My interest in coral nutrition began in the late 1980's, when the reef aquarium hobby in North America was in its nascent stages. At that point in time, the solutions offered to some of the mysteries of 'mini-reefs' were technological in nature and centered mostly on water quality parameters. Biological requirements such as lighting of corals and their captive algae were largely unexplored, and debates raged about whether corals actually required feeding. My attempts at keeping 'difficult' corals met with poor success rates – I watched several *Goniopora* specimens waste away over a period of 18 months or so. I was convinced poor nutrition was the problem and began research. That effort resulted in a series of early 1990's articles in *Freshwater and Marine Aquarium* magazine.

珊瑚营养，第三部分:关于氨基酸和氨基酸补充剂的讨论

作者：dana riddle　翻译：四川雅安 benben

我对珊瑚营养的兴趣始于20世纪80年代末，当时北美的家庭养殖珊瑚的爱好正处于萌芽阶段。在那个时候，“微缩珊瑚礁”之谜的解决方向主要集中在水质参数上。诸如珊瑚及其共生的藻类的照明等生物需求在很大程度上还没有被研究过，关于珊瑚是

否真的需要进食的争论也很激烈。但是，我自己养殖几种“困难”珊瑚的成功率很低——在大约 18 个月的时间里，我看着我养殖的几个珊瑚死去。我确信营养不良是问题所在，于是开始了这方面的研究。我的这一努力最终变成了 20 世纪 90 年代早期淡水和海洋水族馆杂志上的一系列文章。（好牛逼一样，哈哈）

在作者于 1992 年进行的珊瑚营养实验中，一颗 *Goniopora* 摄取了一张浸有氨基酸的正方形纸。

Today, many problems related to coral nutrition have been resolved yet some remain, and even veteran hobbyists still report ‘mysterious’ losses among their captive corals. Is improper nutrition to blame? This series of articles greatly expands upon my works that were published over 20 years ago and provides new insights.

In Part One of this series, we examined the care and feeding of zooxanthellae, including their lighting and nutritional requirements. Part Two reviewed what corals (mostly small polyp stony corals) can ingest or absorb.

This time, we’ll look at the importance of proteins and their amino acid subunits.

This article takes a decidedly, yet necessary, technical turn in order to understand coral and other marine invertebrate nutrition.

今天，许多与珊瑚营养有关的问题已经解决，但仍有一些问题存在，甚至资深的爱好者也报告说，他们在人工条件下养殖的珊瑚中会有“神秘”的损失（莫名其妙的死亡）。营养不当是罪魁祸首吗？这一系列文章（这些文章是 2015 年左右发表的）大大扩展了我 20 多年前发表的作品，并提供了新的见解。

在本系列的第一部分，我们研究了虫黄藻的护理和喂养，包括它们的光照和营养需求。第二部分回顾了珊瑚(主要是小水螅体石珊瑚 sps)可以摄取或吸收的物质。

这一次，我们将关注蛋白质和它的组成单位--氨基酸(氨基酸是蛋白质的基本组成单位)的重要性。这篇文章采取了必要的技术手段来帮助我们理解珊瑚和其他海洋无脊椎动物的营养。

Introduction

Protein (from the Greek word prte, meaning ‘first’ or ‘primary’) composes a large amount of dry tissue weight (about 50%) in corals. See Figure 1. Proteins can exist in many forms and have dozens of functions. Muscle is composed of protein fibers, enzymes are specialized proteins that act as biological catalysts, some fibrous proteins act as scaffolds for cytoskeletons, fluorescent proteins (and/or non-fluorescent chromoproteins) which give corals their wondrous colorations, mycosporine-like amino acids provide protection from ultraviolet radiation, and so on. In short, proteins are essential for life.

Proteins are polymers composed of subunits called polypeptides, which in turn are made of ‘building blocks’ called amino acids. Amino acids (AAs) are organic compounds composed of an amine (-NH2) and carboxyl group (-COOH.) All proteins consist of carbon, hydrogen, oxygen, and nitrogen. Some contain phosphorus, sulfur, iron, zinc, and copper. It should be of note that proteins are usually 16% nitrogen by weight.

导论

蛋白质(来自希腊单词 prte，意为“第一”或“初级”)在珊瑚干组织重量中占比较大(约 50%)。参见图 1。蛋白质可以以多种形式存在，并具有数十种功能。肌肉由蛋白质纤维组成，酶是充当生物催化剂的特殊蛋白质，一些纤维状蛋白质充当细胞骨架的支架，荧光蛋白质(和/或非荧光色素蛋白质)赋予珊瑚奇妙的颜色（这个应该是大家都喜欢的东西，也是我们家庭养殖观赏珊瑚的重要目的），类真菌（mycosporine-like）氨基酸提供对紫外线辐射的保护，等等。简而言之，蛋白质对生命至关重要。

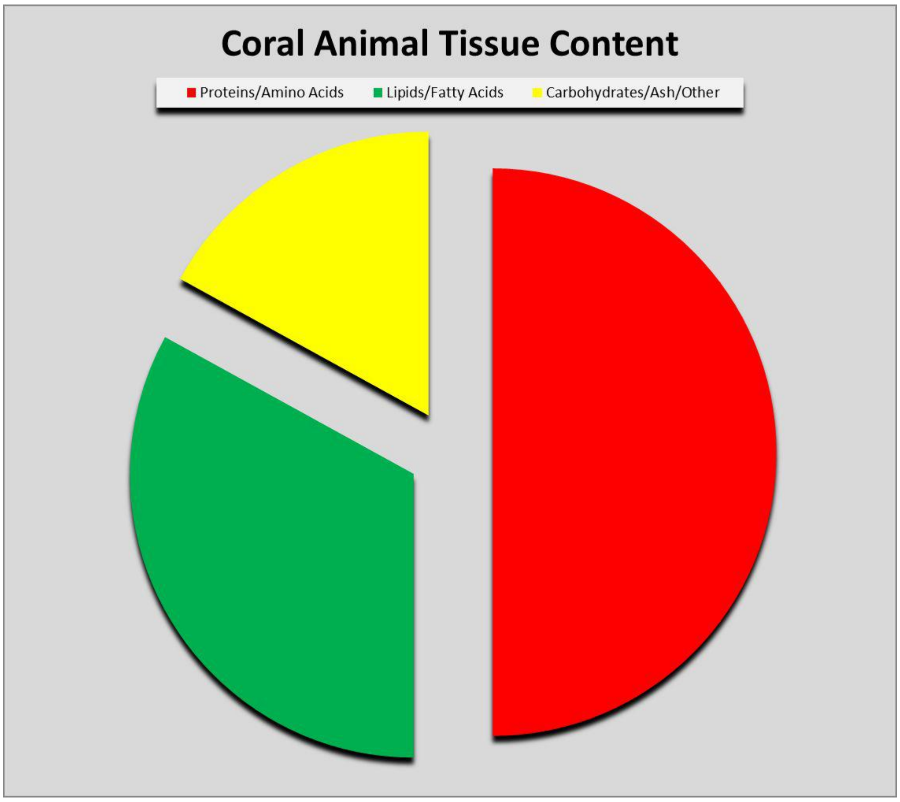


图 1　蛋白质可以构成多达 50%或更多的珊瑚软组织。

蛋白质是由称为多肽的亚单位组成的聚合物，而多肽又由称为氨基酸的“构件”组成。氨基酸是由胺(−nh_2)和羧基(−cooh)组成的有机化合物。所有的蛋白质都由碳、氢、氧和氮组成。有些含有磷、硫、铁、锌和铜。应当注意，蛋白质通常含 16%的氮（按重量计）。

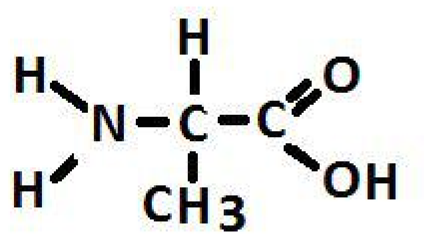


图 2 .丙氨酸，一种由虫黄藻产生的氨基酸，有可能转移到珊瑚虫体内。而一些珊瑚自己也会产生丙氨酸。

There are 23 proteinogenic (protein-building) amino acids in prokaryotes (bacteria, for example) and 21 in eukaryotes (animals, as an example.)

An amino acid can exist in two forms that are mirror-images of each other. The orientation can be designated as ‘L’ or ‘D.’

Unlike fats or starches, the body does not store excess amino acids; hence they must be consumed regularly. If amino acid ingestion is insufficient, muscle and other tissues will be consumed for their AA content. This condition is seen in starving children – although their bellies may seem fat, just the opposite is true: They have consumed the muscle mass in their abdominal walls and their gut is no longer supported and bulges outwards. This condition is known as ‘kwashiorkor’ (one reference says it means ‘golden boy’ for the pale appearance of a starving person. Others’ definitions differ.)

原核生物(例如细菌)中有 23 种构成蛋白质(蛋白质构建)的氨基酸，真核生物(例如动物)中有 21 种。

氨基酸可以以两种形式存在，它们是彼此的镜像。这两种方向可以描述为“L”或“D”。

不像脂肪或淀粉，身体不储存过多的氨基酸；因此，他们必须定期补充。如果氨基酸摄入不足，肌肉和其他组织将因其氨基酸含量而被消耗（这句应该意思是肌肉和其他组织因为缺乏氨基酸的多少而消耗多少，不是很理解）。这种情况在饥饿的儿童身上可以看到——尽管他们的肚子看起来很胖，但事实正好相反：他们消耗了肚子上的肌肉，他们的肠道不再受其支撑，并向外膨胀（显得肚子很胖）。这种情况被称为“kwashiorkor ”（一个参考文献说它的意思是“金色男孩”，意思是一个饥饿的人苍白的外表，其他的参考文献对其的理解不同）。

“Essential” and “Non-Essential” Amino Acids

Plants, algae, bacteria, and fungi are capable of producing all their required amino acids. Animals aren’t so fortunate; hence amino acids can be classified as ‘essential’ and ‘non-essential.’ Essential amino acids are those that must be obtained through diet and in proper quantities, while non-essential are those that the animal can make, given sufficient nutrition (such as nitrogen) is available. Essential amino acids can be species specific.

It is thought that some amino acids were so abundant (and hence easily obtained) during early evolutionary stages that some animals lost their ability to synthesize these amino acids. Some, if not many, corals seem to have taken a different evolutionary path from other metazoans (animals) and have retained the ability to manufacture some amino acids considered as ‘essential’ for humans. And the plot thickens…

.Essential Amino Acids Required by Humans:

.Histidine
.Isoleucine
.Leucine
.Lysine
.Methionine
.Phenylalanine
.Threonine
.Tryptophan
.Valine

“必需”和“非必需”氨基酸

植物、藻类、细菌和真菌能够产生它们所需的所有氨基酸。动物就没那么幸运了(珊瑚是动物，☺️)；因此，氨基酸可以分为“必需的”和“非必需的”。必需氨基酸是那些必须通过饮食以适当的量获得的氨基酸，而非必需氨基酸是那些动物可以制造的氨基酸，只要有足够的营养(如氮)就行。必需氨基酸可以是物种特异性的（不同物种之间有差异）。

人们认为，一些氨基酸在生物早期进化阶段非常丰富(因此很容易获得)，以至于一些动物失去了合成这些氨基酸的能力。一些(如果不是很多的话)珊瑚似乎走了一条不同于其他后生动物(动物)（这里是区别于珊瑚和其他更为高等的动物，珊瑚还是趋向于更为原生的动物。。）的进化道路，并保留了制造一些被认为是人类“必需”的氨基酸的能力(也就是说有些氨基酸在人类来说是必需氨基酸，但是某些珊瑚却能自己制造，也就是在某些珊瑚中是非必需氨基酸）。事情就变得越来越复杂...

人类所需的必需氨基酸:

. 组氨酸

. 异亮氨酸

. 亮氨酸

. 赖氨酸

. 甲硫氨酸

. 苯丙氨酸

. 苏氨酸

. 色氨酸

. 缬氨酸

. (这个点号应该是等的意思)

Nitrogen Sources in Seawater

Nitrogen is an essential element in the formation of amino acids and hence proteins. Usable inorganic nitrogen can exist in several common forms in water: Nitrogen gas (which must be 'fixed' by certain bacteria), ammonia/ammonium (species depending upon pH) and nitrate. Organic forms include urea, dissolved free and combined amino acids, and particulates.

Figures 3, 4, and 5 demonstrate uptake of various compounds that contain nitrogen.

海水中的氮源

氮是氨基酸和蛋白质形成的基本元素。可用的无机氮可以以几种常见的形式存在于水中:氮气(必须被某些细菌“固定”)、氨/铵(取决于 ph 值)和硝酸盐。有机形式包括尿素、溶解的游离和结合氨基酸以及微粒。

图 3、4 和 5 显示了珊瑚对各种含氮化合物的吸收。

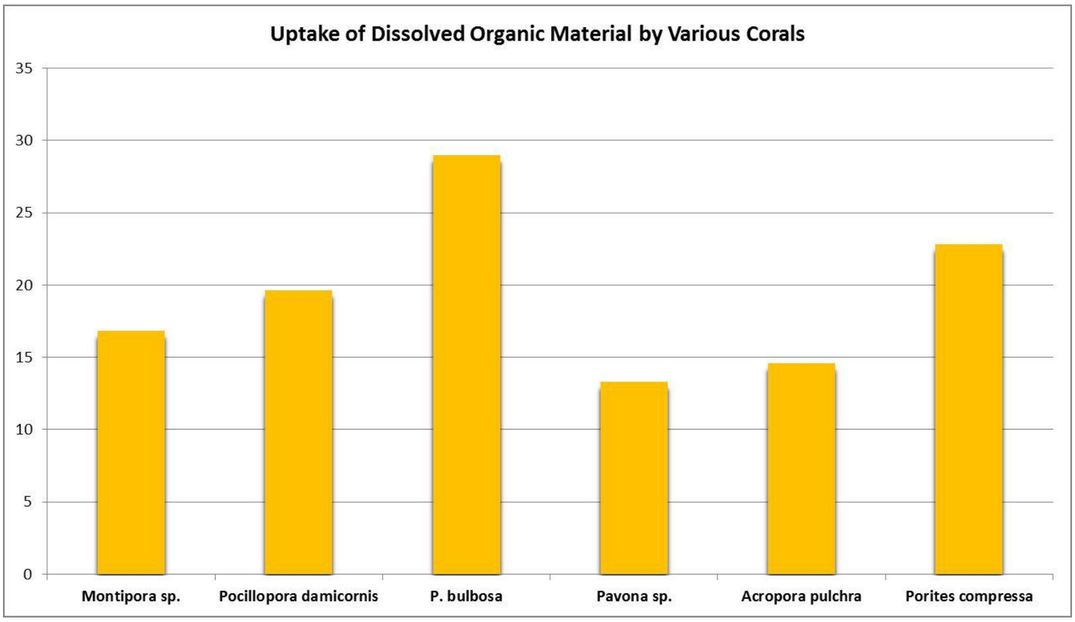


图 3 .在这个实验中显示了各种珊瑚对混合有机物的吸收。Sorokin，1973 年。

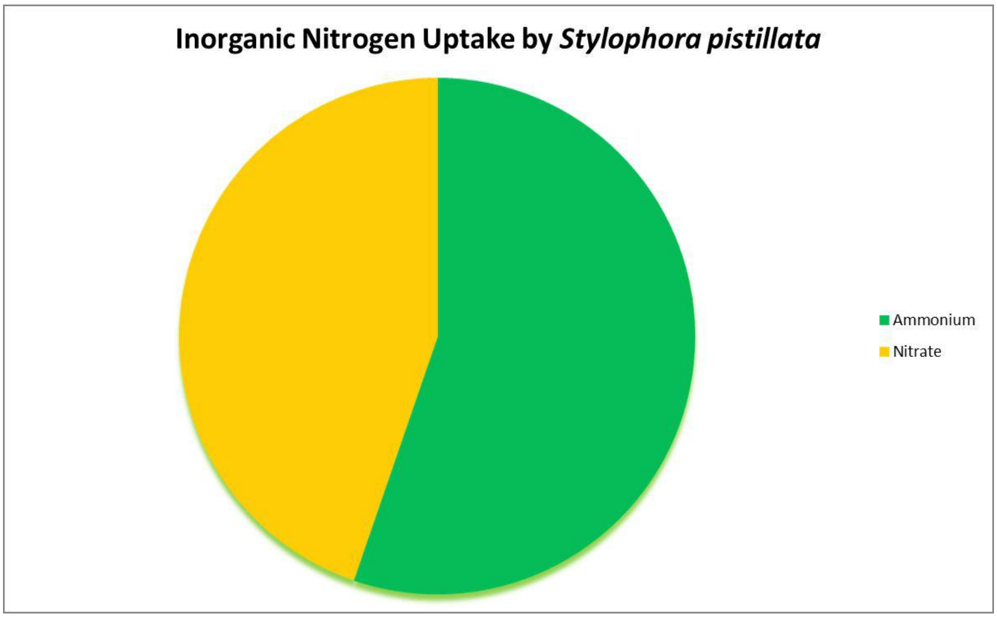


图 4 .铵是这种珊瑚优选的无机氮源。在某些情况下，固氮细菌存在于珊瑚的骨骼/组织中，可以提供由溶解的氮气制成的可用氮气（这就是前面提到的氮气由特定的

细菌固定后变成珊瑚可利用的氮源）。

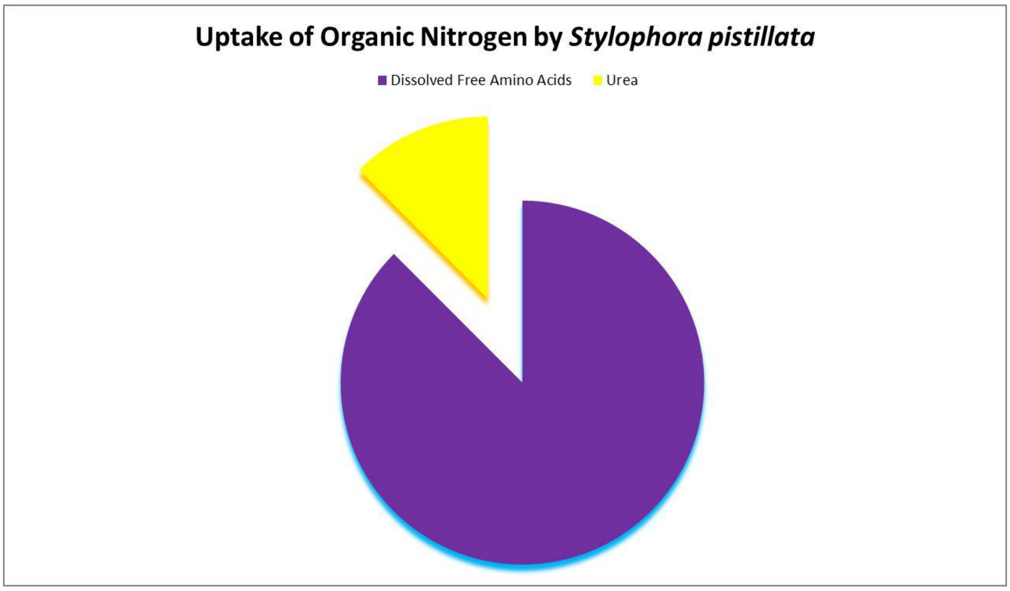


图 5。水族箱常见的珊瑚——*Stylophora*（*一种柱形珊瑚*）可以吸收游离氨基酸和尿素。

Amino Acids: A Concise List

Amino acids will be listed by 'family' or 'group.' Amino acids within a Family share similar biosynthetic pathways (See Figures 10 and 11.) Those listed as 'essential' refers to human dietary requirements except where noted.

