Adjacent bleached and non-bleached conspecifics of the family Pocilloporidae

The Metabolic Signatures of Historic Thermal Responses Reveal Susceptibility and Resilience in Reef-Forming Corals

Chris Aslett

Numerous entirely non- and -bleached pairs of *Montipora capitata* growing side by side were permanently tagged on reefs during the 2015 bleaching event in Hawai'i's Kāne'ohe Bay (Matsuda et al. 2019). Such foresight has facilitated the examination of surviving duos for biochemical differences that bestow permanence of colouration or those that predispose them to a loss of pigment (Roach et al. 2020).

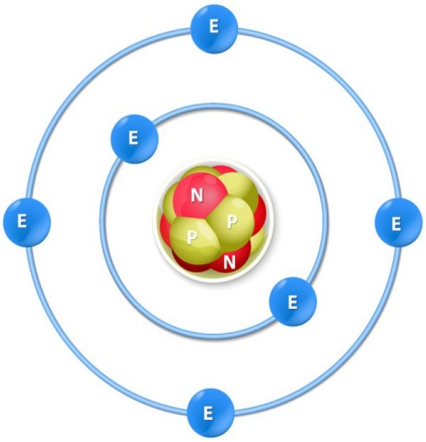

Fig. 1. The basic structure of an average carbon atom which has a nucleus comprising six positively charged protons and six neutrally charged neutrons, which are orbited by six negatively charged electrons distributed into two shells. The inner holds a maximum of two, whereas the outer is populated by four, which may contain up to eight. Each one of these four outer electrons can therefore become one half of the electron pair of a covalent bond. Thermodynamics drives an atom to fill its outermost shell.

Some Fundamentals of In- and -Organic Chemistry

You may be familiar with some inorganic carbon-containing compounds such as carbon dioxide (CO_2) or dissolved ions like carbonate (CO_3^{2-}) or bicarbonate (HCO_3^-). Conversely, all organic molecules are synthesised by living organisms and contain carbon and hydrogen (H) as Earth is home to carbon-based lifeforms, where many are referred to as hydrocarbons. Organic compounds can also comprise atoms of nitrogen (N), phosphorus (P), oxygen (O), sulphur (S), and many others, which may be exceedingly complex and sizeable, whilst some are merely linear and two or more carbons long. Many are cyclic meaning they form rings, whilst others assemble into branches. Intriguingly, carbon atoms self-organise / assemble.

The atoms within organic molecules such as carbon and hydrogen are usually held together with covalent bonds, where the unpaired outer (valence) electrons of opposing kinds with dissimilar spin are shared. Atom to atom bonds may be single, double, triple, quadruple or more, where each one represents a pair of contrarotating electrons, while the outer orbital (electron cloud) of each atom overlaps that of the other (Fig. 1.). Inorganic molecular dinitrogen is held together by three covalent bonds ($N \equiv N$; N_2) while molecular dioxygen is combined with two ($O=O$; O_2).

A long linear molecule made up of only single carbon to carbon bonds $(-CH_2)_\chi$ sequentially terminated by a methyl ($-CH_3$) and a carboxylic group ($-COO^- H^+$) comprising a hydroxyl (-OH) and a carbonyl ($-C=O^-$) are known as carboxylic or fatty acids (Fig. 2.). Such molecules are hydrophobic (water-fearing) hence they form water-excluding spheres which creates perceptible globules which when shaken, much like French or Italian salad dressing, form an emulsion. Hydrophobic hydrocarbons like the oils from your skin

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typically flatten the foam of protein skimmers, whilst nitrogen-containing proteins with exterior water-fearing amino acids are the ones exported. Fatty acids whose chains are made up of single covalent bonds are known as saturated (Fig. 2. “1”), whilst those whose chains comprise at least one double covalent bond (C=C) are unsaturated (Fig. 2. “2”). Nonetheless, polyunsaturated fatty acids (PUFAS) are those with multiple carbon to carbon double covalent bonds (Fig. 2. “3”). You may have been told that ingesting these kinds of fats is good for your heart. A double bond introduces a kink in the otherwise linear fatty acid which lends fluidity when integrated into a cellular membrane.

