept in the solution for 1–3 h (ref. 10). The solution eventually was replaced by 70% ethanol for fixation. The tunics of individuals were removed using scissors along the midline from the place of attachment to both siphons. An Olympus stereo dissection microscope was used for the examination of smaller specimens and their interior organs were investigated. Afterwards, the mantle was opened along the ventral midline of body close to the endostyle.

In order to have a better resolution of the anatomical and morphological features for describing the specimens, we used SEM images. The specimens were transferred to 96–100% ethanol for a day. Then, they were dried with BAL-TEC CPD 030 critical point dryer following the standard protocol, and mounted to the SEM stubs and coated with a gold layer using a BAL-TEC SCD 005 sputter coater for 5 min. Subsequently, the samples were analysed in a LEO 1430 SEM and photographed.

In order to identify the specimens, we followed a key provided in Monniot and Monniot[11]. Accordingly, some important characters were investigated such as: the shape of stigmata, branchial baskets, associated vessels, papillae projections, the shape and numbers of oral tentacles, dorsal lamina, shape and orientation of dorsal tubercle and position of gonads associated to digestive tracts.

Systematics: Kingdom: Animalia; Phylum: Chordata; Subphylum: Tunicata; Class: Ascidiacea; Order: Stolidobranchiata; Family: Pyuridae Hartmeyer, 1908; Genus *Pyura* Molina, 1782; Species: *gangelion* (Savigny, 1816).

Synonyms: Cynthia gangelion Savigny, 1816; *Halocynthia gangelion* Savigny, 1816; *Pyura albanyensis* Michaelsen, 1927; *Pyura scoresbiensis* Kott, 1972; *Pyura tongaea* Monniot and Monniot, 1976; *Halocynthia gangelion* Sluiter, 1905; *Pyura sansibarica* Michaelsen, 1918; *Pyura obesa* Hartmeyer, 1919; *Pyura robusta* Hartmeyer, 1922.

---

*For correspondence. (e-mail: majidask@gmail.com; afzaliamin@gmail.com)