See a greatly simplified biosynthesis pathway for these amino acids in Figure 9.

Arginine

Composition: ($C_6H_{14}N_4O_2$)

Shorthand: Arg, or R

Group: Basic

Essential (Humans): Conditionally essential

Non-essential in humans, but can become essential in some cases (such as disease.) Detected in very small quantities in zooxanthellate corals Montastrea faveolata, Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.)

Arginine is an immediate precursor of ornithine and is necessary for the formation of creatine.

Glutamic Acid

Composition: ($C_6H_{14}N_4O_2$)

Shorthand: Glu, or E

Group: Acidic

Required for Synthesis: Vitamin B-6

Essential (Humans): No

Considered non-essential, this amino acid is the most abundant AA found in the human body. The most successful feeding activator in Montastrea cavernosa (Lehman and Porter, 1973), it also acts as an antioxidant in plants, animals and some bacteria.

Glutamine

Composition: ($C_5H_{10}N_2O_3$)

Shorthand: Gln, or Q

Group: Neutral, polar

Essential (Humans): Conditionally essential in humans. Hydrolysis converts glutamine into glutamate.

· Glx (Glutamine and Glutamate)

Glutamine and glutamate ($C_5H_9NO_4$); glutamate is non-essential in humans.

Detected in zooxanthellate corals Montastrea faveolata, Acropora cervicornis, Porites divaricata, and azooxanthellate coralsTubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.)

· Glutathione

Composition: ($C_{10}H_{17}N_3O_6S$)

An important antioxidant and a strong feeding activator in some cnidarians. It is made from the amino acids cysteine, glutamic acid, and glycine.

· Proline

Composition: ($C_5H_9NO_2$)

Shorthand: Pro, or P

Group: Hydrophobic, non-polar

Required for Synthesis: Vitamin C

Essential (Humans): No

Trace quantities detected in zooxanthellate corals Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.)

氨基酸:一份简明的清单

这份清单中氨基酸将按“家族”或“组”列出。一个家族中的氨基酸有着相似的生物合成途径(见图 10 和 11)。那些被列为“必需”的是指对于人类是必需，除非另有说明。

-酮戊二酸家族

精氨酸、谷氨酸、谷氨酰胺、脯氨酸和非蛋白原性羟脯氨酸(在一些珊瑚体内有发现)属于-酮戊二酸家族。

参见图 9，对这些氨基酸的生物合成途径的简要示意。

. 精氨酸

.化学式:($c_6h_{14}n_4o_2$)

.简写: Arg，或 R

.组:基本组

. 是否必需(人类):一定条件是必需的

对人类来说不是必需的，但在某些情况下可能变成必需的(例如在人发生某些疾病时)在一些具有共生藻(虫黄藻)的珊瑚中检测到少量这种氨基酸的存在: montastrea faveolata、 acropora cervicornis、porites divaricata 和 azoxantheurie tubatrea coccinea 和 astrangia poculata （前面这些都是珊瑚名，a 属，p 属，各种珊瑚）(fitzgerald 和 szmant，1997 年）精氨酸是鸟氨酸的直接前体，是肌酸形成所必需的。

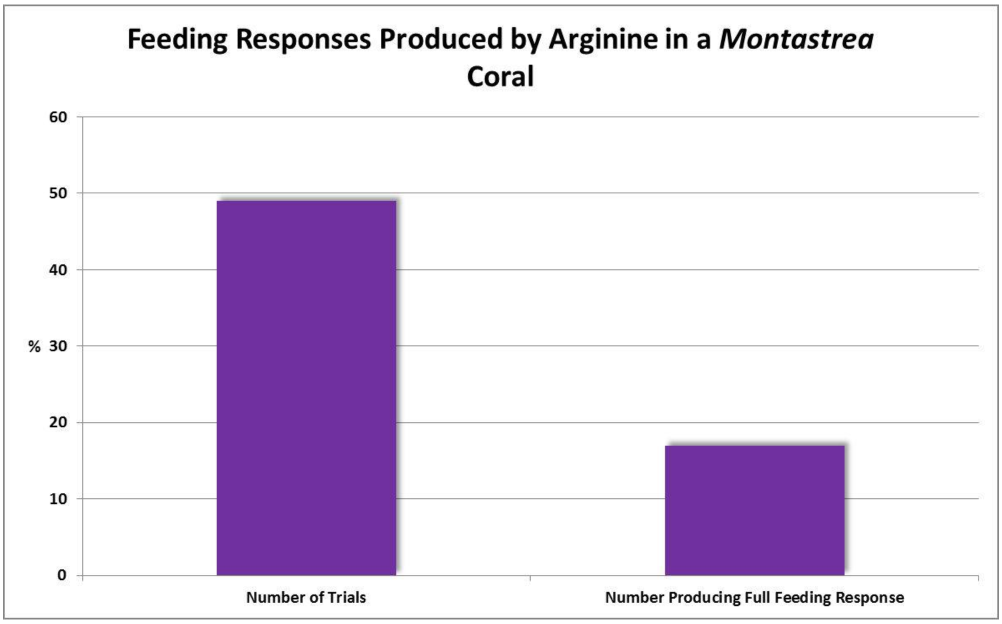


图 6　在这种珊瑚中，会在三分之一的测试时间中对精氨酸产生摄食反应。（这个图我不是很理解是怎么个三分之一，是三分之一的实验珊瑚，还是说珊瑚在三分之一的时间对这种氨基酸产生摄食反应？？？？只能说能肯定的一点这种珊瑚会吸收精氨酸）

. 谷氨酸

.化学式:($c_6h_{14}n_4o_2$)

.简写：Glu，或 E

.组：酸性组

. 合成所需：维生素 b-6（看到了吗，有些氨基酸合成是必须要维生素的，所以 af 把维生素作为其补充营养剂的一种在某种程

度上可以理解）

.是否必需(人类):否

被认为是非必需的氨基酸，这种氨基酸是人体内发现的最丰富的氨基酸。在 montasteria cavernosa（一种类似于微孔珊瑚的蜂巢珊瑚。。。）(Lehman and porter，1973)中最成功的喂养激活剂（加这种氨基酸，然后触手就会伸出来的那种。。。），它也在植物、动物和一些细菌中作为抗氧化剂。

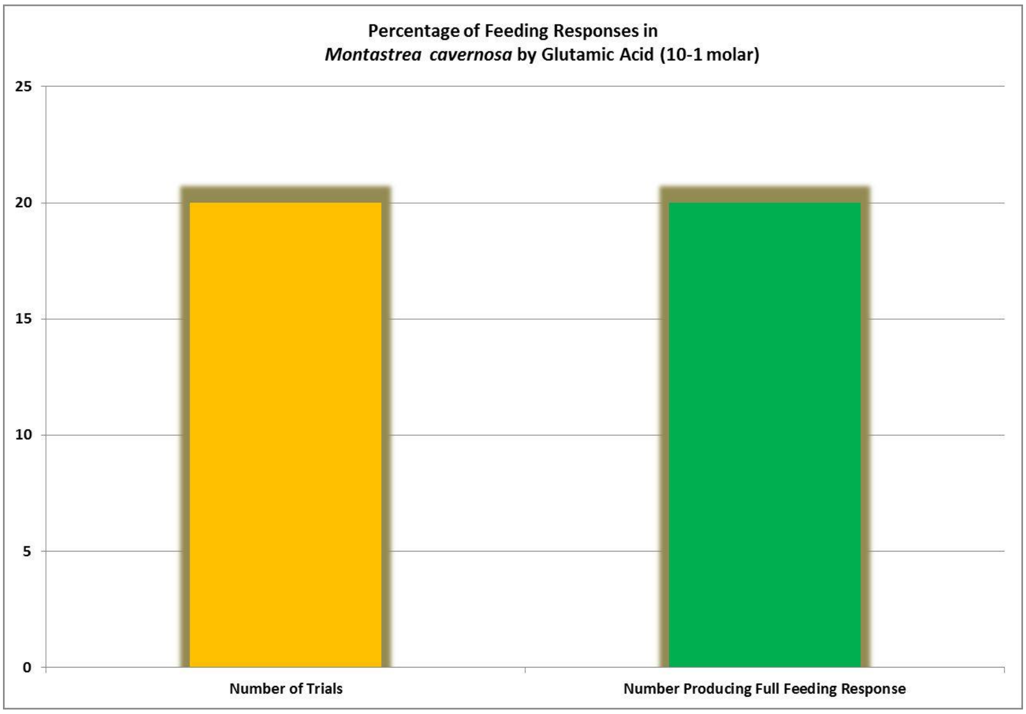


图 7 谷氨酸在这种产自大西洋的珊瑚中引发了 100%的摄食反应。

.谷氨酰胺

.化学式:($c_5h_{10}n_2o_3$)

.简写：Gln，或 Q

.组：中性，极性（有磁性）

.是否必需(人类):一定条件是必需的。谷氨酰胺通过水解转化为谷氨酸盐。

.GLX(谷氨酰胺和谷氨酸盐)(这可能代表这一种混合物)

谷氨酰胺和谷氨酸盐（$c_5h_9no_4$），谷氨酸盐对人类来说不是必须的。

在这些和虫黄藻共生的珊瑚中检测到（对应于无虫黄藻珊瑚）: *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,*，在这些无虫黄藻珊瑚中检测到: *Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.)

.谷胱甘肽

.化学式:($c_{10}h_{17}n_3o_6S$)

一种重要的抗氧化剂，也是一些刺胞动物(珊瑚)的一种强烈的进食激活剂(诱食剂)。它由半胱氨酸、谷氨酸和甘氨酸制成。

.脯氨酸

.化学式:($c_5h_9no_2$)

.简写: Pro, 或 P

.组:疏水性、非极性.

.是否必需(人类):否

在这些和虫黄藻共生的珊瑚中检测到微量(对应于无虫黄藻珊瑚): *Acropora cervicornis*, *Porites divaricata,*，在这些无虫黄藻珊瑚中检

测到微量：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚)*, and *Astrangia poculata（后面这个不知道是啥，反正也是一种无共生藻的珊瑚）* (Fitzgerald and Szmant, 1997.)

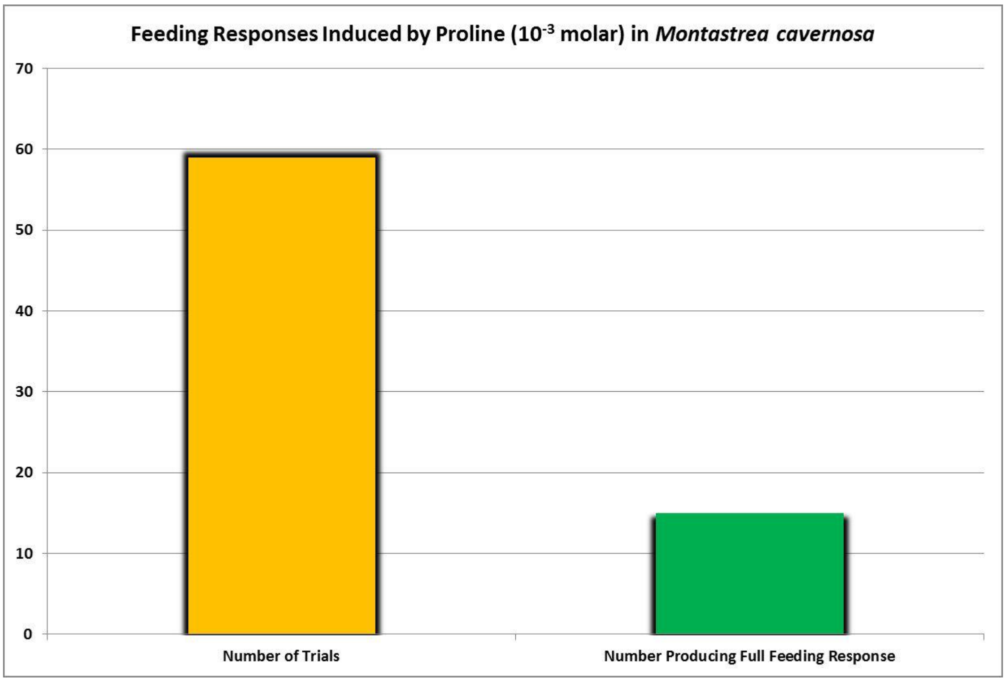


图 8 脯氨酸在大约 15%的时间里会诱发摄食反应。（我还是不明白这个百分之十五时间是啥意思，硬翻。。就简单的看成这个氨基酸对摄食反应的诱导程度好了。。。）

Hydroxyproline

.Composition: ($C_6H_9NO_3$)

.Shorthand: Hyp

.Required for Synthesis: Vitamin C

.Essential (Humans): No

.Hydroxyproline is similar to proline, with the difference being hydroxyproline contains a hydroxyl (OH) molecule. It is thought to play a role in the incorporation of silica into diatom skeletons. Hydroxyproline is found in very small quantities in zooxanthellate corals Montastrea faveolata, Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata. (Fitzgerald and Szmant, 1997.) However, it is considered non-proteinogenic (it is not found in the genetic code of any organism.)

· Pipecolic Acid

Composition: ($C_6H_{11}NO_2$)

An analogue of the amino acid Proline, and used in feeding activator responses by Lehman and Porter (1973.) Interestingly, this substance has been found in meteorites.

The Pyruvate Family

The Pyruvate Group contains alanine, isoleucine, leucine, and valine.

· Alanine

.Composition: ($C_3H_7NO_2$)

.Shorthand: Ala, or A

.Group: Hydrophobic, non-polar

.Essential (Humans): No

.Translocated from zooxanthellae to the coral host. Precursor is glucose. Detected in zooxanthellate corals Montastrea faveolata,Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.) Non-polar. Alanine is second in abundance only to leucine. Considered non-essential in humans.

. 羟脯氨酸

. 化学式:($c_6h_9no_3$)

.简写: Hyp

.合成所需: 维生素 C.

. 是否必需 (人类) : 否

羟脯氨酸类似于脯氨酸，区别在于羟脯氨酸含有一个羟基 (oh) 分子。它被认为在把二氧化硅结合到硅藻骨架的过程中起作用。在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中发现很少量的羟脯氨酸: *Montastrea faveolata*, *Acropora* *cervicornis*, *Porites divaricata*,在这些无虫黄藻珊瑚中检测到少量该氨基酸：*Tubastrea coccinea*(*筒星珊瑚属 类似太阳花珊瑚*), and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.)然而，它被认为是非蛋白原性的(在任何生物体的遗传密码中都找不到)。

. 吡哌酸

. 化学式:($c_6h_{11}no_2$)

一种类似脯氨酸的氨基酸，由 lehman 和 porter (1973)用于喂食激活反应。有趣的是，这种物质在陨石中被发现（天外来客？天外来氨基酸，哈哈）。

. 丙酮酸家族

丙酮酸组包含丙氨酸、异亮氨酸、亮氨酸和缬氨酸。

. 丙氨酸

. 化学式:($c_3h_7no_2$)

.简写：Ala 和 A

. 组: 疏水性、非极性.

. 是否必需(人类): 否

从虫黄藻转移到珊瑚宿主,前驱物是葡萄糖。在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中发现: *Montastrea faveolata*,*Acropora cervicornis*, *Porites divaricata*,,在这些无虫黄藻珊瑚中检测到: *Tubastrea coccinea*(*筒星珊瑚属 类似太阳花珊瑚*), and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.)非

极性的,丙氨酸的丰富程度仅次于亮氨酸，被认为对于人类是非必需氨基酸。

· Isoleucine

.Composition: ($C_6H_{13}NO_2$)
.Shorthand: Ile, or I
.Group: Hydrophobic, non-polar
.Essential (Humans): Yes
.Essential amino acids in humans. No feeding response at all Montastrea cavernosa (Lehman and Porter, 1973.)

· Leucine

.Composition: ($C_6H_{13}NO_2$)
.Shorthand: Leu, or L
.Group: Hydrophobic, non-polar
.Essential (Humans): Yes

Leucine is the most abundant amino acid in nature and is considered essential in humans. Produced in small quantities by zooxanthellate corals Montastrea faveolata, Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.)

· Valine

.Composition: ($C_5H_{11}NO_2$)
.Shorthand: Val, or V
.Group: Hydrophobic, non-polar
.Essential (Humans): Yes
.Produced in small quantities by zooxanthellate corals Montastrea faveolata, Acropora cervicornis, Porites divaricata, and azooxanthellate corals Tubastrea coccinea, and Astrangia poculata (Fitzgerald and Szmant, 1997.)

The Oxoloacetate or Aspartate Family

Amino acids found in this family include asparagine, aspartic acid (and hence aspartate), lysine, sulfur-containing methionine, and threonine.

· Asparagine

.Composition: ($C4H8N2O3$)

.Shorthand: Asn, or N

.Group: Uncharged, polar

.Essential (Humans): No

Non-essential for humans as it is one of the most common of the 20 proteinogenic amino acids.

· Aspartic Acid

.Composition: ($C4H7NO4$)

.Shorthand: Asp, or D

.Group: Acidic

.Essential (Humans): No Carboxylate and salts of Aspartic Acid is called aspartate.

. 异亮氨酸

. 化学式:($c_6h_{13}no_2$)

.简写： Ile 或 I

. 组: 疏水性、非极性.

