

Misconceptions in Primary Level Science — Rate of Photosynthesis 小学科学的一些错误概念 — 光合作用

Singapore's Maths and Science teaching is widely regarded to be amongst the best in the world. Indeed, Singapore regularly ranks either at or towards the top in international comparisons such as the Trends in International Mathematics and Science Study (TIMSS) which looks at student performance from Primary 4 to Secondary 2 in these subjects. However, misconceptions about certain aspects of Science still exist, as is evident from their appearance in many schools' test papers. In this column *In the Classroom* we would like both to address some of these and to provide a platform for further discussion.

新加坡学的数理教学是全球最好的系统之一。一直以来，它都获得了非常好的成绩，包括最近对小四和中二学生进行评估的TIMSS。尽管如此，学校试卷的科学考题仍然出现一些错误概念。在新加坡，有相当多的教师、学生和家長在使用这些题目。为了厘清这些概念以方便大家的使用，也为了提供一个平台供进一步的讨论，“新学教室”栏目以这篇文章做个开始，欢迎大家讨论和指正，以起到抛砖引玉的作用。

1. Question 问题

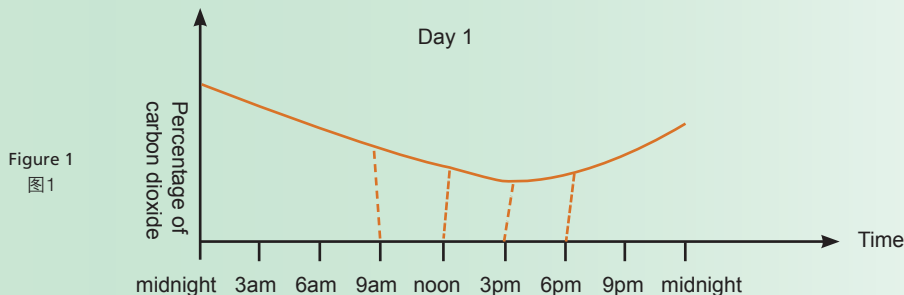
The following question (Figure 1) is from a Primary 6 Science preliminary examination paper. 以下题目出自一所小学的小六会考模拟试卷。

The graph below shows the percentage of carbon dioxide within a greenhouse in one day. 下图记录了某一天温室中二氧化碳百分浓度的变化。

At what time was the rate of photosynthesis the highest on that day?

这天中，最高的光合作用速率发生在何时？

The answer provided by the paper is 3 pm. 试卷提供的答案是下午3点。



2. Discussion 讨论

The question setter here might think that the plants in the greenhouse would absorb the most carbon dioxide when the rate of photosynthesis was at its height, and therefore as 3 pm was the time at which the level of carbon dioxide in the air in the greenhouse was at its lowest then this was

also the time at which the rate of photosynthesis was at its highest. Unfortunately, this is not necessarily the case. 出题者也许认为，当光合作用速率最大时，植物吸入大量的二氧化碳，从而导致最低浓度的二氧化碳含量。下午3点的二氧化碳浓度最低，这意味着光合作用速率最高。但实际上这样的概念是错的。

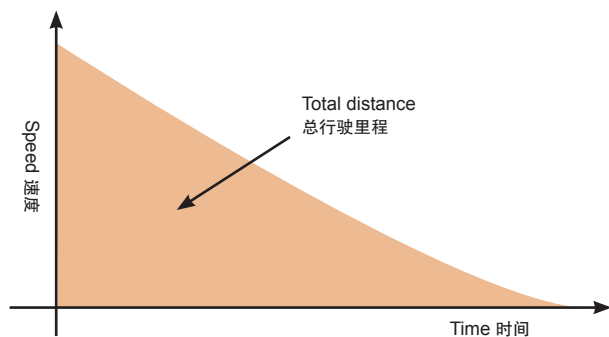


Figure 2 图2

There are, in fact, two misconceptions here. The first arises from the failure to distinguish an instantaneous effect from a cumulative one. The rate of photosynthesis is an instantaneous effect, but the level of carbon dioxide is a cumulative one. To take the analogy of a car, photosynthesis is equivalent to the speed of the car whereas the level of carbon dioxide equates to the distance it travels. It therefore follows that whatever the speed of the car (i.e. even when it slows down) the total distance it has covered always increases. In other words it is cumulative, as in Figure 2. The total distance is indicated by the shaded area which necessarily increases with time. And the same is true for the level of carbon dioxide in the greenhouse — provided that the rate of photosynthesis (i.e. the absorption of CO_2) remains higher than the rate of respiration (i.e. the giving out of CO_2) in the greenhouse, the carbon dioxide level will progressively fall.