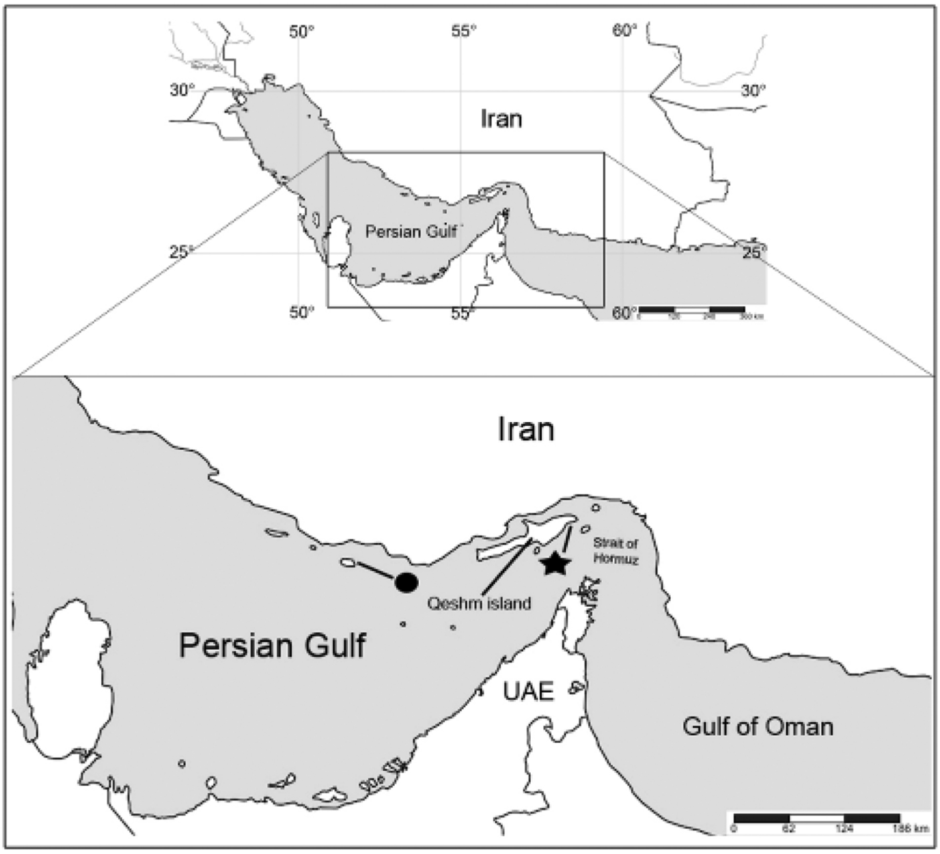

Figure 1. Overview on sampling locations in the Persian Gulf. Black star; Ramchah, Qeshm Island and black circle; Kish Island.

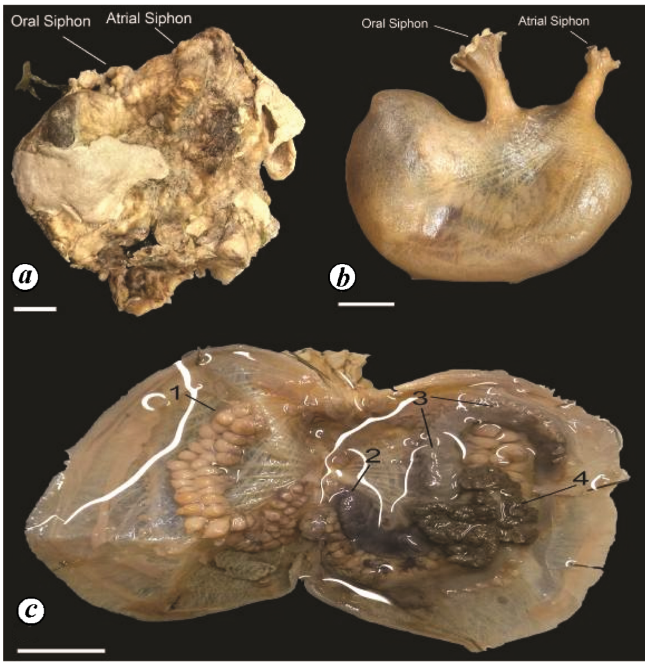

Figure 2. External and internal appearances of *Pyura gangelion*. ***a***, *P. gangelion* covered with epibionts; ***b***, with removed tunic, ***c***, internal organization in which number 1 refers to gonads, number 2 refers to oesophagus, numbers 3 and 4 refer to intestine and hepatic cecum respectively. Scale bar is 1 cm.

Individuals are solitary with leathery, brownish to reddish tunic in external appearance. Tunic is tough and sometimes covered with sediment or epibionts such as other ascidians (Figure 2 *a*). Siphons are not easily visible, the visibility of siphon depended on the age and size of live specimens, and in the fixed specimens it depended on the state of relaxation. Both siphons are in upright position with each siphon having four lobes; the siphons are located comparatively far apart from each other (Figure 2 *a* and *b*).

Mantle is thin and covers the entire body and is whitish to greyish in colour. The longitudinal and transverse muscle bands in the mantle are thick and dense. Muscle bands are visible on the entire body in both sides but are thicker and denser on the right side. Muscle bands are denser near to the siphons (Figure 2 *b*). Oral tentacles are branched and occur in different sizes (Figures 3 *a* and 4 *c*). Each individual contains about 50 tentacles; the number of tentacles depends on the age of individual. The branchial sac is folded with six folds on each side of the body. Both internal longitudinal and transverse vessels are present, no papillae is present on the top of longitudinal vessels (Figures 3 *c* and 4 *a*). Stigmata is straight (Figures 3 *c* and 4 *d*) and 4–6 stigmata are counted per mesh (Figure 3 *c*). The dorsal organ consists of a series of