. 是否必需 (人类) : 是

人类必需氨基酸。在 *Montastrea cavernosa*（一种类似微孔的珊瑚）这种珊瑚中完全不会引起进食反应。 (Lehman and Porter, 1973.)（看来这种氨基酸至少对于一些种类的珊瑚是没有啥用的啊。）

. 亮氨酸

. 化学式:($c_6h_{13}no_2$)

.简写： Leu 或 L

. 组: 疏水性、非极性.

. 是否必需 (人类) : 是

亮氨酸是自然界中最丰富的氨基酸，被认为是人类必需的。

在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中发现很少量的亮氨酸：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata*, 在这些无虫黄藻珊瑚中检测到少量该氨基酸：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata（后面这个不知道是啥，反正也是一种无共生藻的珊瑚）* (Fitzgerald and Szmant, 1997.)

. 缬氨酸

. 化学式:($c_5h_{11}no_2$)

.简写： Val 或 v

. 组: 疏水性、非极性.

. 是否必需 (人类): 是

在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中发现很少量的缬氨酸：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata*, 在这些无虫黄藻珊瑚中检测到少量该氨基酸：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata（后面这个不知道是啥，反正也是一种无共生藻的珊瑚）* (Fitzgerald and Szmant, 1997.)

氧代丙酸酯或天冬氨酸酯家族

这个家族中发现的氨基酸包括天冬酰胺、天冬氨酸 (包括天冬氨酸盐)、赖氨酸、甲硫氨酸和苏氨酸。

. 天冬酰胺

. 化学式:($c_4h_8n_2o_3$)

.简写： Asn 或 n

. 组: 不带电荷、极性.

. 是否必需 (人类): 否

对人类来说不是必需的，因为它是20种蛋白质氨基酸中最常见的一种。

. 天门冬氨酸

. 化学式:($c_4h_7no_4$)

.简写： Asp 或 D

. 组: 酸性.

. 是否必需(人类): 否, 天冬氨酸的羧酸盐和盐被称为天冬氨酸盐。（这句没明白啥意思。。）

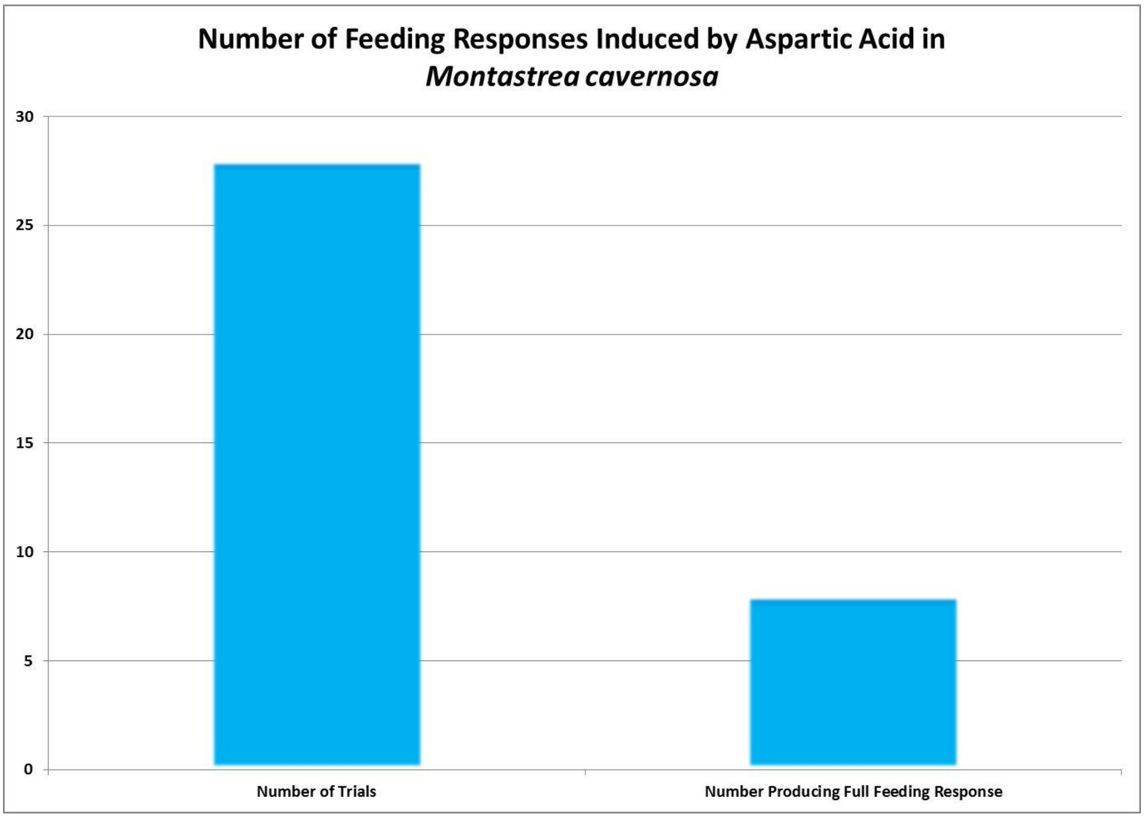


图 9 montastrea cavernosa(一种类似微孔的珊瑚）对天冬氨酸产生微弱的摄食反应。

· Aspartate

- Composition: ($C_4H_7NO_4$)
- Shorthand: Asp, or D
- Group: Negative charge, polar
- Essential (Humans): No

Aspartate can be formed from Aspartic Acid.

· Asx (Asparagine and Aspartic Acid)

Asparagine and Aspartic Acid. Detected in zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,* and azooxanthellate corals *Tubastrea coccinea*, and *Astrangia poculata* (Fitzgerald and Szmant, 1997.)

· Carnitine

Derived from lysine and methionine, and important in transporting fatty acid across the mitochondrial wall. Also found in meats.

· Lysine

- Composition: ($C_6H_{14}N_2O_2$)
- Shorthand: Lys, or K
- Group: Hydrophobic, non-polar
- Essential (Humans): Yes

· Methionine

- Composition: ($C_5H_{11}NO_2S$)
- Shorthand: Met, or M
- Group: Hydrophobic, non-polar
- Essential (Humans): Yes

Considered essential in humans. Methionine contains sulfur. Produced in small quantities by zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,* and azooxanthellate corals *Tubastrea coccinea*, and *Astrangia poculata*(Fitzgerald and Szmant, 1997.) Requires selenium and zinc for formation.

· Threonine

- Composition: ($C_4H_9NO_3$)
- Shorthand: Thr, or T
- Group: Uncharged, polar
- Essential (Humans): Yes

Considered essential in humans. Not detectable by methods used by Fitzgerald and Szmant, 1997.

The 3-Phosphoglycerate Family

The 3-Phosphoglycerate amino acid family contains cysteine (and hence cysteine), glycine and serine.

· Cysteine

- Composition: ($C_3H_7NO_2S$)
- Shorthand: Cys, or C
- Group: Uncharged or neutral, polar
- Essential (Humans): Conditionally essential

Non-essential in humans, but can become essential in some cases. Cysteine contains sulfur and requires Vitamins B6 and C for formation. Paired cysteines allow disulfide bonds to form. Susceptible to degradation in presence of carbohydrates.

· Cystine

- Composition: ($C_6H_{14}N_2O_4S_2$)
- Essential (Humans): No

Formed by the oxidation of two cysteine molecules.

· Glycine

Composition: ($C_2H_5NO_2$)

- Shorthand: Gly, or G
- Group: Uncharged, polar
- Essential (Humans): Conditionally essential in humans.

· Serine

- Composition: ($C_3H_7NO_3$)
- Shorthand: Ser, or S
- Group: Uncharged or neutral, polar

- Essential (Humans): No

Produced by zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,* and azooxanthellate corals*Tubastrea coccinea*, and *Astrangia poculata* (Fitzgerald and Szmant, 1997.) Non-essential in humans, but can become so in certain cases. Requires choline (a substance related to the B vitamin group) for formation.

Phosphoenolpyruvate and Erythrose 4-Phosphate, or Aromatic Families

This group contains the amino acids (or amino acid-like) phenylalanine, tryptophan, tyrosine, histidine, and ornithine.

The Shikimic Pathway is involved in the production of aromatic amino acids, including mycosporine-like amino acids (MAAs), which provide some protection from ultraviolet radiation. This pathway is not found in animals hence corals receive MAAs from their zooxanthellae, or through consumption of algae or animals that have consumed algae.

· Phenylalanine

- Composition: ($C_9H_{11}NO_2$)
- Shorthand: Phe, or F
- Group: Neutral
- Essential (Humans): Yes

Considered essential in humans. Produced by zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,*and azooxanthellate corals *Tubastrea coccinea*, and *Astrangia poculata* (Fitzgerald and Szmant, 1997.) No feeding response at all*Montastrea cavernosa* (Lehman and Porter, 1973.) Requires Vitamin B6.

· Tryptophan Composition: ($C_{11}H_{12}N_2O_2$)

- Shorthand: Trp, or W
- Group: Hydrophobic, non-polar
- Essential (Humans): Yes

· Tyrosine

- Composition: ($C_9H_{11}NO_3$)
- Shorthand: Tyr, or Y
- Group: Hydrophobic, non-polar
- Essential (Humans): Conditionally essential

Produced by zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,* and azooxanthellate corals*Tubastrea coccinea*, and *Astrangia poculata* (Fitzgerald and Szmant, 1997.) No feeding response at all *Montastrea cavernosa*(Lehman and Porter, 1973.) Vitamin B6 required for synthesis.

· Histidine

- Composition: ($C_6H_9N_3O_2$)
- Shorthand: His, or H
- Group: Basic
- Essential (Humans): Yes

Considered essential for humans. Produced by zooxanthellate corals *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,*and azooxanthellate corals *Tubastrea coccinea*, and *Astrangia poculata* (Fitzgerald and Szmant, 1997.) No feeding response at all*Montastrea cavernosa* (Lehman and Porter, 1973.) Histidine is somewhat of an oddity among amino acids. It is considered by some to be an ancient relic from the evolutionary transition from RNA-based to protein-based life forms.

· Ornithine

- Composition: ($C_5H_{12}N_2O_2$)
- Shorthand: Orn
- Group: Basic
- Essential (Humans): No

Non-essential, but can be under some conditions. Ornithine is an important part of the Urea Cycle. It can be synthesized by some bacteria from L-glutamate.

· Taurine

- Composition: ($C_2H_7NO_3S$)
- Shorthand: Tau

Taurine is a major component in animal tissues although it is not a true amino acid (it lacks a carboxyl group.) The amino acid cysteine is a precursor.

. 天冬氨酸盐

. 化学式:($c_4h_7no_4$)

.简写： Asp 或 D

. 组: 负电荷、极性.

. 是否必需 (人类): 否

天冬氨酸盐可以由天冬氨酸形成。

. ASX 天冬酰胺和天冬氨酸

天冬酰胺和天冬氨酸。

在以下一些和虫黄藻共生的珊瑚 (对应于非虫黄藻珊瑚，非光珊瑚) 中发现: *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,* 在这些无虫黄藻珊瑚中发现: *Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.)

. 肉碱

来源于赖氨酸和甲硫氨酸，在通过线粒体壁运输脂肪酸中起重要作用。也存在于肉类中。

. 赖氨酸

. 化学式:($c_6h_{14}n_2o_2$)

.简写: Lys 或 K

. 组: 疏水性、非极性.

. 是否必需 (人类): 是

. 甲硫氨酸

. 化学式:($c_5h_{12}no_2S$)

.简写: Met 或 M

. 组: 疏水性、非极性.

. 是否必需 (人类) : 是

被认为对人类至关重要。甲硫氨酸含有硫。在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中可以产生（这种氨基酸）：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,*在这些无虫黄藻珊瑚中可以产生（这种氨基酸）：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.) 生物在制造这种氨基酸的过程中需要硒和锌。

. 苏氨酸

. 化学式:($c_4h_9no_3$)

.简写：Thr 或 T

. 组: 不带电荷、极性.

. 是否必需 (人类) : 是

被认为是人类必须的，fitzgerald 和 szmant 使用的方法无法检测到，1997 年。（这两个人做的实验应该是在珊瑚中，也就是这个氨基酸对于珊瑚来说应该也是必须的）

3-磷酸甘油酸家族

4-磷酸甘油酸氨基酸家族包含半胱氨酸(以及胱氨酸)、甘氨酸和丝氨酸。

. 半胱氨酸

. 化学式:($c_3h_7no_2S$)

.简写: Cys 或 C

. 组: 不带电荷或中性，极性

. 是否必需 (人类): 一定条件下必需

对人类来说不是必需的，但在某些情况下可能变得必需。半胱氨酸含有硫，需要维生素 b6 和碳来合成。成对的半胱氨酸由二硫键链接形成。在碳水化合物的存在下易降解。

. 胱氨酸

. 化学式:($c_6h_{14}n_2o_4S_2$)

. 是否必需 (人类): 否

由两个半胱氨酸分子氧化形成。

. 甘氨酸

. 化学式:($c_2h_5no_2$)

.简写: Gly 或 G

. 组: 不带电荷的，极性的

. 是否必需 (人类): 一定条件下必需

. 丝氨酸

. 化学式:($c_3h_7no_3$)

.简写：Ser 或 S

. 组: 不带电荷或中性，极性

. 是否必需(人类): 否

在以下一些和虫黄藻共生的珊瑚(对应于非虫黄藻珊瑚，非光珊瑚)中可以产生（这种氨基酸）：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata,*在这些无虫黄藻珊瑚中可以产生（这种氨基酸）：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata*（*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*）(Fitzgerald and Szmant, 1997.) 对人类来说不是必需的，但在某些情况下会变得必需。需要胆碱(一种与 b 族维生素相关的物质)来形成。（从这里看也就是缺 B 族维生素的时候应该会变成必需）

磷酸烯醇式丙酮酸和赤藓糖-4-磷酸，或芳香族家族

这一组包含氨基酸(或类似氨基酸)苯丙氨酸、色氨酸、酪氨酸、组氨酸和乌氨酸。

芳香氨基酸由莽草酸途径合成，包括类菌胞素蛋白氨基酸(MAAs)，这为防护辐射提供了一些帮助（前面这种类菌胞素蛋白氨基酸被学术界认为是水生生物的一种辐射防护剂），这种莽草酸途径在动物体内没有发现，所以珊瑚是通过它们

的共生虫黄藻、藻类或捕食食用这些藻类的动物来获得这种氨基酸的。(这里可以看到这种氨基酸的来源)

苯丙氨酸

. 化学式:($C_9H_{11}NO_2$)

.简写：Phe 或 F

. 组: 中性

. 是否必需(人类): 是

被认为是人类的必需氨基酸，在以下一些和虫黄藻共生的珊瑚(对应于非虫黄藻珊瑚，非光珊瑚)中可以产生(这种氨基酸): *Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata*, 在这些无虫黄藻珊瑚中可以产生(这种氨基酸): *Tubastrea coccinea*(*筒星珊瑚属 类似太阳花珊瑚*), and *Astrangia poculata*(*后面这个不知道是啥，反正也是一种无共生藻的珊瑚*) (Fitzgerald and Szmant, 1997.) 人类必需氨基酸。在 *Montastrea cavernosa* (一种类似微孔的珊瑚)这种珊瑚中完全不会引起进食反应。(Lehman and Porter, 1973.) 需要维生素 B6 来进行合成。

. 色氨酸

. 化学式:($C_{11}H_{12}N_2O_2$)

.简写：Trp 或 W

. 组: 疏水性、非极性

. 是否必需(人类): 是

. 酪氨酸

. 化学式:($C_9H_{11}NO_3$)

.简写：Tyr 或 y

. 组: 疏水性、非极性

. 是否必需 (人类): 一定条件下必需

在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中可以产生（这种氨基酸）：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata*,在这些无虫黄藻珊瑚中可以产生（这种氨基酸）：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚）*, and *Astrangia poculata（后面这个不知道是啥，反正也是一种无共生藻的珊瑚）*(Fitzgerald and Szmant, 1997.) 人类必需氨基酸。在 *Montastrea cavernosa* （一种类似微孔的珊瑚）这种珊瑚中完全不会引起进食反应。 (Lehman and Porter, 1973.)需要维生素 B6 来进行合成。

组氨酸

. 化学式:($c_6h_9n_3o_2$)

.简写：His 或 H

. 组: 基础组

. 是否必需 (人类): 是

被认为是人类的必需氨基酸，在以下一些和虫黄藻共生的珊瑚（对应于非虫黄藻珊瑚，非光珊瑚）中可以产生（这种氨基酸）：*Montastrea faveolata*, *Acropora cervicornis*, *Porites divaricata*,在这些无虫黄藻珊瑚中可以产生（这种氨基酸）：*Tubastrea coccinea(筒星珊瑚属 类似太阳花珊瑚)*, and *Astrangia poculata（后面这个不知道是啥，反正也是一种无共生藻的珊瑚）*(Fitzgerald and Szmant, 1997.) 人类必需氨基酸。在 *Montastrea cavernosa* （一种类似微孔的珊瑚）这种珊瑚中完全不会引起进食反应。 (Lehman and Porter, 1973.)

组氨酸在氨基酸中有点独特，一些人认为这是从基于 rna 的生命形式进化到基于蛋白质的生命形式的古老遗迹。

鸟氨酸

. 化学式:($c_5h_{12}n_2o_2$)

.简写：Orn

. 组: 基础组

. 是否必需(人类): 否

非必需，但在有些情况下可能变成必需。鸟氨酸是尿素循环的重要组成部分。它可以由一些细菌利用 L-谷氨酸合成。

牛磺酸

. 化学式:($c_2h_7no_3S$)

.简写：Tau

牛磺酸是动物组织中的主要成分，尽管它不是真正的氨基酸(因为它缺少羧基）。半胱氨酸是其合成的前体。

Pathways for Biosynthesis of Amino Acids

Figures 9 and 10 show greatly simplified pathways for synthesis of 20 amino acids.