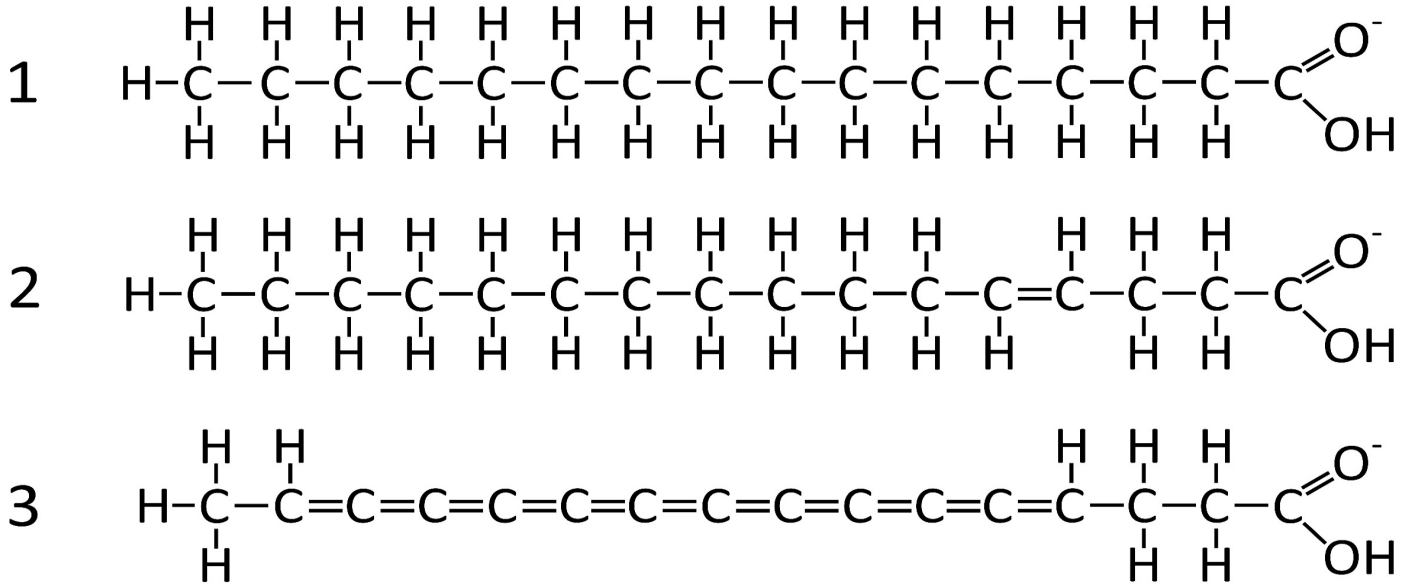

Fig. 2. [1] a saturated fatty acid; [2] an unsaturated fatty acid, and [3] a polyunsaturated fatty acid. Each carbon only forms a maximum of four covalent bonds commensurate with its four outer electrons, whereas each hydrogen has only one electron in a shell that can hold a maximum of two, which fills their outer shells, whilst oxygen has five so it can form up to three. These fatty acids thus approach their most stably-diminished energetic state, insomuch as most of their atoms attain the configuration of an “inert” noble gas.