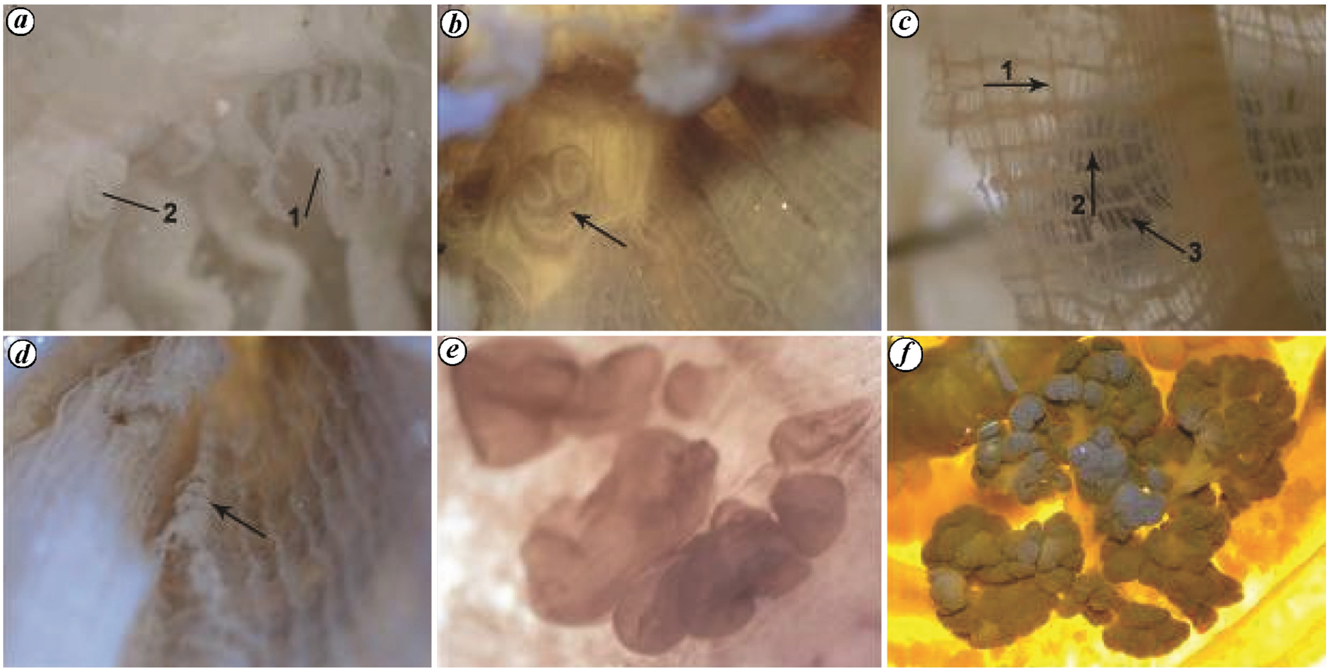

Figure 3. Internal appearances of *P. gangelion*. ***a***, Numbers 1 and 2 are oral tentacle and dorsal tubercle respectively; ***b***, dorsal tubercle; ***c***, branchial basket: number 1 refers to longitudinal vessel, numbers 2 and 3 refer to transverse vessel and stigmata respectively; ***d***, dorsal languets; ***e***, endocarps; ***f***, hepatic cecum.

