Methylo trophy versus heterotrophy: a misconception

I still remember the confusion in my mind when, in 1992, as a first-year PhD student, I attended the 7th 'C1-meeting' at the University of Warwick. I was working with methanol and methane oxidizers and several times speakers in the conference used the word heterotroph to quickly describe non-methylotrophic organisms or non-methylotrophic metabolism within facultative methylotrophs. Based on my first-degree knowledge, I was pretty sure the bugs I was studying were heterotrophic, but I humbly thought I had a lot to learn and that my doubts would be solved by reading more about the subject. However, a few years later now, after making some order in the facts about the types of methylotrophic metabolism that have been described, I am sure that heterotroph is not the antonym (word of opposite meaning) of methylotroph, and that my original sense of confusion was not caused by my ignorance.

Let us start with three simple textbook definitions.

- Autotroph: an organism that derives its cell carbon from CO2 (inorganic carbon) by fixation and reduction.
- Heterotroph: an organism that obtains its cell biomass by incorporating directly reduced (organic) molecules.
- Methylotroph: an organism that derives energy and, in many cases, cell carbon from reduced molecules that have no C–C bond (also called C1 compounds).

From these standard definitions it is clear that methylotrophy is not the opposite of heterotrophy. Nevertheless, in many reports in the literature (Megraw & Knowles, 1989; Krafzik & Conrad, 1991; Spivak & Rokem, 1994, 1995; Thompson et al., 1995; Nanba et al., 1999; Goodwin et al., 2001; Bothe et al., 2002; Korotkova et al., 2002; Chistoserdova et al., 2003; Van Dien et al., 2003) and at congresses, the term heterotroph has been constantly used to define non-methylotrophs (contaminants or symbions for instance) even by some of the most pre-eminent scholars in the field. In some cases (Levering et al., 1981; Levering & Dijkhuizen, 1985) the uneasiness with this choice surfaced in the usage of inverted commas ('heterotrophic').

As a matter of fact, methylotrophy does not describe one type of metabolism; it includes under a common name a bunch of different ways of utilizing C1 compounds. I see at least four reasons that can account for this inappropriate usage of the term heterotroph.

- Some micro-organisms do indeed grow on C1 compounds autotrophically, fixing the CO2 produced (Ralstonia, Xanthobacter, Paracoccus, the methylotrophic Archaea, the methylotrophic clostridia). Thus, for these organisms (exclusively) heterotrophic would be the proper antonym of methylotrophic.
- Furthermore, other autotrophic micro-organisms (lithotrophs or phototrophs) can utilize C1 compounds (methanol, formate) as a supplementary source of energy besides their more typical ones.
- Some methylotrophs are mixotrophic. Methyllococcus capsulatus fixes carbon derived from methane mostly at the level of formaldehyde, through the ribulose monophosphate (RuMP) pathway (heterotrophic), but also in part at the level of CO2 through the Calvin–Benson–Bessham (CBB) cycle (autotrophic) (Taylor et al., 1980; Baxter et al., 2002). Also, the serine cycle for carbon fixation is intrinsically mixotrophic in that it incorporates one molecule of CO2 for every two of formaldehyde fixed.
- Many of the reactions that compose the RuMP pathway are common to the CBB cycle. Some authors (Quayle & Ferenci, 1978) have hypothesized that the CBB cycle actually originated from the RuMP pathway and that organisms like Methyllococcus capsulatus, in which both pathways work simultaneously, may be ‘transition organisms’ between the two metabolic types (Taylor et al., 1980).
- Formaldehyde, which is the molecule fixed by the heterotrophic methylotrophs, is obviously not inorganic, but it is not at all ‘far’ from CO2 (just two dehydrogenation steps away); it is easy to slip into the mistake of considering it as ‘almost inorganic’. Or as Foster put it back in 1951 (as cited in Quayle, 1961): ‘...It is more the fact that these organisms synthesize their complex cell constituents from simple 1-carbon compounds chemically analogous to carbon dioxide that has resulted in their association with
autotrophs, than demonstrated proof of their ability to develop at the expense of CO₂.

These last points may explain how the misuse of the word heterotroph arose, but do not justify the persistence of this inaccuracy.

We have to recognize that we lack a proper term to concisely describe non-methylotrophic metabolism. The adjective multcarbon has been used in a many an instance (Korotkova et al., 2002; Chistoserdova et al., 2003; Van Dien et al., 2003), but we still lack a noun. The most appropriate solution to this question has been so far the utilization of the cumbersome phrase ‘non-methylotroph(ic)’.

I am writing to propose the creation of a new word to solve the problem and avoid confusions: since methylotrophy is, simplifying, the utilization of single-carbon molecules, its antonym could be polycarbohydrotrophy (poly, many; carbo, carbons; trophy, nutrition), or, more simply, polyotrophy (-ph, -phic). The linguistic opposite of polyotrophy(y) would be monotrophy(y), but I am not going to propose here to replace the 30-year-old cherished methylotroph(y) word: it would be complicated and indeed unnecessary. But I urge all colleagues in the field to avoid making indiscriminate use of heterotroph in opposition to methylotroph: it will help the PhD students of today and tomorrow a great deal.

Paolo De Marco

IBMC, R. Campo Alegre, 823, Porto, 4150-180, Portugal

Correspondence: Paolo De Marco (pmarco@ibmc.up.pt)


DOI 10.1099/mic.0.27165-0