（这里原文有误，应该是图 10 和图 11）

氨基酸生物合成途径

图 10 和 11 简要的显示了合成 20 种氨基酸的途径。

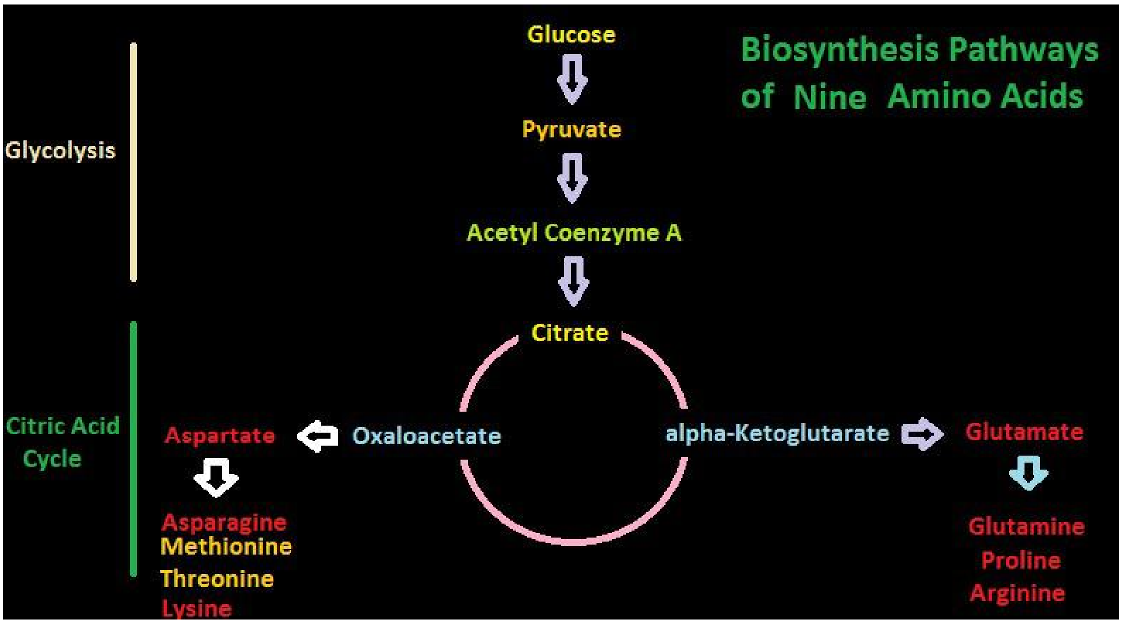


图 10.九种氨基酸的两种生物合成途径——黄色列出的那些氨基酸被认为是氨基酸中必需的。珊瑚也是这样的吗?

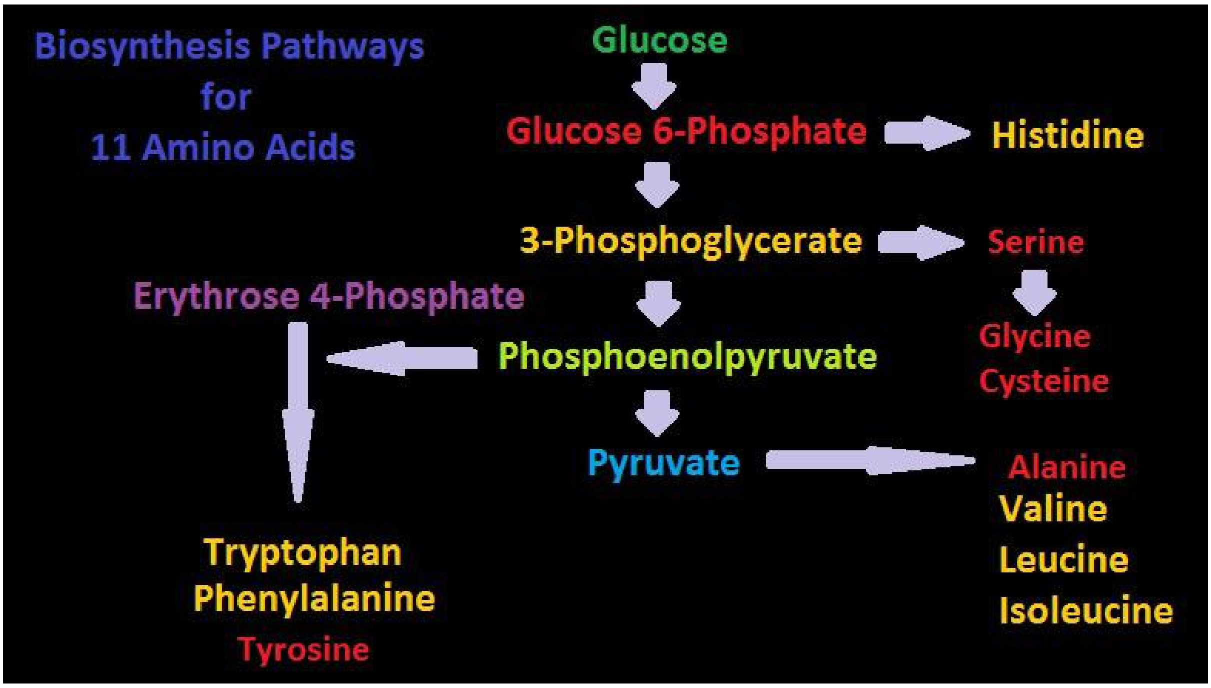


图 11.十一种氨基酸的生产途径。对这方面的研究有助于了解珊瑚的营养需求。黄色的氨基酸被认为是人体必需的。

Amino Acids – Which Ones Do Corals Need?

A little investigation answers this question – corals need all proteinogenic amino acids. If all are needed, then it is the proportions that become important. Figure 12 shows the amino acid content of a fluorescent protein made by the Atlantic stony coral*Montastrea cavernosa*. Figure 13 shows the amino acid content of the organic matrices of Caribbean stony corals *Acropora cervicornis* and *Acropora palmata;* Figure 14 is that of *Porites porites,* while Figure 15 shows AA contents of matrices found in a number of Atlantic marine invertebrates.

Since the coral animal produces these colorful proteins, we can safely assume corals need all amino acids required for building proteins. I'll have much more to say about amino acids and coral coloration in a future article. But which are essential?

氨基酸——珊瑚需要哪些氨基酸？

一项小调查回答了这个问题——珊瑚需要所有的合成蛋白质所需的氨基酸。那么如果所有的都需要，所需的氨基酸比例就变得重要了。图 12 显示了一种大西洋石珊瑚 Montastrea cavernosa. 制造的荧光蛋白中各种氨基酸的含量。图 13 显示了产自加勒比海的石珊瑚 Acropora cervicornis and Acropora palmata 中有机基质的各种氨基酸的含量；图 14 显示的是 porites（一种石珊瑚）的氨基酸含量，而图 15 显示的是一些产自大西洋的海洋无脊椎动物体内的氨基酸含量。

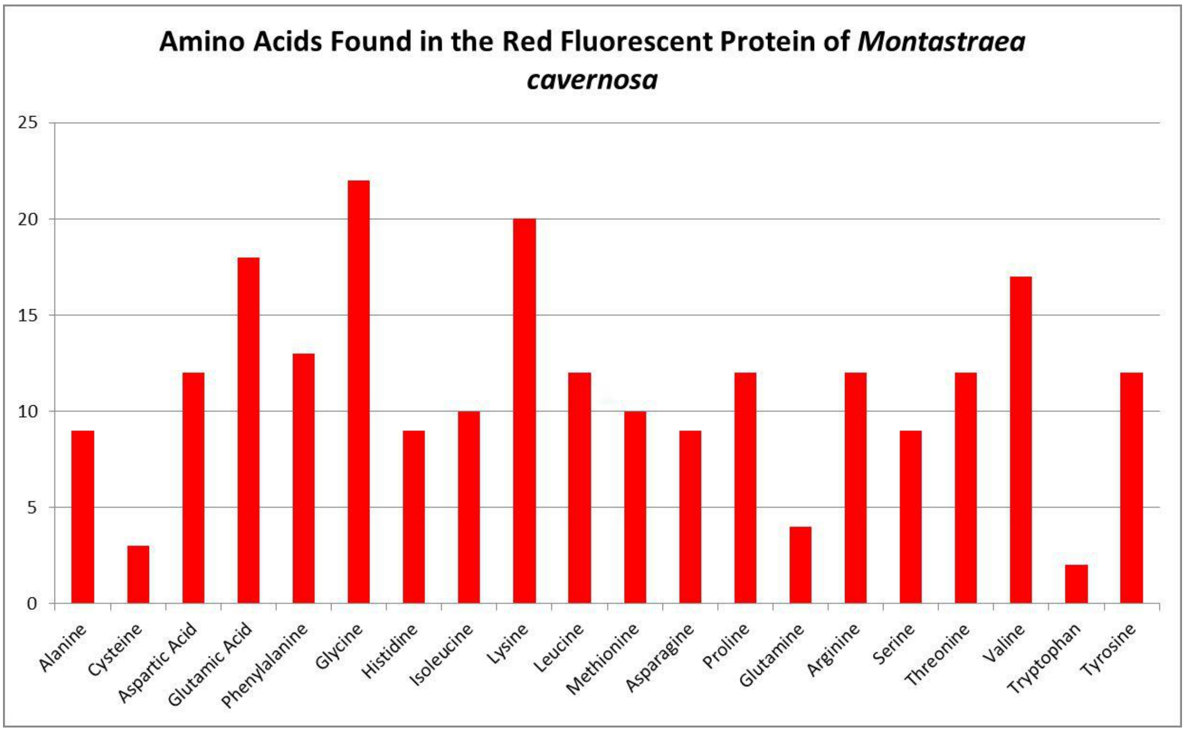


图 12.这种荧光蛋白的遗传密码(我觉得这里应该就是荧光蛋白组成，不应该是遗传密码，但是原文确实是 genetic）包含 20 个氨基酸。chalfie 和 kain，2006 年。

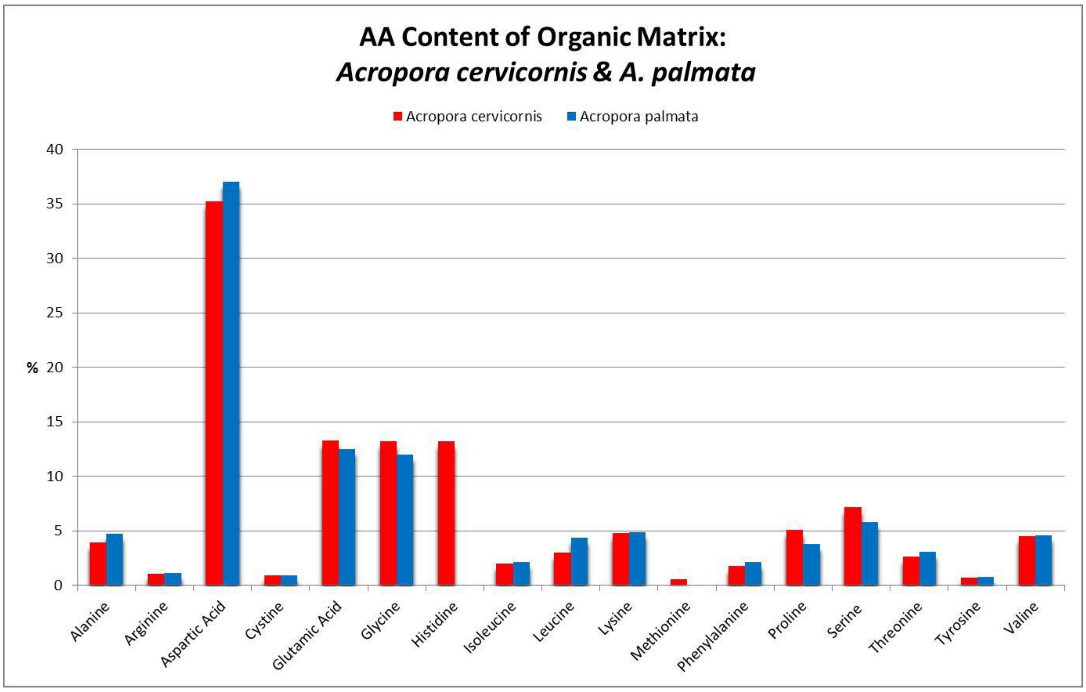


图 13 注意氨基酸在两种珊瑚基质组成中的差异——*Acropora palmata* 缺乏组氨酸和甲硫氨酸。

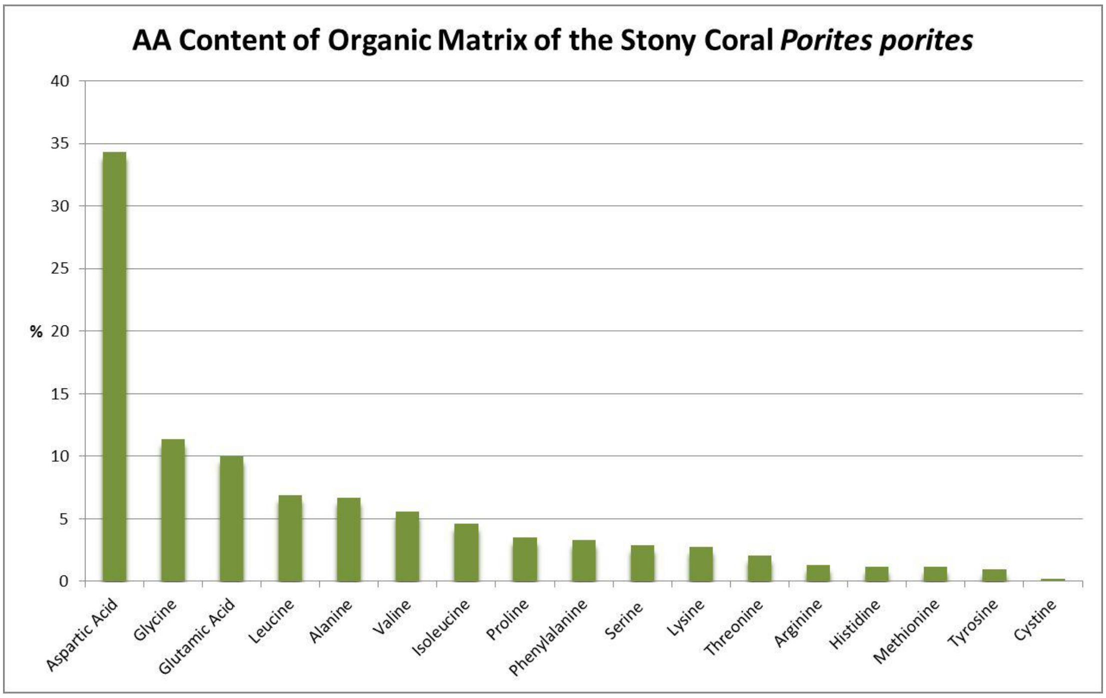


图 14.这种趋势还在继续(不同珊瑚组织中氨基酸组成的差异）。天冬氨酸是加勒比海 porites（一种石珊瑚）中最常见的氨基酸。

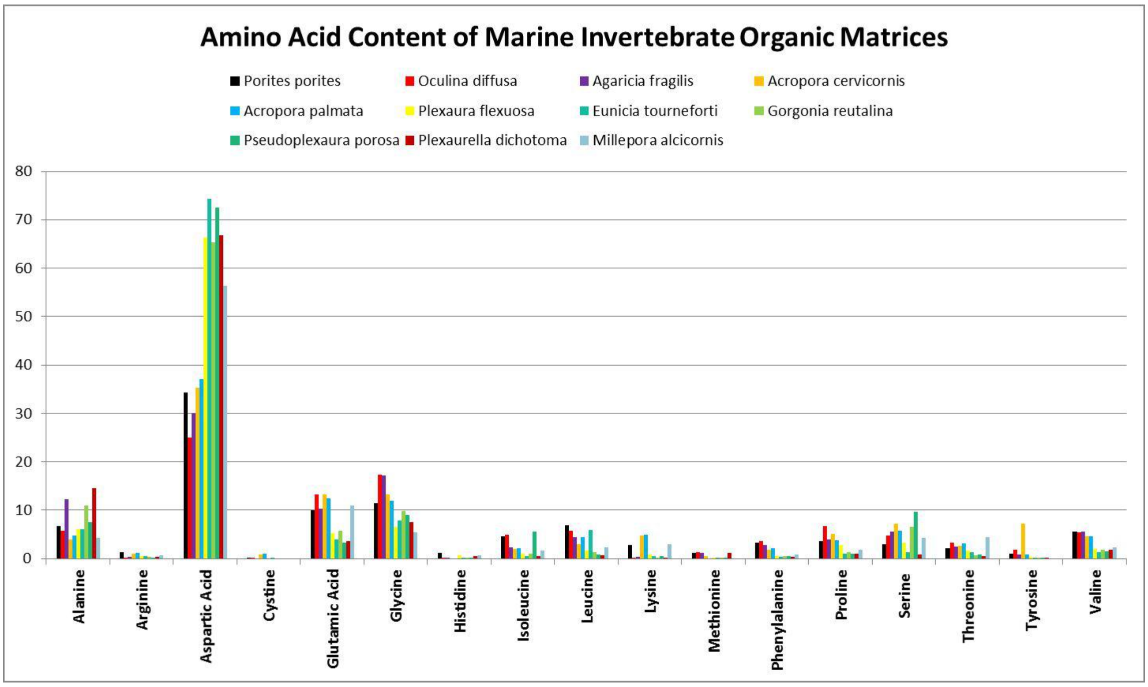


图 15 天冬氨酸是所有测试的珊瑚有机基质中含量最丰富的氨基酸，很明显，它不是必需氨基酸。

由于珊瑚产生这些色彩丰富的蛋白质，我们可以大胆地假设珊瑚需要构建蛋白质所需的所有氨基酸。在未来的文章中，我会对氨基酸和珊瑚颜色之间的关系有更多的论述。但是哪些方面是必要的呢？

A Glance at Amino Acid Requirements of Two Fishes

Although this article will attempt to mesh together pieces of the puzzle as to which amino acids are 'essential' to cnidarians, much research is needed before the picture is complete. It would be easy to assume those amino acids considered essential to Homo sapiens would be the same for another animal, such as, say, Acropora millepora. Unfortunately, such is not the case. Study of various research papers reveals that amino acid requirements are species specific.

As an example, Figure 16 shows the amino acid requirements of two fishes – the Chinook Salmon requires two amino acids (cystine/cysteine and tyrosine) that the Common Carp does not.