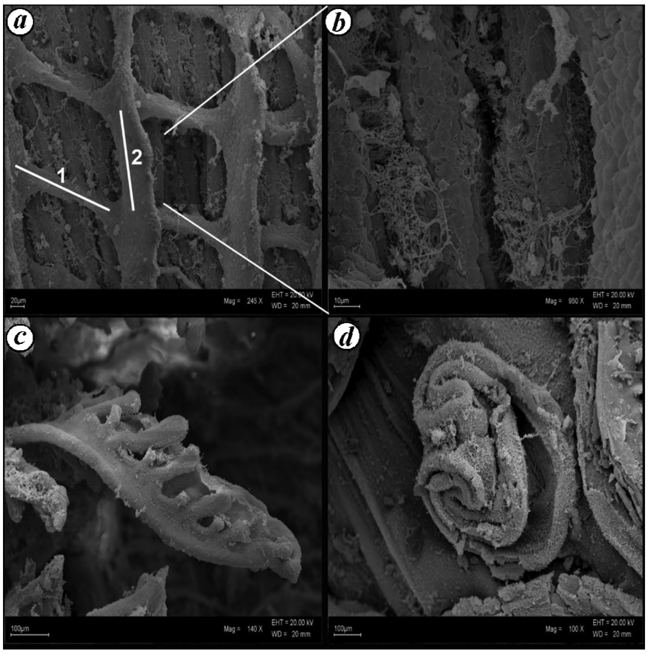

Figure 4. SEM micrographs of the internal organization of *P. gangelion*. ***a***, (1) transverse vessel; (2) longitudinal vessel; ***b***, stigmata; ***c***, oral tentacle; ***d***, dorsal tubercle.

languets (Figure 3 *d*) and ended just posterior to the dorsal tubercle. The dorsal tubercle is U-shaped with horns of the U enrolled (Figures 3 *b* and 4 *b*).

There is only one hermaphroditic gonad on the right side (with single ovary and numerous testis follicles) and the same on the left. On the left side, the gonads are included in the gut loop and lie parallel to the intestine and end in the atrial cloaca (Figure 2 *c*). Endocarps, conspicuous projections into the atrium are visible in both sides (Figures 2 *c* and 3 *e*). A hepatic cecum is positioned on the left side with a close connection to the branchial basket (Figures 2 *c* and 3 *f*).

The ascidian fauna of Indian Ocean is poorly known[12] and the available reports are mostly from the African coast[13]. A first record and description of ascidians from the Red Sea has been published by Savigny[14]. Since that time, extensive studies have been carried out on the ascidian fauna of the Red Sea and to a lesser extent neighbouring regions[8,13,15,16]. More recently, Khaleghi[17] listed six species from Iranian waters of the Gulf of Oman and recorded *Phallusia nigra*, *Ecteinascidia thurstoni*, *Styela canopus*, *Styela plicata*, *Ascidia* sp., *Cnemidocarpa* sp. for this region.

Among the few studies which are available on the ascidian fauna of the Persian Gulf[8,18], none of them reported the occurrence of *Pyura gangelion* in this region. Afkhami *et al.*[18] reported *Phallusia nigra* from the Persian Gulf and studied its distribution from four different sites including Larak Island, Hengam Island, Qeshm Island and Bandar-e-Lengeh. The previous nearest record of *P. gangelion* to the present location is from the Red Sea region, and therefore, this study is the first report of the occurrence of this species from the Persian Gulf.

Several synonyms have already been identified for *Pyura gangelion* and listed[19]. A combination of characters has been used by several authors to identify and describe the ascidian species, i.e. the presence of papillae in branchial basket, the shape of dorsal tubercle, position of the dorsal tubercle in relation to dorsal organ, the number of stigmata per mesh, the number and shape of oral tentacles and the position of gonads[6,13,20,21].

Pyura gangelion is distinguished from *Herdmania momus* by having six branchial folds on each body side. The latter has 12–13 folds[6]. No papillae projection was observed in *P. gangelion* (see also Figures 3 *c* and 4 *a*) and a spoon-shaped or curved-shaped papillae is present in *Phallusia nigra*[21]. The dorsal tubercle is U-shaped with enrolled horns in *P. gangelion* (see also Figures 3 *b* and 4 *b*), whereas it is simple and C- or U-shaped in other solitary ascidians[20–22]. Moreover, in *P. gangelion* the dorsal organ is present as a row of dorsal languets that ends immediately to the posterior of dorsal tubercle, while there is a clearly recognizable gap between the dorsal lamina and the dorsal tubercle in *Ascidia cannelata*[20]. The number of stigmata per mesh is 4–6 in *P. gangelion* (Figure 3 *c*) and up to eight stigmata per mesh are present in its close relative *Herdmania momus*[6]. In *P. gangelion*, gonads are located on both sides of the body (Figure 2 *c*) and in *Phallusia nigra* they are located only on the left side[21].