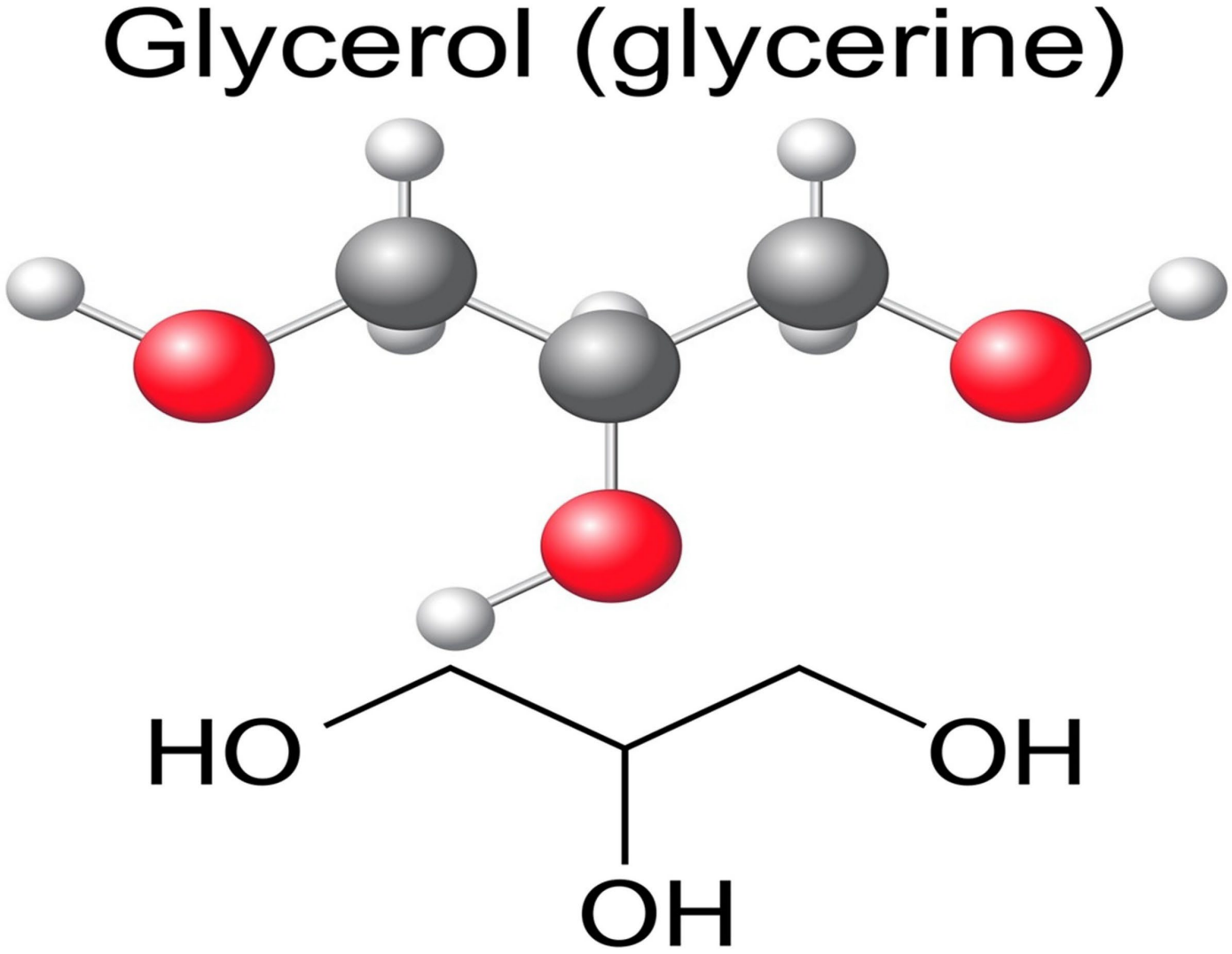

Fig 3. The structure of glycerol (glycerine) where dark grey, red, and white spheres represent respective carbon, oxygen, and hydrogen.