两种鱼的氨基酸需求一瞥

尽管这篇文章将试图把关于哪些氨基酸对刺胞动物“至关重要”的谜题拼凑起来，但在这幅拼图完成之前，还需要做大量的研究。很容易假设那些被认为对人类来说至关重要的氨基酸对另一种动物来说也是一样的，比如说，Acropora millepora（鹿角珊瑚）。然而不幸的是，情况并非如此。各种研究结果表明，氨基酸需求因物种而异。

例如，图 16 显示了两种鱼的氨基酸需求——大鳞大马哈鱼（哈哈鲑鳟鱼可是我硕士的研究方向。。）需要两种氨基酸(胱氨酸/半胱氨酸和酪氨酸)，而普通鲤鱼不需要。

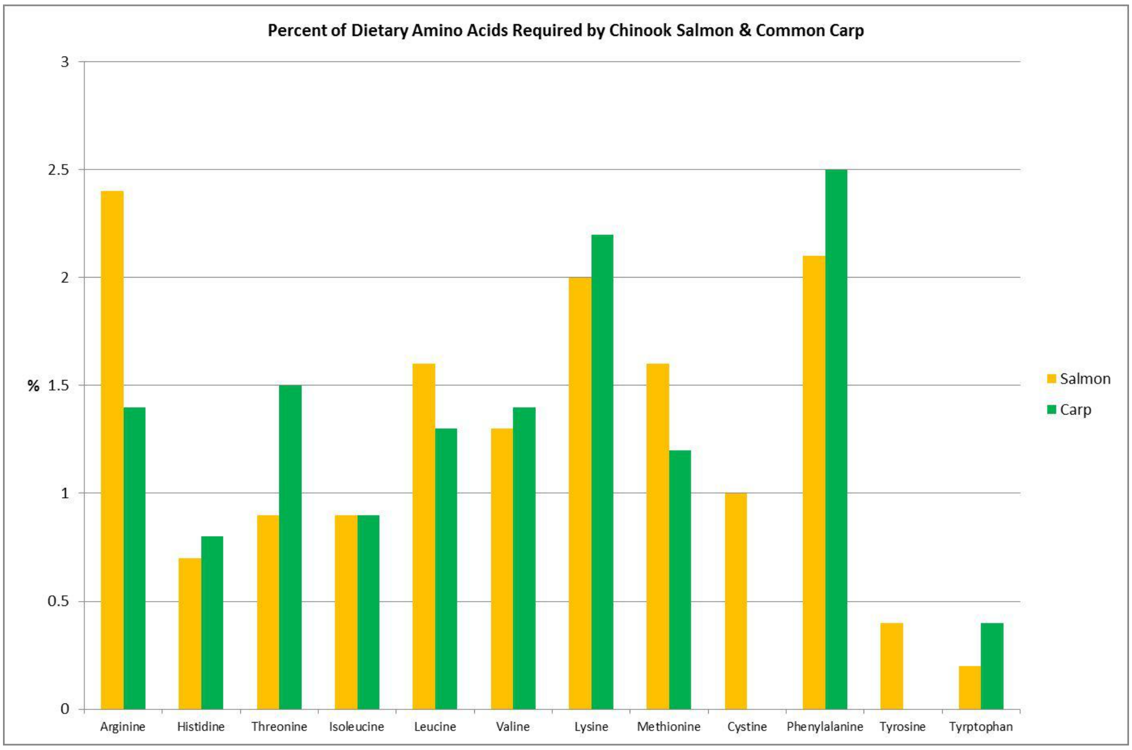


图 16.这两种鱼都需要大约 40%的蛋白质,这些是它们必需的氨基酸。来自 Spotte，1992 年。

Synthesis by Zooxanthellae

Nature loves to confound us, and the symbiotic relationship between Symbiodinium species/clades and the coral animal and the nutritional implications is a good example.

虫黄藻合成

大自然喜欢让我们困惑， 虫黄藻等共生物种和珊瑚之间的

共生关系以及营养的关系就是一个很好的例子。

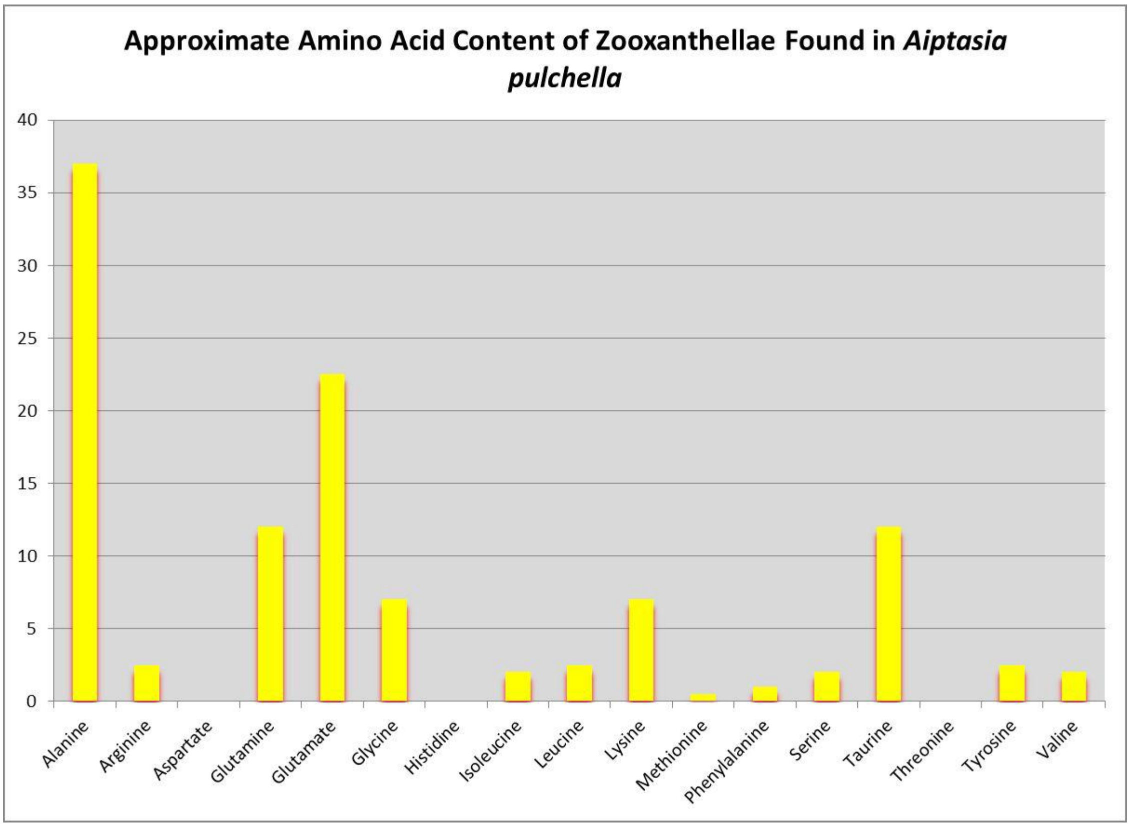


图 17 难怪虫黄藻会将丙氨酸转移到它们的宿主身上.虫黄藻的一种分支藻种类似于 b 或 b1（这后面一句我没理解啥意思）

Translocation of Photosynthetic Products

As we know, Symbiodinium (zooxanthellae) are considered primary producers, hence they can produce all their nutritional needs given proper conditions. Symbiotic zooxanthellae are known to be ‘leaky’ with some of the substances they produce. Figure 18 shows those substances shared (translocated) by zooxanthellae with its Atlantic coral host Acropora cervicornis. Most of the translocated product is lipid (81%), while two neutral amino acids (alanine and glutamine) stand at 1% and 2%, respectively.

光合作用产物的转移

众所周知，珊瑚的共生体(虫黄藻)被认为是主要的生产者，如果条件适宜，它们可以生产并提供它们所有的营养需求。众所周知，共生的虫黄藻会“泄漏”它们产生的一些物质。（这在讲虫黄藻的部分透露过），图 18 显示了虫黄藻与其大西洋的珊瑚宿主 acropora cervicornis（珊瑚名）共享(转运)的物质。大多数转运产物是脂质(81%)，而两种中性氨基酸(丙氨酸和谷氨酰胺)分别占 1%和 2%。

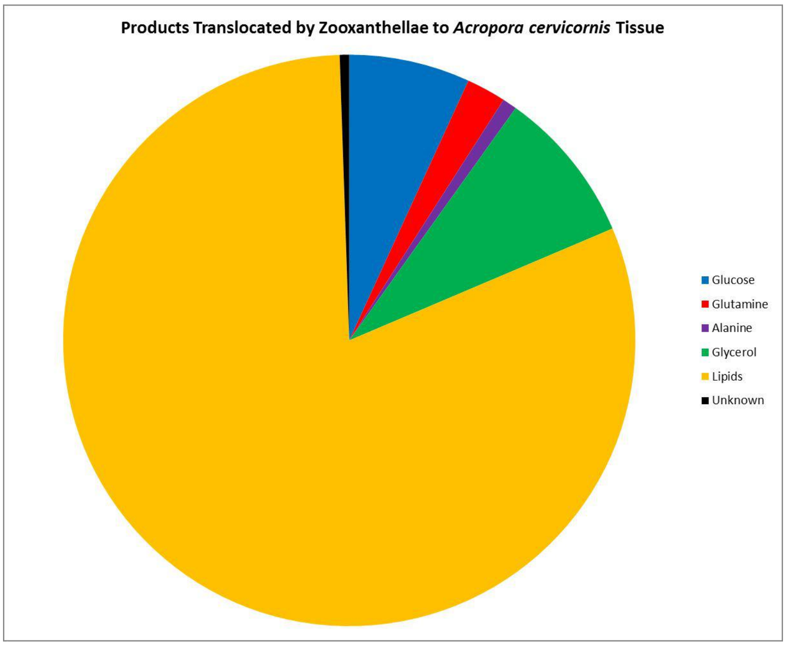


图 18 虫黄藻可能与其宿主珊瑚共享这些有机化合物。

Synthesis of Amino Acids by Cnidarians

Before reviewing some of the works on amino acid synthesis by corals, we should remember that bacteria can produce all amino acids. While researchers have taken steps to suppress bacterial activity in or on corals using antibiotics and aggressive rinsing, some bacteria undoubtedly remain, raising the possibility that they are the producers and not the cnidarian host. Still, this would be important, as production of amino acids by bacteria and translocation to the coral host could be an important source of nutrition.

Wang and Douglas (1999) found the anemone Aiptasia pulchella produce amino acids generally considered to be essential for animals – methionine and threonine.

中枢神经系统合成氨基酸

在回顾珊瑚合成氨基酸的工作之前，我们应该记住细菌可以产生所有的氨基酸。尽管研究人员已经采取措施，使用抗生素和强力冲洗来抑制珊瑚内部或表面的细菌活动，但一些细菌无疑仍然存在，这增加了它们是独立的生产者而不是珊瑚宿主的可能性。尽管如此，这仍然是重要的，因为细菌产生氨基酸并转移到

珊瑚体内----这可能是珊瑚一个重要的营养来源。

wang 和 douglas (1999)发现 *Aiptasia pulchella*（一种珊瑚）产生通常被认为是动物必需的氨基酸——蛋氨酸和苏氨酸(动物必需的也就是说动物一般不能自身产生的，这种珊瑚能生产，结合上下文，也就是说研究者推测这有可能是细菌产生的转移到了珊瑚体内)

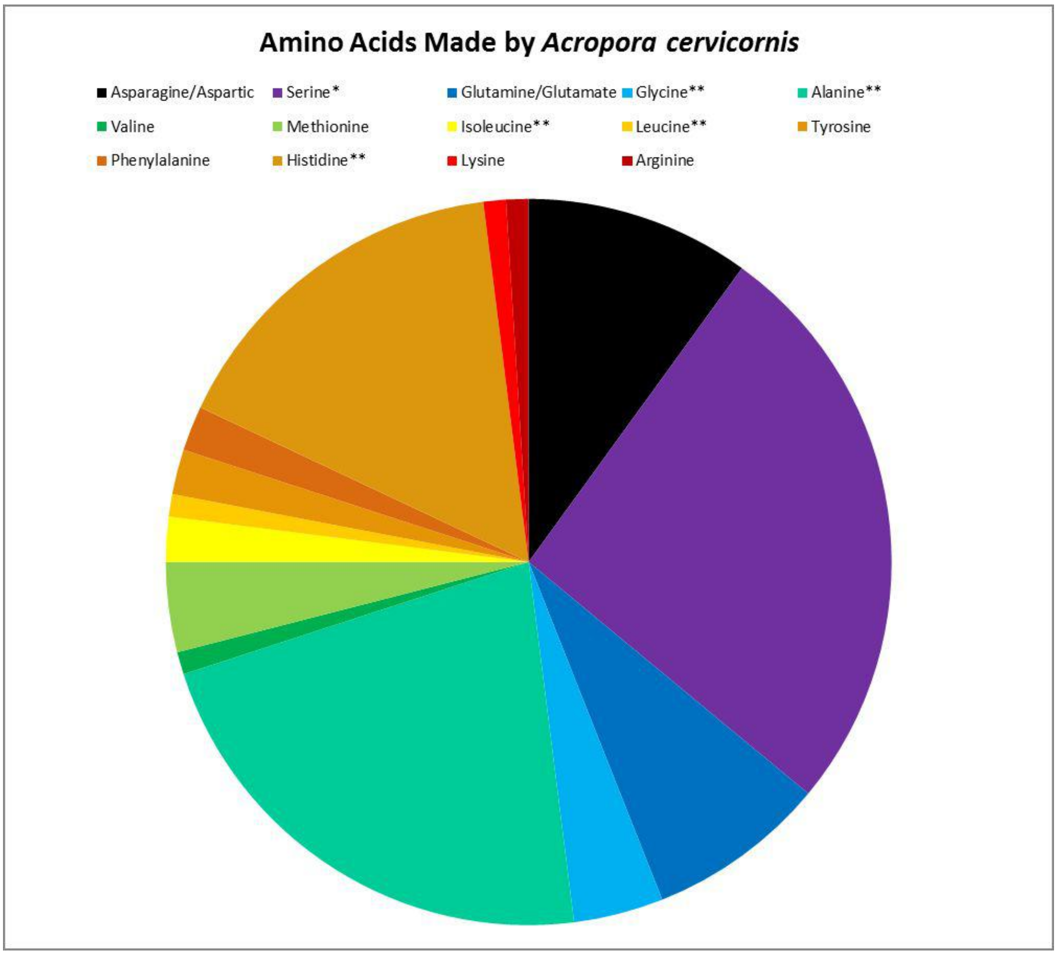


图 19。大西洋珊瑚 *Acropora cervicornis*.合成的蛋白质氨基酸。** =不是细菌合成。* =（合成能力）可能被低估。实验所用的方法不能检测色氨酸和半胱氨酸。（也就是说）毫无

疑问，这种珊瑚真正能产生的氨基酸比测试中显示的要多。

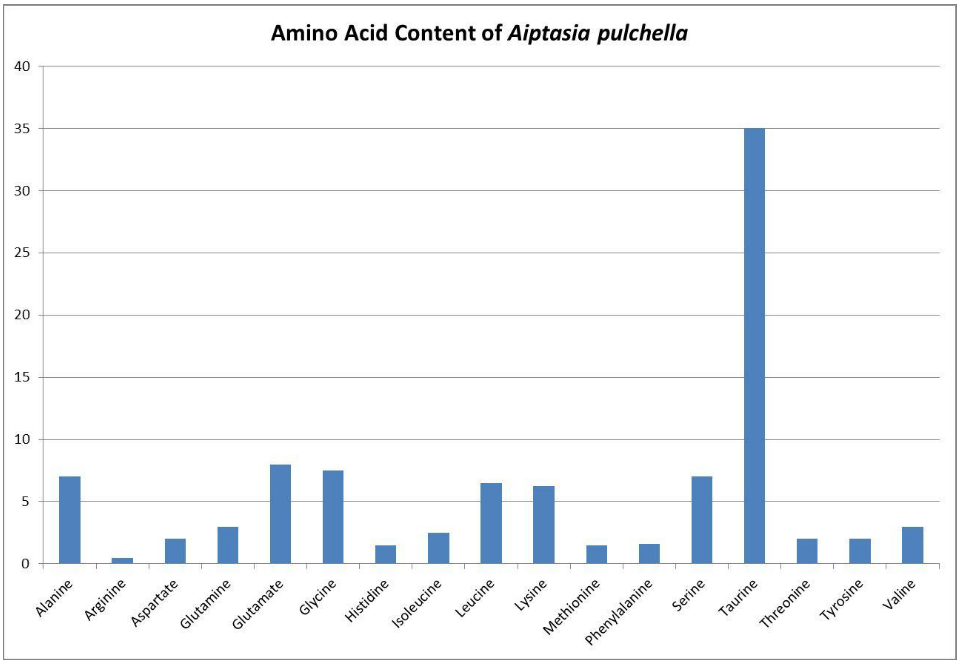


图 20 Aiptasia（一种珊瑚）组织中氨基酸的含量

Uptake of Amino Acids by Marine Invertebrates

Once we have an idea of which amino acids are produced by zooxanthellae and by the host, we can look at another method marine animals obtain them – diffused and carrier mediated transport.

海洋无脊椎动物对氨基酸的吸收

一旦我们知道了哪些氨基酸是由虫黄藻和宿主产生的，我们就可以研究海洋动物获取它们的另一种方法——扩散和载体介导的运输（载体运输，细菌和其他被珊瑚能捕食的生物都能成为这个载体）。

Dissolved Amino Acids

Generally, amino acids dissolved in water can exist in two forms: *Combined* and *Free*.

溶解氨基酸

一般来说，溶解在水中的氨基酸可以以两种形式存在：化合态和游离态。

Dissolved Combined Amino Acids (DCAA)

Amino acids can be adsorbed to humic and fulvic acids (major substances of soil resulting from decaying organic matter), clay particles and other substances. These are known as dissolved *combined* amino acids.

溶解的化合态氨基酸

氨基酸可以被吸附到腐殖酸和富里酸(土壤中由腐烂的有机物产生的主要物质)、粘土颗粒和其他物质上。这些被称为溶解的

化合态氨基酸。

Dissolved Free Amino Acids (DFAA)

Discrete amino acids (those not adsorbed to other substances) that are dissolved in the water column are known as *free* amino acids. Grover et al. (2008) report oligotrophic Mediterranean seawater contains 0.11 to 0.37 µMol/L DFAA as N, with an average of 0.24 µMol/L, or about 0.003 mg/L as Nitrogen. Figure 20（这里原文有点问题，应该是图 21） shows DFAA concentrations from various locations.