The members of the genus *Pyura* have folded branchial sacs which may vary among the species. There are 6 folds in *P. gangelion*, *P. arenosa*, *P. australis*, *P. curvigona*, *P. elongata*, *P. gibbosa*, *P. isobella*, *P. littoralis*, *P. obesa*, *P. scortea*, *P. spinosa*, *P. tasmanensis*, *P. vittata*, *P. setosa*, *P. chilensis*, *P. lignosa*, *P. haustor* and *P. mozambica*, while 4 folds exist in *P. stubenrauchi*, 6–7 in *P. sacciformis*, *P. spinifera* and *P. stolonifera*, 7 in *P. crassacapitata*, *P. fissa*, *P. navicula*, *P. pantex*, *P. discoveryi*, *P. mirabilis* and *P. viarecta*, 7–8 in *P. irregularis*, 8–9 in *P. confragosa* and 9 in *P. abradata*.

In all of the species of *Pyura gangelion*, branchial folds are suited with the same number on the both sides of the body. In contrast, the exceptions are *P. molguloides* (8–9 branchial folds exist on the left side and 7–8 on the right side) and *P. antillarum* (6 folds exist on the left side and 7 on the right side)[6,13,21].

Four to six stigmata per mesh exist in *P. gangelion*, *P. elongata*, *P. navicula*, *P. obesa*, *P. sacciformis*, *P. spinosa* and *P. viarecta*, while 1–5 in *P. lignosa*, 3–5 in *P. arenosa* and *P. littoralis*, 4–5 in *P. stubenrauchi*, 5–8 in *P. stolonifera*, 6 in *P. abradata*, *P. confragosa*, *P. curvigona*, *P. fissa*, *P. gibbosa*, *P. pantex* and *P. scortea*, 6–8 in *P. irregularis*, *P. isobella*, *P. paessleri* and *P. spinifera*, 8 in *P. australis*, *P. crassacapitata* also, 9–12 in *P. setosa*[6,21].

The oral tentacles are branched in all the members of the genus *Pyura*[6,21]. There are eight oral tentacles present in *P. arenosa* and *P. crassacapitata*, while 12 in *P. curvigona*, *P. fissa* and *P. littoralis*, 12–16 in *P. legumen*, 16 in *P. stolonifera,* 16 or more in *P. lignosa*, 16–24 in *P. chilensis*, 18–24 in *P. mirabilis* (according to von Drasche[23]), about 20 in *P. tasmanensis*, 21 in *P. obesa* and about 50 in *P. gangelion*[6,13,21].

Dorsal tubercle is U- or C-shaped with enrolled horns in *P. arenosa*, *P. australis*, *P. elongata*, *P. isobella*, *P. navicula*, *P. obesa*, *P. tasmanensis*, *P. vittata*, *P. legumen*, *P. abradata* and *P. gangelion*, while it is simple U-shaped in *P. crassacapitata* and *P. molguloides*, slightly irregular U- or S-shaped in *P. fissa*, oval and S-shaped in *P. littoralis*. Moreover, it is U-shaped with horns turned out in *P. confragosa* and *P. scortea*. Dorsal tubercle suited anteriorly to the dorsal organ which consists of a series of languets in all *Pyura* species[6,21].

As a common feature in the genus *Pyura*, all species have gonads on both left and right sides of the body. The left gonads are included in the gut loop in all members, while in some species such as *P. fissa*, *P. littoralis*, *P. obesa*, *P. australis*, *P. confragosa*, *P. mozambica* and *P. gangelion* the right gonads are in corresponding position opposite of the left gonad on the body wall. The number of gonads varies on each body side, i.e. one and two gonads on the right and left side in *P. antillarum* respectively[6,13,21].