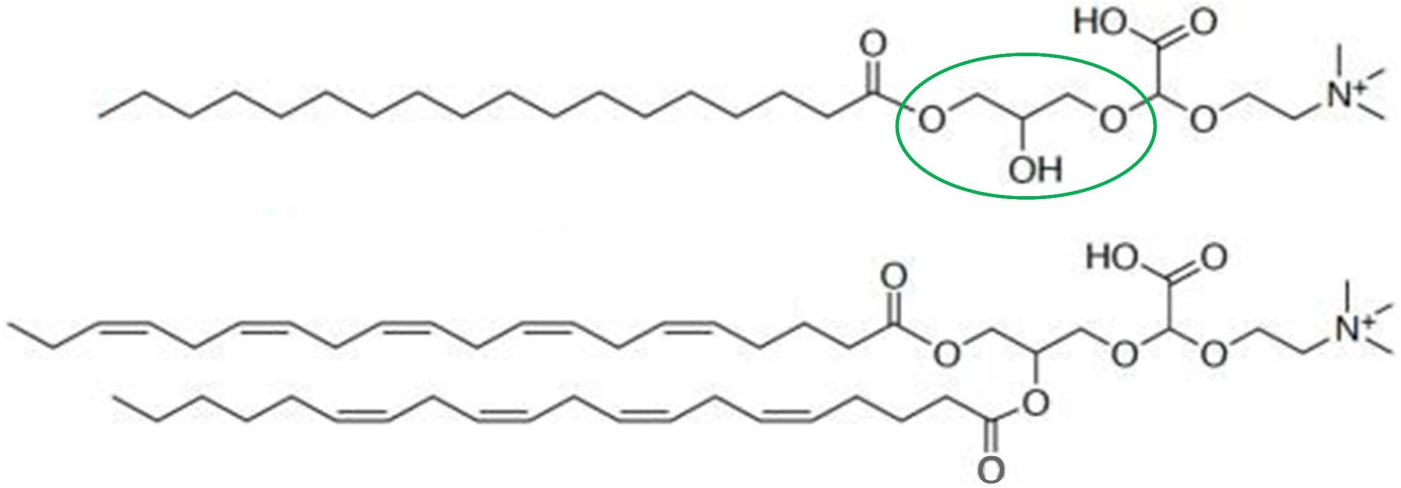

Fig. 4. Top - a saturated betaine monoglyceride prevalent in the flesh and endosymbiome of bleach-resistant *Montipora capitata* and a polyunsaturated betaine diglyceride peculiar to those colonies with a history of bleaching (bottom). The green ellipse surrounds a molecule of glycerol that adjoins the fatty acid to the left and a molecule of betaine to the right, where a condensation reaction covalently bonds two hydroxyls (2OH) to one another whilst liberating a molecule of water (H_2O). Each kink represents a CH_2, while "═" specify carbon to carbon double covalent bonds, whereas betaine's positively-charged nitrogen is bonded to a carbon and three protons (H^+). The charged head is water-loving (hydrophilic) which ensures when integrated into a cellular membrane, that the tails are buried within its hydrophobic core, whereas betaine faces outward into aqueous solution (Fig. 5.). Adapted from and courtesy of Roach et al. 2020 and The Creative Commons International license 4.0 (CC-BY-NC).

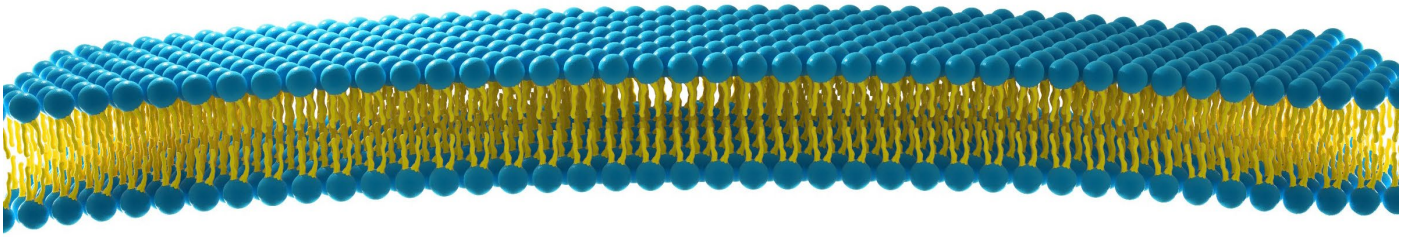

Fig. 5. An illustration of a cellular membrane made up of a bilayer of yellow hydrophobic diglycerides covalently bonded to a charged usually phosphate-comprising hydrophilic head (blue). Bilayers become more elastic when they include kinked fatty acids with at least one double covalent bond.

So, what has all this got to do with *Montipora capitata*.

One or more fatty acids bonded to an oily molecule of glycerol ($C_3H_8O_3$; glycerine; Figs 2. & 3.) which is in turn bonded to another organic compound called betaine ($C_5H_{11}N^+O_2$) forms what is known as a betaine lipid (Fig. 4.). Betaine is an intermediate used in the biosynthesis of the amino acid serine (Stryer 1995) which are modest-sized nitrogen-containing organics that are the fundamental building blocks of proteins.

Roach and allies discovered that only saturated betaine lipids were found in the flesh and zooxanthellae of bleach-resilient *M. capitata*, whilst most significantly, unsaturated betaine lipids were peculiar to those that had lost pigment (Roach et al. 2020).

References

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As the principal director of Reef Ranch Publishing Ltd (https://reefranch.co.uk/) and author of The Complete Reef Aquarist – A Conservation Manual (https://reefranch.co.uk/reef-aquarium-guide/), Chris has over 55 years of experience keeping aquatic animals with 47 of them nurturing marine species. His innate passion for system dynamics drove him from the laboratory to university where he gained a greater appreciation of biochemistry, biotechnology, epidemiology, genetics, histology, inorganic and organic chemistry, mariculture, molecular and microbiology, saltwater zoology, and the diagnosis and treatment of aquatic diseases. His dedicated marine livestock supplier, The Reef Ranch™, demanded he devise, streamline, and establish protocols for combined acclimation and prophylactic pest/parasite clearance, and innovate system design, optimisation, maintenance, and husbandry in the face of incessant influxes of hundreds of delicate marine animals. With exceptional, uncompromising, and likely the UK's most disease-free reef and fish-only facilities, losses were less than one resident every six months. 20 years hence, he has refined his expertise for digesting, authoring, editing, and publishing reef conservation-driven scientific literature (https://reefranch.co.uk/reef-research-and-aquarium-advice/), to an end of diminishing the impact the tropical marine ornamental industry exerts in the wild.

Hashtags: #coralconservation #coralreefconservation #coralreefs #MarineConservation #oceanconservation #reefaquarium #reefconservation #reefrestoration #thecompletereefaquarist
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