溶解的游离态氨基酸

溶解在海水中的氨基酸(不被其他物质吸附的氨基酸)称为游离态氨基酸。grover 等人(2008 年)报告称，营养较为贫瘠的地中海海水中含有 0.11 至 0.37 微摩尔/升的游离氨基酸，平均含量为 0.24 微摩尔/升，也就是大约 0.003 毫克/升。图 21 显示了不同位置的游离氨基酸浓度。

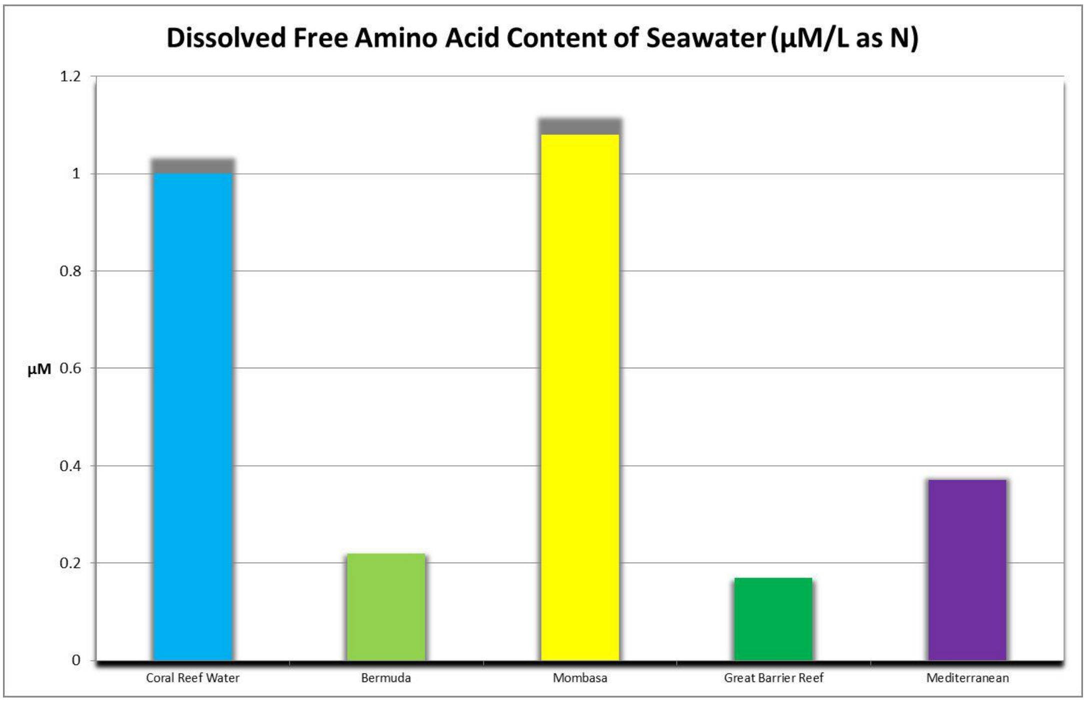


图 21　不同地点海水的氨基酸含量（可以看到，珊瑚礁海域氨基酸含量比较高，第三个蒙巴萨区域也是珊瑚礁区）

Importance of Water Motion

Astute readers will recognize a common thread throughout these articles – that of water velocity. Water velocity controls the thickness of the boundary layer (the higher the water flow across the coral, the thinner the layer of stagnant water – the boundary layer – surrounding the coral.) This is importance as diffusion of substances (such as ammonia/ammonium and dissolved amino acids – good sources of nitrogen so the coral can build proteins) is hampered by poor water flow and a thick boundary layer. Perhaps more importantly, corals can sense water velocity and hence control expansion. If water velocity is too low, the coral will retract it polyps since the energy required to keep the polyp expanded is greater than the energy supplied by food capture. Not surprisingly, food capture rates are finely tuned to water flow rates (see Riddle, 2014 for details.) On the other hand, polyps are retracted when water velocity is too great and they are in danger of being damaged. Water velocity is sufficient when coral polyps look fields of grain rippling in a gentle breeze.

水流的重要性（**这一段的思想几乎贯穿整个珊瑚营养系列文章，这也是我个人推崇高流的原因，动量边界层，流速，我感觉现在很多 sps 玩家缸里的流还是偏低的原因**）

聪明的读者会认识到贯穿这些文章的一个共同线索——水流速度。水流速度控制着动量边界层的厚度(穿过珊瑚的水流越高，珊瑚周围的死水层(边界层)就越薄。)这一点很重要，因为水流不畅和厚厚的边界层阻碍了物质(如氨/铵和溶解的氨基酸——良好的氮源，这是珊瑚制造蛋白质的原材料)的扩散。也许更重要的是，珊瑚可以感知水流速度，从而控制扩张。如果水流速度太低，珊瑚会将珊瑚虫缩回，因为保持珊瑚虫膨胀所需的能量大于食物捕获所提供的能量。（这个我始终觉得人为根据现象推测的成分居多）。食物捕捉率与水的流速密切相关(详情见里德尔，2014 年)。)另一方面，当水流速度过大时，息肉会缩回，有被损坏的危险。（这就是所谓流过大，其实流过大造成的损伤一两天之内就能在我们的鱼缸中体现出来，很快留过大那一块就会脱掉，然后流恢复以后又会长回来，这给 sps 玩家一个很好的提示，可以让流大一些，因为如果流太大了，很快你就会发现，而如果流小了，动量边界层过厚，珊瑚得不到营养慢慢死亡，可能有时候你都不知道是什么原因造成的。）当珊瑚虫的摆动看起来像风吹动一片片涟漪的时候，水流速度就足够了。（这句话其

实更抽象，感觉然并卵。。）

Uptake of Amino Acids – Active Transport or Diffusional Transport?

Do corals selectively transport dissolved amino acids as opposed to simple diffusion transport? The answer is yes, at least in the case of the stony coral *Galaxea fascicularis* (Al-Moghrabi et al., 1992.) This coral expends energy to selectively consume neutral amino acids.

Neutral Amino Acids – Some Corals Uptake These Preferentially:

- Alanine
- Glycine
- Isoleucine
- Leucine
- Methionine
- Phenylalanine
- Proline
- Tryptophan
- Valine

We can remember these using this rather amusing mnemonic: GAV LIMP TP, or a guy named GAVin LIMPs because he has Toilet Paper on his shoe.

氨基酸摄取——主动吸收还是被动扩散转运？

珊瑚选择性地吸收溶解的氨基酸，而不是简单的、无差别的扩散运输吗？答案是肯定的，至少对于 *Galaxea fascicularis*（这好像是一种类似于波罗丁的珊瑚）的情况下是这样(al-moghrabi 等人，1992 年)。这种珊瑚通过消耗能量来选择性地吸收中性氨基酸。

（我觉得关于这个合理的推论应该是大部分的珊瑚应该都是如此，作为一种动物如果连吃啥都没有一点选择性是不是也太没有排面了）

中性氨基酸--一些珊瑚优先吸收这些氨基酸

. 丙氨酸

. 甘氨酸

. 异亮氨酸

. 亮氨酸

. 甲硫氨酸

. 苯丙氨酸

. 脯氨酸

. 色氨酸

. 缬氨酸

我们可以用这个相当有趣的技巧来记住这些氨基酸：gav limp tp，或者一个叫 gavin limps 的家伙，因为他的鞋子上有卫生纸。（可惜不考这个，搞得像上课一样，还快速记住。。。）

How Does Selective Amino Acid Uptake Work?

Many aquatic animals selectively consume dissolved substances via a process called Carrier Mediated Transport. This mechanism allows consumption of larger molecular substances, as opposed to smaller molecules such as oxygen, carbon dioxide, etc. which can pass through a membrane with relative ease.

The ‘carrier’ is a protein with an affinity for a certain substance, and has two openings, although only one might be open at a time. The carrier acts as a gateway for a substance to cross a membrane. See Figure 22 represents how an amino acid moves from extracellular fluid to inside a cell. To the right in the diagram, the carrier’s ‘door’ to extracellular fluid is open, and a specific amino acid (or type of amino acid) is attracted and enters. Once inside, the carrier’s door closes. In step 3, the door to the inside of the cell has opened, and the amino acid has successfully migrated across the cell’s membrane.

（水生动物的）选择性氨基酸摄取是如何工作的

许多水生动物通过一种叫做载体介导的运输过程选择性地消耗溶解的物质（看图很容易理解，载体就像一双手一样，选择性抓取氨基酸然后运输到有机体内）。

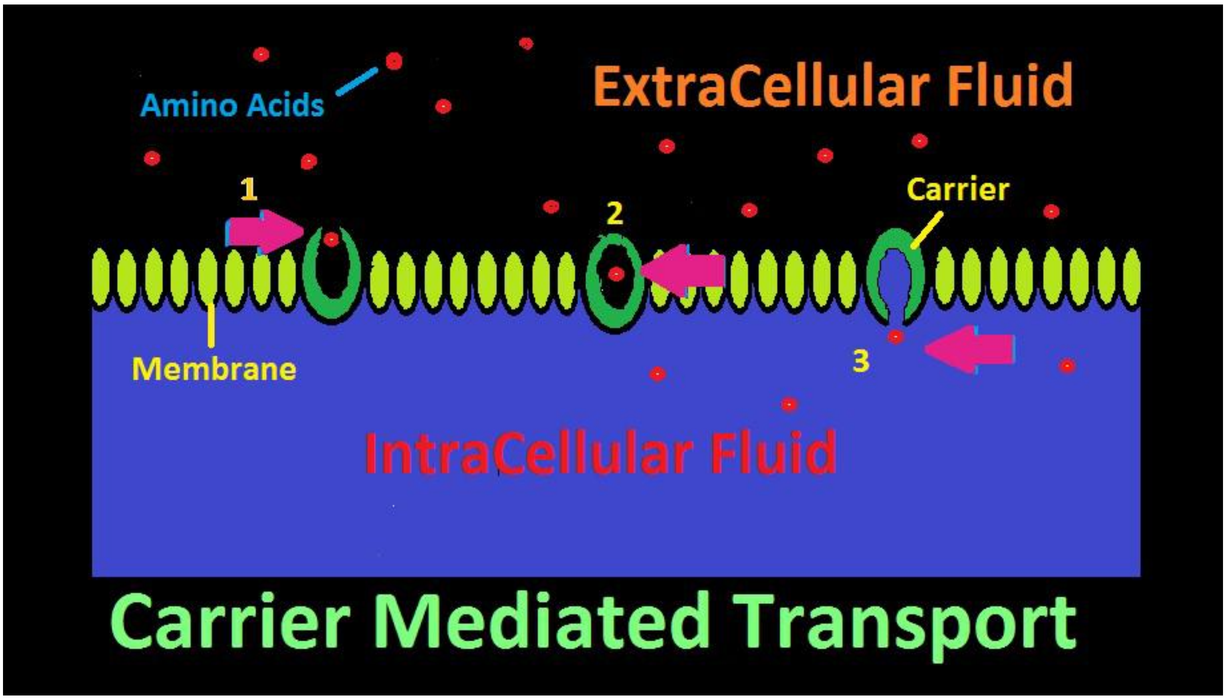


图 22. 载体介导的运输, 在这幅图中，氨基酸被选择性地运输通过生物膜。

这种机制允许消耗较大的分子物质，而不是较小的分子，

如氧气、二氧化碳等，这些较大的分子物质（如氨基酸）可以相对容易地穿过膜。

“载体”是一种对某种物质（如氨基酸）有亲和力的蛋白质，有两个开口，尽管一次可能只开一个开口，“载体”充当物质穿过膜的通道。如图 22 所示，我们可以看到氨基酸是如何从细胞外液转移到细胞内的（通过“载体”的运输）。在图的右边，载体通向细胞外液的“门”是打开的，一种特定的氨基酸(或一类氨基酸)被吸引并进入。一旦进入，运载工具的门就会关闭。在第三步中，细胞内部的门已经打开，氨基酸已经成功地穿过细胞膜。

Uptake of Free Amino Acids

A number of studies have examined the uptake of free amino acids by corals. This is potentially a decent source of nitrogen scarce in ogliotrophic environments for some corals (Figures 23 and 24), but not for *Tridacna* clams (Figure 25.) By extension, we might consider free AA's a poor source of nitrogen in fleshy stony corals.

有许多关于珊瑚对游离氨基酸吸收的研究。对于一些珊瑚来说，这是一种潜在的营养丰富的氮源(图 23 和 24)，但对于砗磲来说则不然(图 25)。)推而广之，我们可能会认为游离氨基酸是石珊瑚氮源不足时候的氮源来源（这句翻译有点别扭，字面翻译是石珊瑚的不良氮源，但是明显上下文逻辑不通，大概我认为应该是这个意思）。

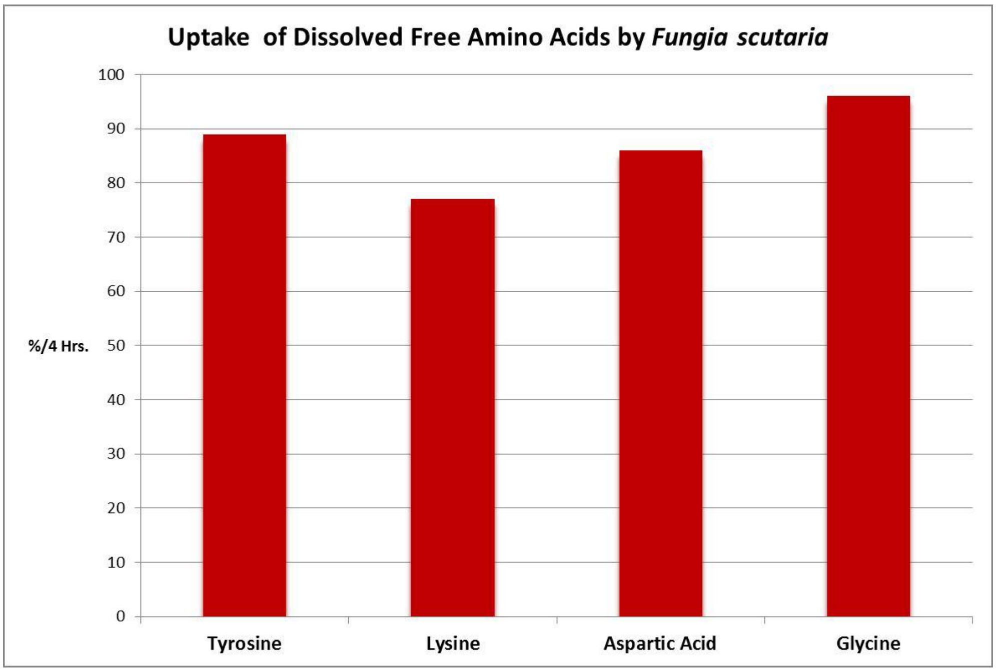


图 23 Fungia scutaria（一种石珊瑚）能够从水中吸收游离氨基酸。其中，酪氨酸、赖氨酸和甘氨酸是中性氨基酸，天冬氨酸是酸性氨基酸。

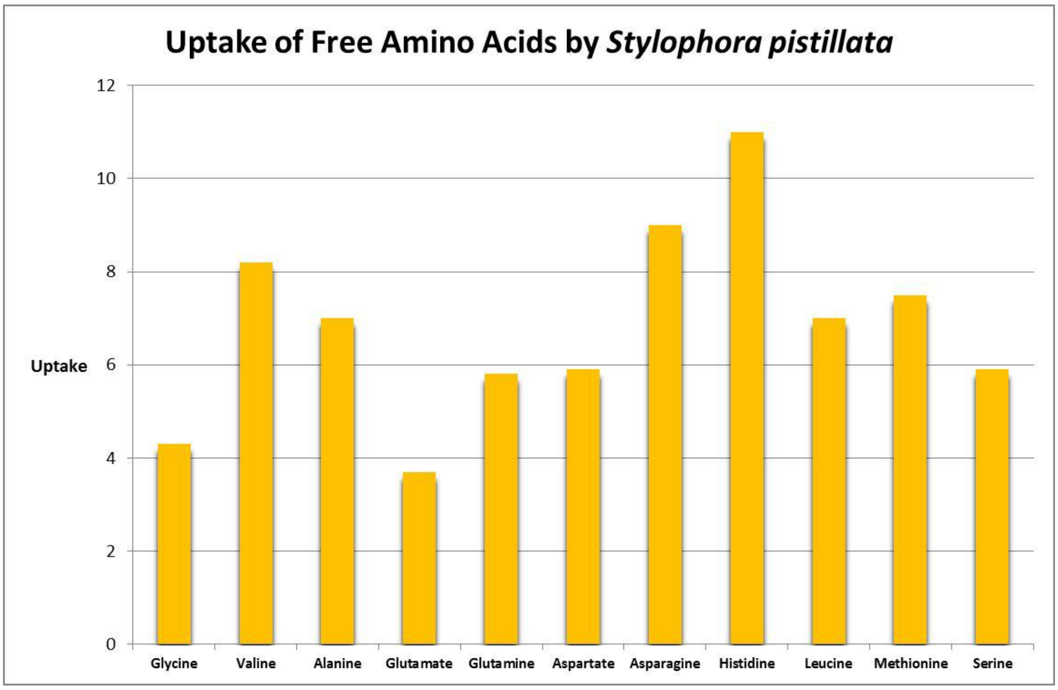


图 24 这种石珊瑚吸收组氨酸吸收得最多（Grover 等人，2008 年）

Effects of Light Intensity on Uptake of Free Amino Acids

Light intensities influence DFAA uptake in the stony corals *Heliofungia actiniformis* (Baker, 1994) and Pocillopora damicornis(Moreno & Hoegh-Guldberg, in Ambariyanto and Hoegh-Guldberg, 1999.) Lower uptake in light thought to be due to relatively high concentrations of amino acids translocated from zooxanthellae to the host.

Ambariyanto and Hoegh-Guldberg (1999) found that the giant clam *Tridacna maxima* aborbs 16 amino acids. Interesting, a chart in this work states there is no uptake of methionine in high light conditions (1,000 – 1,300 µmolm²sec), but there is during periods of darkness. The highest uptake across the 4 conditions of these tests was arginine, while the lowest was histidine. Initial amino acid concentrations were 0.4 µM. (I think the chart in this work may be incorrect due to the absence of uptake of methionine, but approximate concentrations from that work are shown in Figure 25.) The researchers concluded that the uptake of AAs by this clam is not a significant source of nitrogen.