1. Shenkar, N. and Swalla, B. J., Global diversity of Ascidiacea. *PLoS ONE*, 2011, **6**(6).
2. Lahille, F., Sur la classification des Tuniciers. *C.R. Acad. Sci. Paris*, 1886, **102**, 446–448.
3. Stach, T. and Turbeville, J. M., Phylogeny of Tunicata inferred from molecular and morphological characters. *Mol. Phylogenet. Evol*., 2002, **25**(3), 408–428.
4. Tsagkogeorga, G. *et al*., An updated 18S rRNA phylogeny of tunicates based on mixture and secondary structure models. *BMC Evol. Biol*., 2009, **9**(1), 187.
5. Perrier, E., Note sur la classification des Tuniciers. *C.R. Acad. Sci. Paris*, 1898, **124**, 1758–1762.
6. Kott, P., The Australian Ascidiacea. Part 1, Phlebobranchia and Stolidobranchia. *Memoirs of Queensland Museum*, 1985, p. 440.
7. Halim, Y. and Messeih, M. A., Aliens in Egyptian waters. A checklist of ascidians of the Suez Canal and the adjacent Mediterranean waters. *Egypt J. Aquat. Res*., 2016, **42**(4), 449–457.
8. Monniot, C. and Monniot, F., Records of ascidians from Bahrain. The Gulf with three new species. *J. Nat. Hist*., 1997, **31**(11), 1623–1643.
9. Shenkar, N., Ascidian (Chordata, Ascidiacea) diversity in the Red Sea. *Mar. Biodivers*., 2012, **42**(4), 459–469.
10. Abbot, D. P., Newberry, A. T. and Morris, K. M., 6B: Ascidians (Urochordata). In *Reef and Shore Fauna of Hawaii* (eds Abbot, D. P., Newberry, A. T. and Morris, K. M.), Bishop Museum Press, Honolulu, HI, 1997.
11. Monniot, C. and Monniot, F., Clé mondiale des genres d’ascidies. *Arch. Zool. Exp. Gen*., 1972, **113**(3), 311–367.
12. Ali, H. A. J. and Tamilselvi, M., *Ascidians in Coastal Water: A Comprehensive Inventory of Ascidian Fauna from the Indian Coast*, Springer, 2016, pp. 195.
13. Monniot, C., Stolidobranch ascidians from the tropical western Indian Ocean. *Zool. J. Linn. Soc*., 2002, **135**(1), 65–120.
14. Savigny, J. C., Mémoires sur les animaux sans vertèbres, Paris, 1816, pp. 1–239.
15. Sluiter, C. P., Tuniciers récueillis en 1904 par M. Ch. Gravier dans la golfe de Tadjourah (Somalie Française). *Bull. Mus. Natl. Hist. Nat*., 1905, **11**, 100–103.
16. Van Name, W. G., Tunicata of the Manihine Expedition to the Gulf of Aqaba. *Bull. Br. Mus. Nat. Hist. Zool*., 1952, **1**(8), 215–220.

17. Khaleghi, M., First record of six species of Ascidians (Tunicata: Ascidiacea) from Chabahar Bay (Gulf of Oman), Iran. *J. Appl. Environ. Biol. Sci.*, 2016, **6**(2), 122–129.
18. Afkhami, M., Ehsanpour, M., Forouzan, F., Bastami, K. D., Bahri, A. H. and Daryaei, A., Distribution of ascidians *Phallusia nigra* (Tunicata: Ascidiacea) on the north coast of the Persian Gulf, Iran. *Mar. Biodivers. Rec.*, 2012, **5**, 1–4.
19. Kott, P., Ascidian fauna of Western Port Bay, Victoria, and a comparison with that of Port Phillip Bay. *Mem. Natl. Mus. Vict.*, 1976, **37**, 53–95.
20. Hartmeyer, R., Über einige Ascidien aus dem Golf von Suez. *Sitzber Ges Natturforsch Freunde Berlin*, 1915, **9**, 397–430.
21. Van Name, W. G., North and South American ascidians. *Bull. Am. Mus. Nat. Hist.*, 1945, **84**,1-462.
22. Vandepas, L. E., Oliveira, L. M., Lee, S. S., Hirose, E., Rocha, R. M. and Swalla, B. J., Biogeography of *Phallusia nigra*: is it really black and white? *Biol. Bull.*, 2015, **228**(1), 52–64.
23. von Drasche, R., Ueber einige neue und weniger bekannte aussereuropasche einfache Ascidien. *Denkschr. Acad. Wiss. Wien.*, 1884, **48**, 369–386.