光照强度影响 *Heliofungia actiniformis*（一种石珊瑚）(贝克，1994年)和 Pocillopora damicornis（一种石珊瑚）(莫雷诺&霍格-古德伯格，安巴里扬托和霍格-古德伯格,1999 年)对溶解游离氨基酸(DFAA)的吸收。较低的光吸收被认为是由于相对高浓度的氨基酸从虫黄藻转移到宿主。（宿主即是珊瑚或者砗磲这些有共生藻的蚌类本身，珊瑚本身吸收氨基酸较多的话其从光照中获得的能量要稍少一些，这应该符合我们的一般认知）

Ambariyanto 和 Hoegh-Guldberg(1999 年)发现，巨蛤能摄取 16 种氨基酸。有趣的是，图表显示，在强光条件下(1000-1300 摩尔/秒)，没有蛋氨酸的摄入，但在黑暗条件下却会摄取蛋氨酸。在这个试验的 4 种条件下，摄取量最高的是精氨酸，而摄取量最低的是组氨酸。最初的氨基酸浓度是 0.4um(我认为这项工作中

的图表可能是不正确的，因为缺乏蛋氨酸的摄入，但该项工作的近似浓度显示在图 25 中。）研究人员得出结论，这种巨蛤对氨基酸的吸收并不是氮的重要来源。

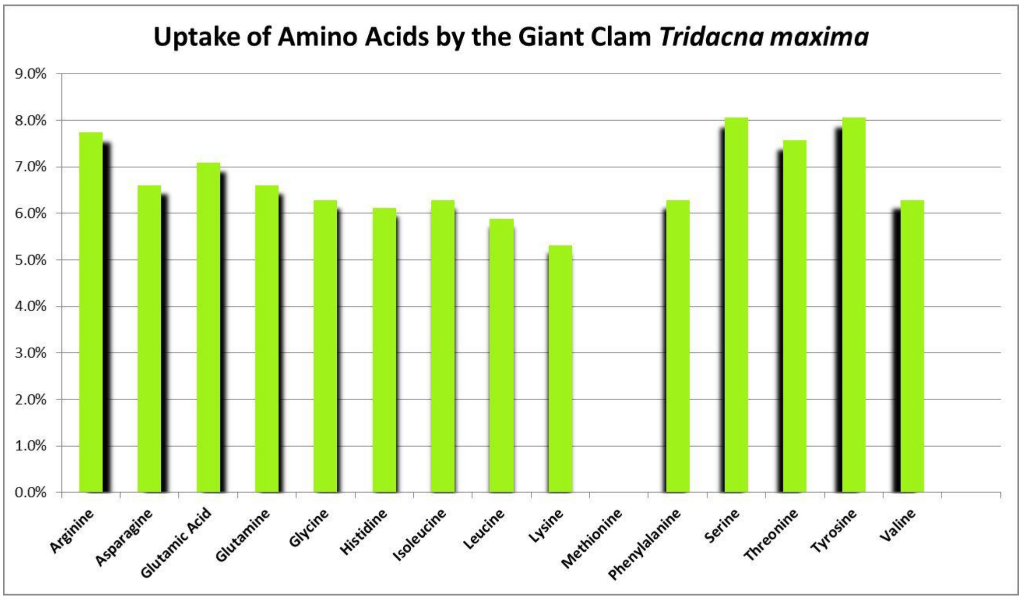


图 25 巨蛤对游离氨基酸的吸收 （格罗弗等人，2008 年）

Feeding Activators

Feeding activators are those substances that produce a feeding response (ingestion.) These experiments are easily performed. Small squares of Whatman filter paper are soaked in dilute solutions of amino acids and placed on the oral disk or near the mouth(s) of corals (a photo of a *Goniopora* specimen ingesting such a small bit of AA-soaked lab paper is at the introduction of this article). Feeding activators are shown in Figures 26 and 27.

摄食激活剂（**这里说的是氨基酸是一种摄食激活剂，然后所以说我们喂食氨基酸的时候也加一些其他珊瑚粮**）

摄食激活剂是促使珊瑚产生摄食反应的物质。这些实验（要验证这一物质的实验）很容易进行，将一小片方形的沃特曼滤纸（一种滤纸品牌）浸泡在氨基酸的稀溶液中，放在珊瑚口器的上方或靠近珊瑚口器的地方(这篇文章的引言部分有一张珊瑚在靠近少量的浸泡过氨基酸的滤纸下的照片)。各种氨基酸对摄食反应的诱发程度如图 26 和 27 所示。（这个图显示了这种 M 属的珊瑚在各种氨基酸下面的摄食反应的程度，如果有很多种珊瑚的该图表就好了，或许可以给 DIY 自制氨基酸添加剂提供指导。。😄。。）

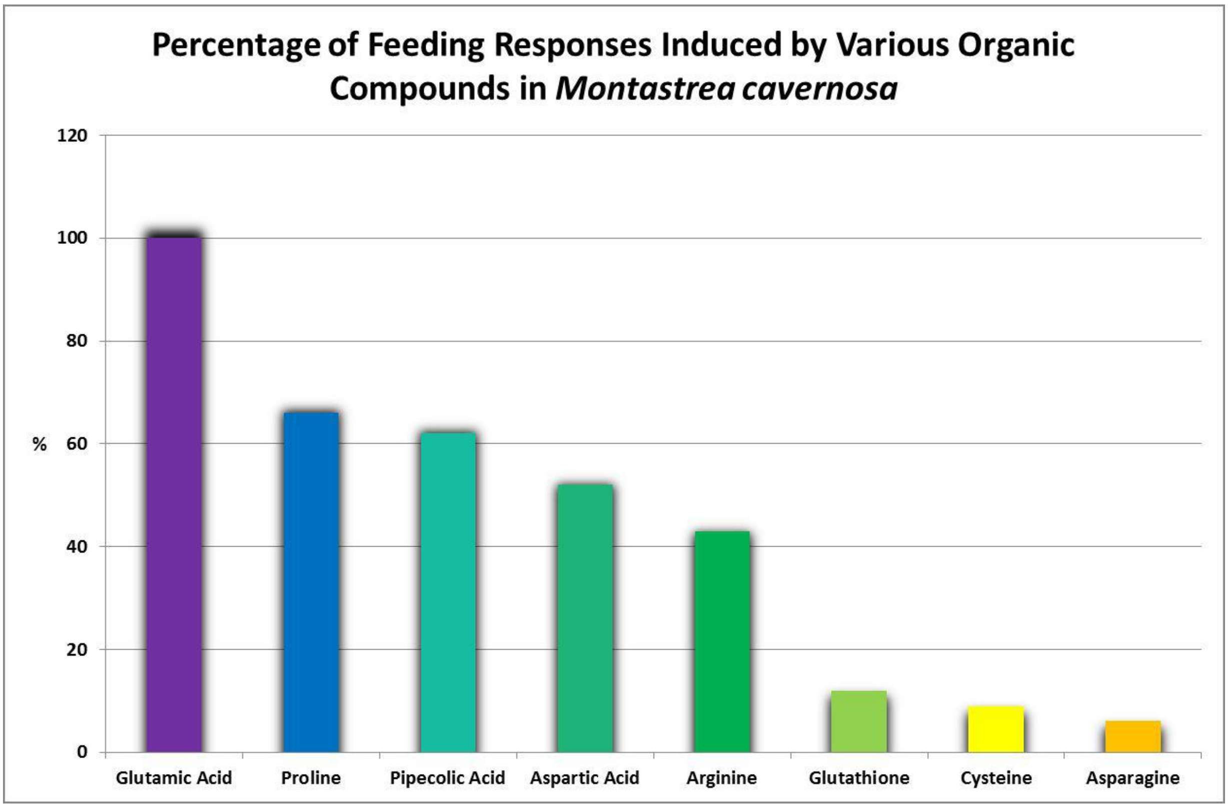


图 26 奇怪的是，这些（能诱发珊瑚摄食反应的）氨基酸没有一种被认为是人类必需的。这项工作是在其他研究人员研究珊瑚对氨基酸需求之前几年完成的

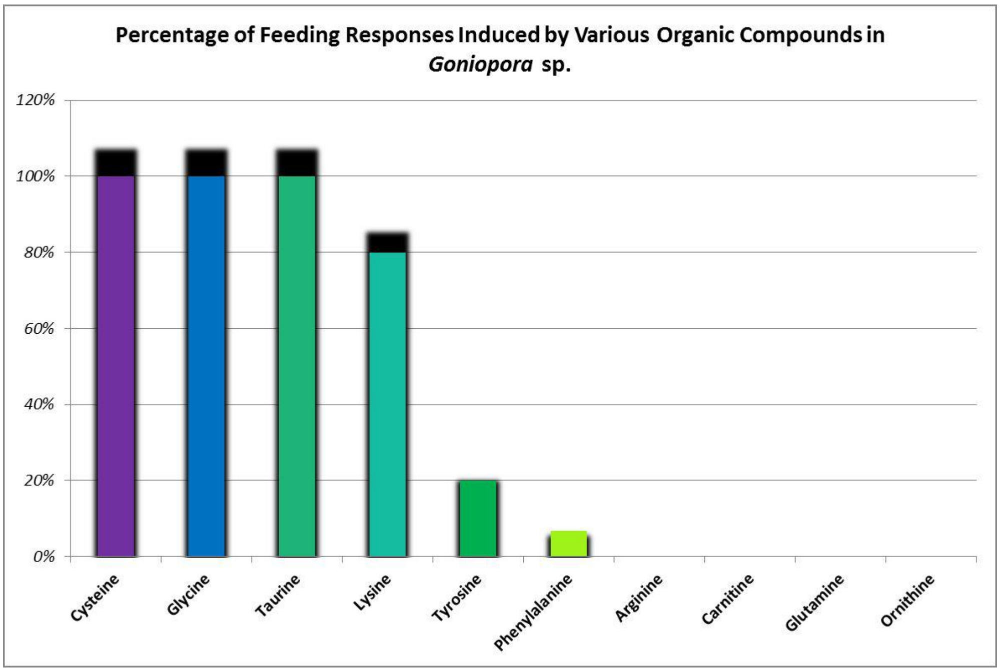


图 27 Goniopora（一种珊瑚）的进食反应。A Catalaphyllia (Elegance coral))（一种珊瑚）对甘氨酸、赖氨酸和牛磺酸有类似的反应，见下文，来自 Riddle，1994。

Feeding Activators
in *Catalaphyllia jardinei*

Glycine, lysine, and taurine produced a feeding response in this coral (ingestion of paper squares soaked in various amino acids.) Although cysteine-soaked paper was ingested by *Goniopora*, it was not so with *Catalaphyllia*. Arginine, carnitine, cysteine, glutamine, ornithine, phenylalanine, tyrosine produced no feeding response. Ingestion of an amino acid is not necessarily a positive thing. Paper squares soaked in glycine were discharged from this coral's mouths along with hundreds of small, dark particles. These were not examined, but it is possible these were coalesced zooxanthellae.

Other experiments have used different substances. For example, sugars (glucose, fructose, and sucrose) produced no response in *Montastrea cavernosa*.

尼罗河珊瑚的摄食激活剂

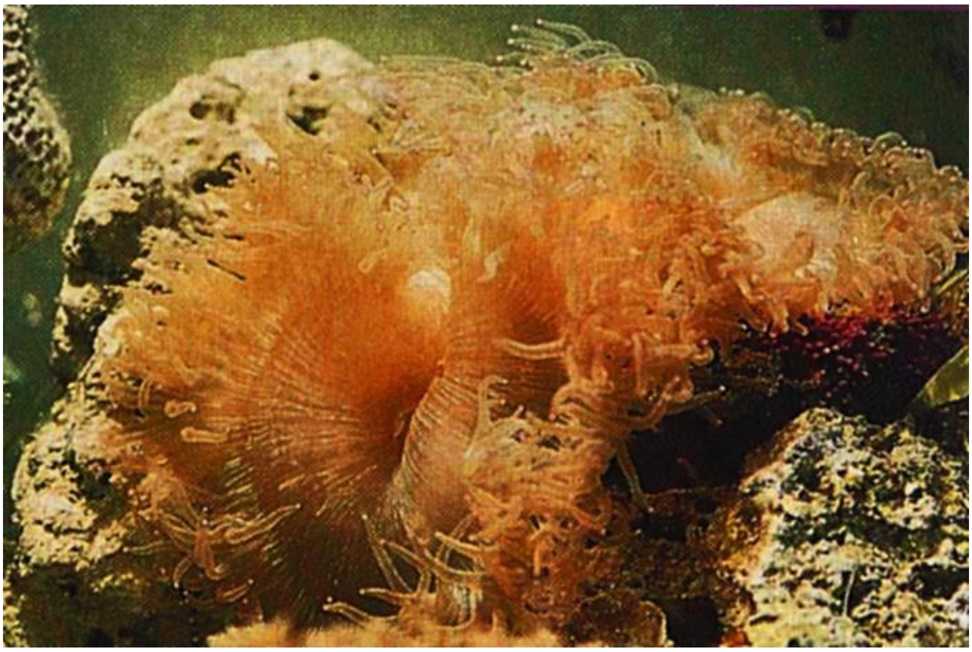


图 28　早在上世纪 90 年代早期，尼罗河就被用作摄食反应的实验样本，当然，并非所有的（氨基酸）结果都是有效的

甘氨酸、赖氨酸和牛磺酸在这种珊瑚中产生摄食反应(变现为该珊瑚会抓取浸泡在各种氨基酸中的纸片)虽然被半胱氨酸浸泡过的纸被角孔珊瑚抓取了，但尼罗河珊瑚却对其不感兴趣（这里可以看出不同珊瑚品种对摄入氨基酸的差异，并不是所有的珊瑚都喜欢同样的氨基酸）。精氨酸、肉碱、半胱氨酸、谷氨酰胺、乌氨酸、苯丙氨酸、酪氨酸则（对尼罗河珊瑚）不产生摄食反应。当然，珊瑚摄入某种氨基酸对于自身来说不一定就是绝对的好事，(实验结果显示)浸泡在甘氨酸中的纸片和数百个暗色的小颗粒一起从珊瑚的嘴里排出。在该实验中并没有对这些吐出物的成分进行分析，但有可能是残渣混合了虫黄藻。（这个地方意思估计是要说过度摄入氨基酸或者摄入了某种特定的氨基酸有可能对珊瑚会产生副作用，这里显示的是吐虫黄藻，但是我个人觉得这里得出这样的结论很不严谨，一是实验人没有对吐出物成分进行分析，二是即便真的是虫黄藻，一定就说明对珊瑚是消极的吗？这些都没有说明，所以姑且一看，我个人认为只要是珊瑚主动摄取的氨基酸，应该在一定量的情况下，效果都是积极的。）

其他（采用这种纸片浸泡方式进行的）实验使用了不同的物质。例如，糖(葡萄糖、果糖和蔗糖)，糖在圆菊珊瑚属（蜂巢珊瑚科下面的一种珊瑚，我自己也养过，商家都会称为微孔）中就不产生任何摄食反应。

Loss of Amino Acids

Amino acid/protein loss is inevitable. Figure 29 shows the composition of coral mucus. Alanine and glutamine are relatively small fractions of the total.

Some critics of coral amino acid uptake studies believe that simultaneous losses to the water column should be included to show the complete picture.

氨基酸损失

氨基酸/蛋白质流失是不可避免的。图 29 显示了珊瑚粘液的组成。丙氨酸和谷氨酰胺是总量中相对较小的部分（粘液的分泌会损失氨基酸，因为氨基酸是其中的组成部分）。

一些珊瑚氨基酸摄取研究的学者认为，珊瑚向水体中损失氨基酸也应该同时考虑在内，这样才能显示完整的（氨基酸损失）的情况。

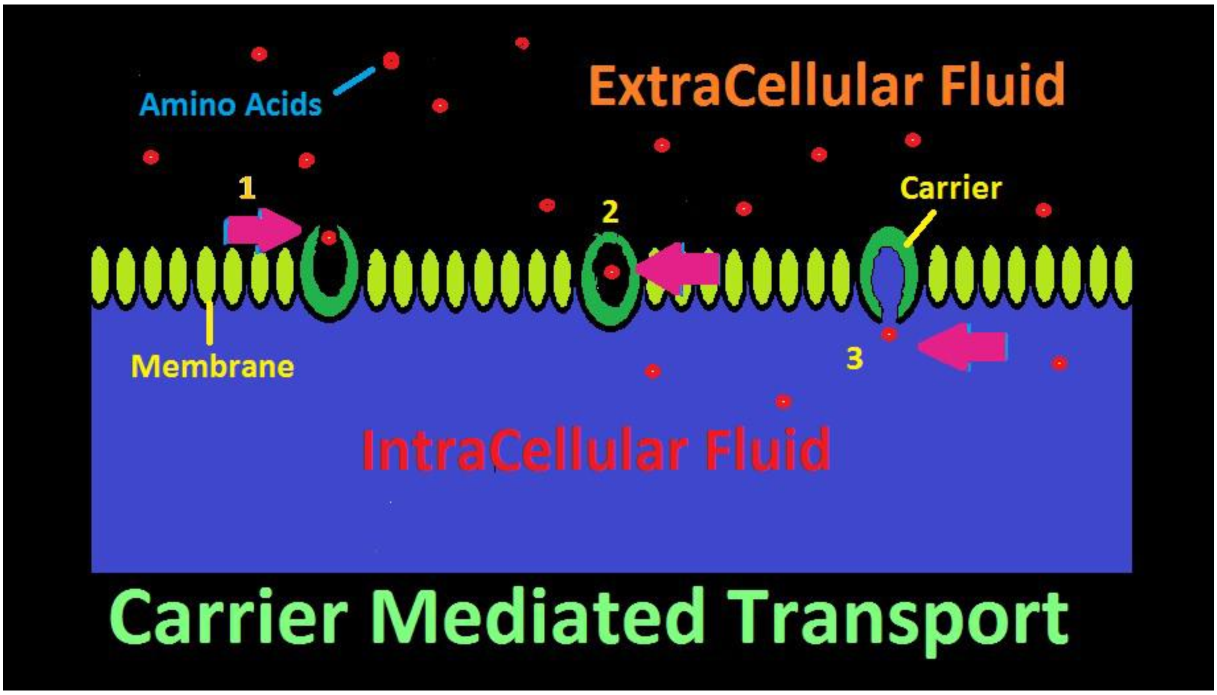


图 29 脂质是组成珊瑚粘液的主要成分，氨基酸只是（粘液）其中很小的一个部分（也就是说粘液损失的氨基酸应该很少咯）

Commercial Amino Acid Supplements

Amino acid supplements are relatively new offerings in the pet industry. Some promise better coral coloration while others advertise their product to mimic amino acid content of natural foods for fishes with narrow dietary requirements.