ACKNOWLEDGEMENTS. We thank Shahid Bahonar University of Kerman and Humboldt University of Berlin financial support. We also thank the Kish Diving Center and its manager G. H. Nargesi for their support during samplings. We are grateful to the members of molecular parasitology department at Humboldt University of Berlin for providing the facilities to work on ascidians. We also thank P. Martin for his assistance during the preparation of samples for SEM photography.

Received 20 August 2018; revised accepted 4 July 2019

doi: 10.18520/cs/v117/i7/1207-1211

Synchronous pulsed flowering in passion flower (*Passiflora incarnata*)

Surender Goyal, Rosmi Reji,
Siddharth S. Tripathi and
Narayanasami Sathyamurthy*

Indian Institute of Science Education and Research Mohali, Sector 81, SAS Nagar, Manauli 140 306, India

Daily observations of the number of flowers blossoming per day of passion flower, *Passiflora incarnata* reveal synchronous pulsed flowering. There seems to be no direct correlation between the observed temporal oscillations in flowering and environmental factors like the change in temperature, humidity and photoperiod. These temporal oscillations are characteristic of an open nonlinear dynamical system and are likely to arise from endogenous factors like the concentration of a florigen and an anti-florigen. A modified Lotka model is shown to mimic the monthly periodicity and the annual recurrence.

Keywords: Florigen, Lotka model, passion flower, *Passiflora incarnate*, temporal oscillations.

PLANTS are generally classified into gymnosperms and angiosperms. The latter yield flowers, which may result in fruits and seeds. Some plants are seasonal and some are perennial. In the latter category, flowering may occur seasonally or may occur over a period of time, each year. Flower opening in many plants follows the circadian rhythm. It has impact on the lives of pollinators and on the production of seeds, which in turn has enormous commercial and societal implications. Therefore, it becomes important to follow and understand the cycle of flowering in plants.

Phenology of flowers has been the subject of several investigations over the years. For example, Gentry[1] found evidence for steady state flowering, cornucopia flowering (flowering over a period of a month or so) and 'big bang' or 'burst' flowering (with synchrony) in some of the species in Central America. Augspurger[2] studied the flowering in 20 individual plants in 6 different shrub species. In addition to counting the number of newly opened flowers every day in each plant, she looked for synchrony, if any, in each set of 20 flowers. Although she noticed a large variation in the number of flowers per individual plant in some of the species, she concentrated on the mean number of flowers per plant. While reporting on the phenology and control of flowering in tropical trees, Borchert[3] emphasized on the difference between trees and herbaceous plants. He also emphasized on flower induction, early differentiation of flower buds, development of flower buds and the onset of anthesis. He pointed out that the environmental factors played little role in flower induction and anthesis. Kochmer and Handel[4] analysed the monthly data on flowering for a large number of species in North and South Carolina and Japan (comparable latitude) and concluded that there was a bimodal distribution in flowering time and it was more dependent on phylogenetic constraints than on competition for pollinators. Toy[5] followed flowering in certain trees in West Malaysia over a period of 75 days. There was some intra-species synchrony; otherwise, there was sequential flowering between species.

Newstrom *et al.*[6] classified the flowering patterns as continual, subannual, annual and supra annual. Each category of flowering was further classified as regular or irregular. Unfortunately, they did not present any time series analysis that could have revealed the underlying nonlinear dynamical behaviour. Wright and Calderon[7] examined weekly phenological data on flowering season length for 217 tropical species and concluded that there was no basis for water stress hypothesis (i.e. flowering precedes development of leaves, which requires more water) or for the shared pollinator hypothesis (i.e. species flowering at about the same time would share the same set of pollinators). Sakai[8] found certain irregular patterns

---

*For correspondence. (e-mail: nsath@iisermohali.ac.in)