Two amino acid products were obtained through commercial channels and analyzed for pH, Total Nitrogen, ammonia, nitrite, nitrate, Biochemical Oxygen Demand and effects on alkalinity.

商业氨基酸补充剂

在宠物行业，氨基酸补充剂是相对较新的产品。有些承诺更好的珊瑚着色，而另一些人则宣传他们的产品模拟了鱼类天然食物的氨基酸含量。（总之就是吹牛逼咯）

通过商业渠道获得两种氨基酸产品，并分析其酸碱度、总氮、氨、亚硝酸盐、硝酸盐、生化需氧量和对碱度的影响。

Total Nitrogen

Two commercially available supplements were analyzed for total nitrogen. One was found to contain 204 mg/L total nitrogen. The other contained over 2,000mg/L, or 0.2%.

Testing Protocol for Total Nitrogen

Hach's method of determining Total Nitrogen was used. The sample, along with potassium persulfate is added to a vial containing acid, and digested at 105°C for 30 minutes. Seawater samples have to be diluted in order to avoid interference from chloride.

总氮

对两种市售补充剂进行了总氮分析。其中一个含有 204 毫克/升的总氮。另一种含有超过 2000 毫克/升，或 0.2%。（可见都是吹牛逼，实际某些数值的相差甚至快要到十倍了。。。。）

总氮测试方案

使用了 Hach 的测定总氮的方法。将样品和过硫酸钾一起加入装有酸的小瓶中，在 105℃下消化 30 分钟。海水样品必须稀释，以避免氯化物的干扰。

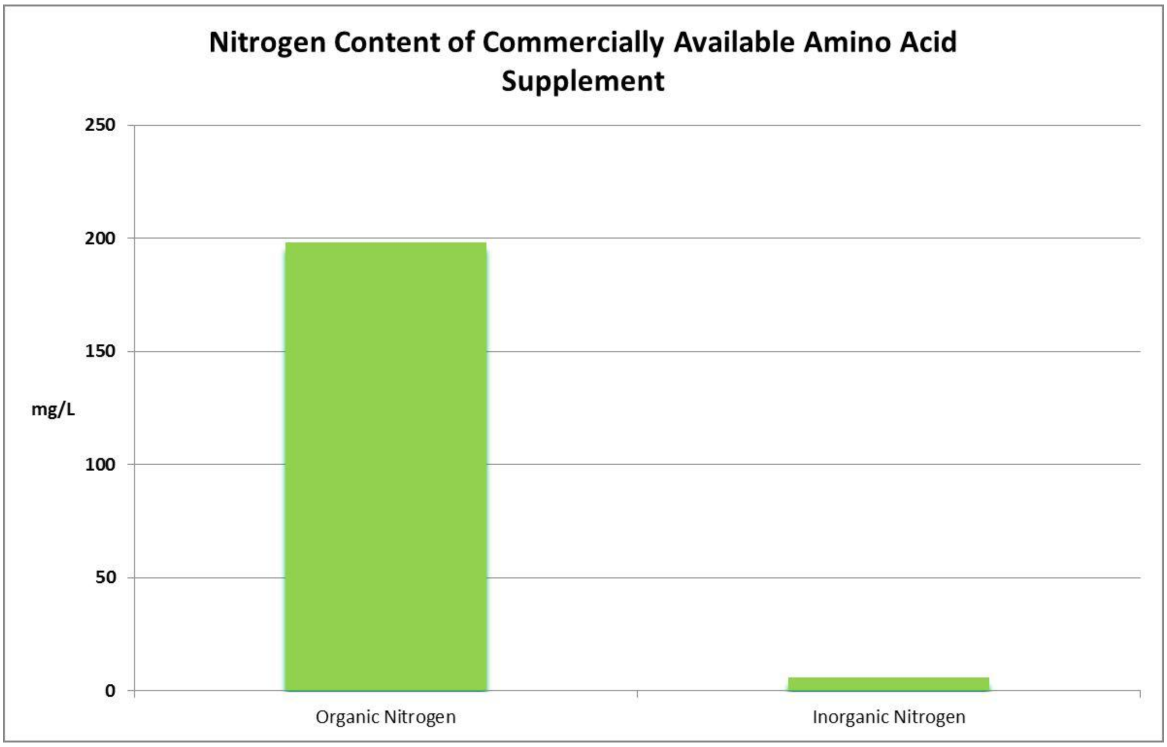


图 30 假设有机部分是氨基酸含量，而无机部分是铵、亚硝酸盐和硝酸盐的总和（这张图不知道是指的哪一款商业氨基酸补充剂）

Biochemical Oxygen Demand (BOD) of Amino Acid Supplements

Biochemical Oxygen Demand (BOD) is a five-day test conducted under controlled conditions. It is sometimes incorrectly called ‘biological oxygen demand.’ The hypothesis for this experiment was as follows: Amino acids would be rapidly consumed by bacteria. The experiment was conducted using standard protocols (incubation of bacteria-inoculated samples in 300 milliliter bottles which were held for at least 5 days in darkness at 20°C.) Simply stated, BOD is the amount of oxygen consumed while bacteria are ‘eating’ a food source. Since some samples do not contain any (or enough) bacteria, it is imperative that bacteria are added to the sample.

In order that the test is concluded successfully, it is important that oxygen content is not depleted (depletion is defined as dissolved oxygen concentration of less than 1 mg/L at the end of the 5-day test.) In many cases, this requires dilution of the sample. In Figure 30, we see bacteria have consumed available substances by Day 7 and 8, as evidenced by stable dissolved oxygen readings.

In these cases, bacteria ‘seeded’ diluted samples, and oxygen concentrations were determined with an oxygen meter and luminescent dissolved oxygen sensor with stirring rod (Hach Corporation, Loveland, Colorado, USA.)

As mentioned, the BOD test is one lasting 5 days, and is determined using this formula:

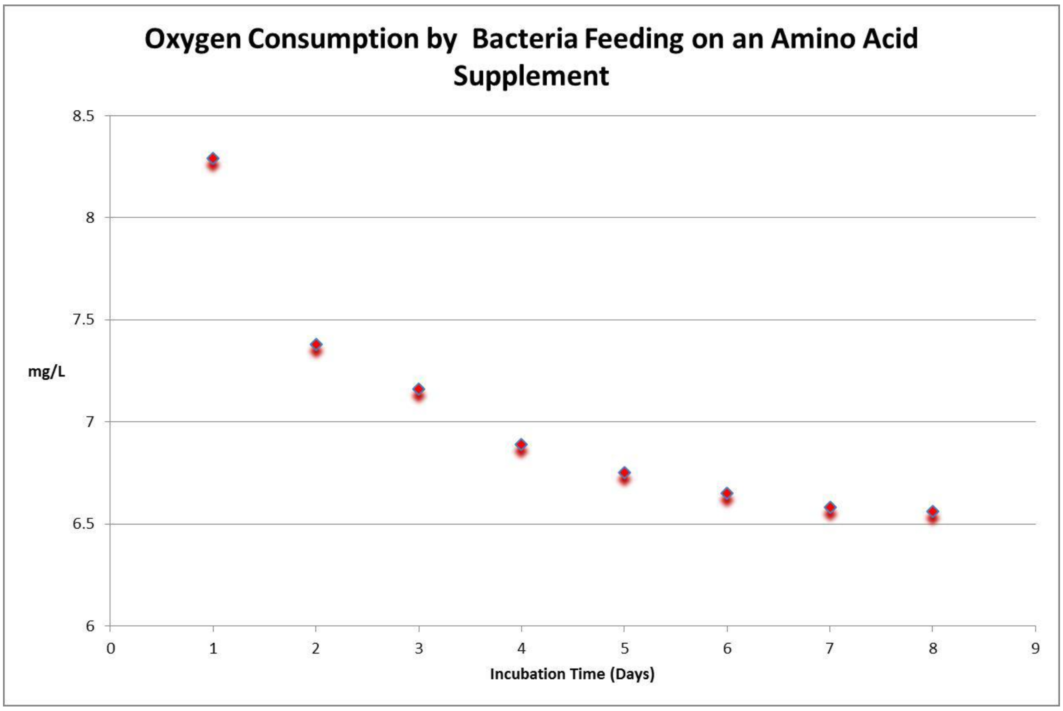
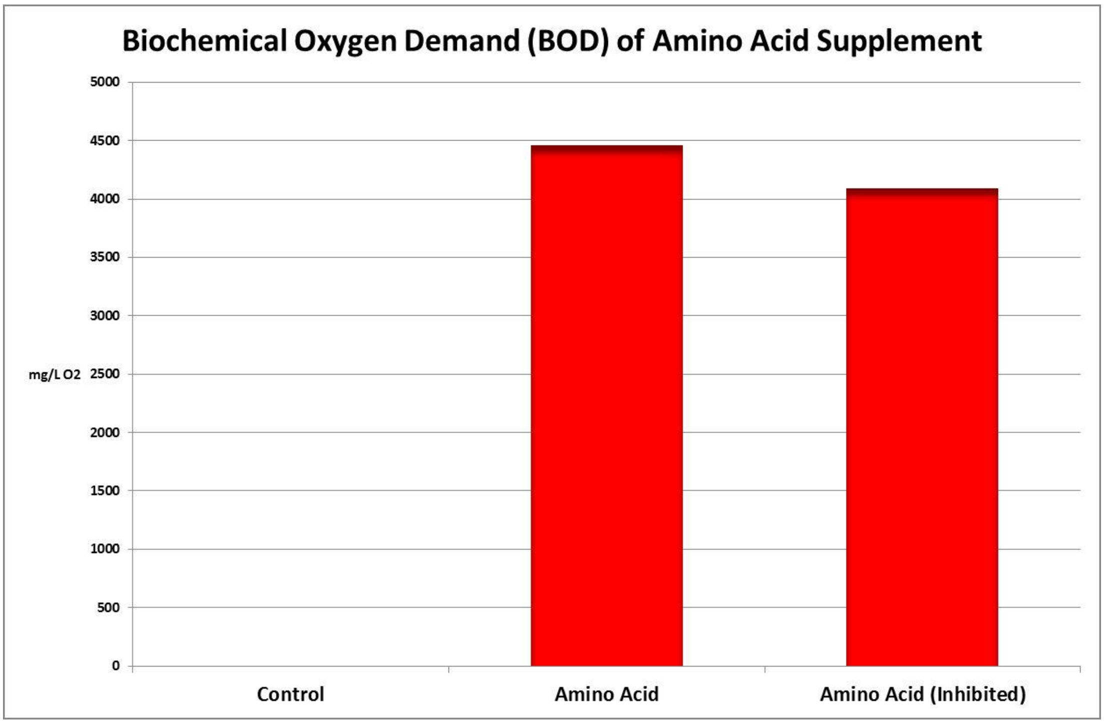


图 31。水族箱中市售氨基酸补充剂稀释样品中细菌的时间进程耗氧量，生化需氧量的计算方法是从初始读数中减去最终溶解氧，然后乘以稀释系数。



图表 32 这种生化需氧量试验表明，这种氨基酸补充剂容易被细菌迅速降解（对于我们这种使用 AF zeo 系统的玩家来说，probios bak 是不是就可以迅速降解某些氨基酸补充剂。。，当然这些或者只是特定的东西，只有一点点参考价值而已）

生化需氧量(BOD)是在受控条件下进行的为期五天的测试。它有时被错误地称为“生物需氧量”。这个实验的假设是这样的:氨基酸会被细菌迅速消耗。实验采用标准方法进行(将接种细菌的样品培养在 300 毫升瓶中，在 20℃的黑暗中保持至少 5 天)。简单地说，生化需氧量是细菌“吃”食物时所消耗的氧气量。由于一些样品不含任何(或足够的)细菌，因此必须向样品中添加细菌。

为了使试验成功结束，氧含量不耗尽是很重要的(耗尽定义为

在 5 天试验结束时溶解氧浓度低于 1 毫克/升。)在许多情况下，这需要稀释样品。在图 31 中，我们看到细菌在第 7 天和第 8 天已经消耗了可用的物质，稳定的溶解氧读数（溶解氧含量不发生变化）证明了这一点。（这个就可以看出多久能消耗掉）

在这些情况下，细菌“接种”到稀释样品中，用氧气计和带搅拌棒的发光溶解氧传感器测定氧气浓度(美国科罗拉多州洛弗兰德 Hach 公司。)

如上所述，生化需氧量测试是一个持续 5 天的测试，并使用以下公式确定:

初始溶解氧含量 - 5 天后溶解氧含量 x 稀释系数

图 32 显示了结果——生化需氧量几乎为 4500 毫克/升。从这个角度来看，未经处理的生活污水的生化需氧量为 250-300 毫克/升。经处理的废水排放量通常控制在 30 毫克/升或更低。海洋海水的 BOD 约为 0.2 毫克/升。

一些推论是合理的。回顾一下这 5 天的耗氧量。氨基酸中的氮并没有消失——它们被细菌吸收后可能会变为细菌的组成部分，或者转化为氨(用一种已知能抑制硝化作用的物质(2-氯-6-三氯甲基吡啶)稀释的样品中 BOD 减少了 10%就证明了这一点。（抑制硝化作用就是抑制细菌，这里也是体现细菌对氨基酸的利用和作用的一个证据）

Discussion

Amino acids/proteins are an important part of corals' diets, although amino acid requirements are species specific.

Zooxanthellae are primary producers and produce all their required amino acids, with at least two being translocated to the coral host (alanine and glutamine.)

Corals can make many amino acids considered to be essential to humans – they haven't lost the ability to synthesize them. However, some amino acids are produced by the coral animal in small amounts and may not be sufficient for tissue maintenance. Amino acids produced by Acropora cervicornis in small amounts (<5% of total) are: Glycine, isoleucine, leucine, lysine, methionine, phenylalanine, tyrosine, and valine.

Tryptophan is only sometimes described as present in marine invertebrate tissues. Is this caused by the testing method used, or is tryptophan truly seldom seen in coral tissues?

Vitamins B6 and C are important in the synthesis of some amino acids, as is choline. Metals (such as zinc and selenium) are important as well.

There is little doubt that marine invertebrates (including corals) can uptake dissolved amino acids. However, there is some evidence suggesting that uptake will be higher at night when amino acids are not produced (or produced in lesser amounts) by the coral or translocated to corals from zooxanthellae. Researchers have shown that neutral amino acids are preferentially ‘eaten’ by at least one coral species (which is not particularly surprising since these AAs are the majority of those considered proteinogenic.)

Amino acid supplements are highly acidic and vary in their amino acid content. Testing showed AA content can vary on the order of at least a magnitude. Biochemical Oxygen Demand tests showed supplements’ amino acids to be degraded quickly (starting immediately, and consumed almost totally in days) by bacteria. Severe overdosing could result in lowered oxygen concentrations due to bacterial blooms as well as reduced alkalinity and pH. The benefit of AA supplementation might not be the amino acid content, but the resulting bacterial bloom (in itself a food source for many corals.) This is strictly speculative, but deserves further attention.

Feeding activators also vary by species. Surprisingly, most studies have used those amino acids considered to be non-essential to humans.

This concludes our short examination of the importance of amino acids in coral nutrition. Next time, we’ll look at something a little more difficult – fatty acids, requirements, and what some, acting as indicators, tell us.

讨论（这个部分就是一般学术文章的结论或者说归纳总结）

氨基酸/蛋白质是珊瑚食物的重要组成部分，氨基酸需求因珊瑚品种不同而异。

虫黄藻是主要的氨基酸生产者，生产珊瑚所需的所有氨基酸，其中至少有两种被转移到宿主（珊瑚）体内(丙氨酸和谷氨酰胺)。

珊瑚可以制造许多被认为对人类来说必需的氨基酸——它们没有失去合成它们的能力。然而，一些氨基酸是由珊瑚动物少量产生的，可能不足以维持组织。摩羯鹿角珊瑚(一种鹿角珊瑚)产生的少量(<总量的5%)氨基酸有:甘氨酸、异亮氨酸、亮氨酸、赖氨酸、蛋氨酸、苯丙氨酸、酪氨酸和缬氨酸。（也就是说这些氨基酸虽然珊瑚可以合成，但是不足量，仍然需要外界提供）

色氨酸仅偶尔被发现存在于海洋无脊椎动物组织中（有发现，但发现次数少）。这是使用的检测方法造成的，还是珊瑚组织中色氨酸真的很少见（偶尔被发现）?

维生素B6和维生素C在一些氨基酸的合成中很重要，胆碱也是如此。金属(如锌和硒)也很重要。

毫无疑问，海洋无脊椎动物(包括珊瑚)可以摄取溶解的氨基

酸。然而，有一些证据表明，当珊瑚不产生氨基酸(或产生较少的氨基酸)或从虫黄藻转移到珊瑚的氨基酸减少时，夜间的吸收会更高。研究人员已经表明，中性氨基酸优先被至少一种珊瑚物种“吃掉”(这并不特别令人惊讶，因为这些氨基酸大多数是被认为是蛋白原的氨基酸。)

氨基酸补充剂是高度酸性的，其氨基酸含量各不相同。测试表明，氨基酸含量可以变化至少一个数量级。生化需氧量测试显示，补充剂的氨基酸被细菌快速降解(立即开始，几天内几乎完全消耗掉)。严重过量可能会导致氧浓度降低，因为细菌大量繁殖以及碱度和 pH 值降低。补充氨基酸的好处可能不是氨基酸含量，而是导致细菌大量繁殖(这本身就是许多珊瑚的食物来源。)这严格来说是推测性的，但值得进一步关注。（这一段真的有意思，在除了柏林系统外的几种 ULNS 系统中，氨基酸和细菌的补充几乎都是必须品，细菌作为珊瑚食物的重要来源和转发缸内营养的媒介在家庭养殖珊瑚中起着十分重要的作用。）

喂养激活剂所起的效果也因珊瑚品种不同而异（纸片浸泡实验）。令人惊讶的是，大多数研究都使用了那些被认为对人类非必需的氨基酸。

我们对氨基酸在珊瑚营养中的重要性的简短研究到此告一段落。下一次，我们将看一些更难的东西——脂肪酸、需求和一些相应的指标告诉我们的东西。

（原文有一个附录，记载了不同的氨基酸对于不同品种的珊

瑚的摄食激活剂的作用，实际上也体现出了不同品种珊瑚对于不同氨基酸的喜好，可到原文中参考，不再翻译。）

附上原文网址:

https://reefs.com/magazine/coral-nutrition-part-three-amino-acids-and-comments-on-amino-acid-supplements/