这里有两个概念上的错误。第一是对即时效果和累积效果的混淆。可以用汽车的速度和行驶里程之间的关系来做个类比说明。光合作用的速率可以比作汽车的速度，是一种即时效果；二氧化碳的浓度则像汽车的总行驶旅程，是一种累积效果。

To return to the car analogy, we can see what might have been in the mind of the question setter here because it is certainly true that the faster the car is going at any single moment in time the longer is the distance it will travel per unit of time, and conversely that the slower it is going the shorter is the distance it will travel per unit of time. In the case of the question, this means that the higher the rate of photosynthesis the more carbon dioxide is absorbed per unit of time. But the fact that 3 pm marked the lowest level of carbon dioxide in the greenhouse does not necessarily mean that this was the time at which the rate of photosynthesis was at its highest, because as with the car

and the total distance it has covered, it might have been slowing down for some time already. Indeed, 3 pm may well have been the time when the rate of photosynthesis was actually at its lowest in that, as implied by the gradient in Figure 2, it could have been close to zero.

图2显示一辆汽车的速度与时间的变化关系。曲线包含的面积是汽车的行驶里程（阴影部分）。无论任何时间，汽车的速度是较大或较小，汽车的总行驶里程都随着时间的变化持续增加。如图2所示，即使汽车的速度一直在降低，总行驶里程仍不断增长。正如汽车的速度是一种即时效果一样，光合作用的速率也是一种即时效果。而二氧化碳的浓度则像汽车的总行驶里程，是一种累积效果。如果光合作用（吸入二氧化碳）的速率大于呼吸作用（放出二氧化碳）的速率，那么二氧化碳的浓度就会随着时间一直下降。光合作用的速率可以用图1中的曲线斜率求得。所以，根据图1，下午3点的斜率几乎等于零，光合作用速率恰恰是最低的。因此，最高的光合作用速率和最低的二氧化碳浓度未必发生在同一时间。

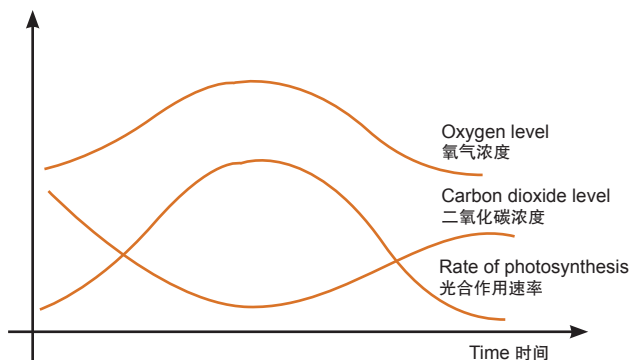


Figure 3 图3

A similar misconception can be seen in Figure 3. 图3所示的情况也犯了同样的概念错误。

Many schools believe that the levels of carbon dioxide and oxygen change with the rate of photosynthesis. In other words, when the rate of photosynthesis is high, they think that the oxygen level is high and the carbon dioxide level is low. However, as explained above, this is to mistake an instantaneous effect for a cumulative one.

很多学校认为，二氧化碳和氧气的浓度都跟随光合作用的速率而变化，光合作用的速率高，氧气浓度就高而二氧化碳浓度就低。根据以上说明，这是混淆了即时效果和累积效果而导致的结果。

The second misconception in the question is to think that an answer can be arrived at when there are two variables in operation. These are: the carbon dioxide level, and the light intensity. Both of these factors will affect the rate of photosynthesis and both will change over time. The question setter would have done better to have made one of these constant as in Figure 4.

另一个错误概念是，这个实验中有两个自变量：二氧化碳浓度和光的强度。这两个量都随时间变化，而且都会影响光合作用的速率。这不是一个公平的实验。只有在面对一个自变量，比如光的强度随时间变化的时候，学生才能够研究光合作用的速率，如图4。

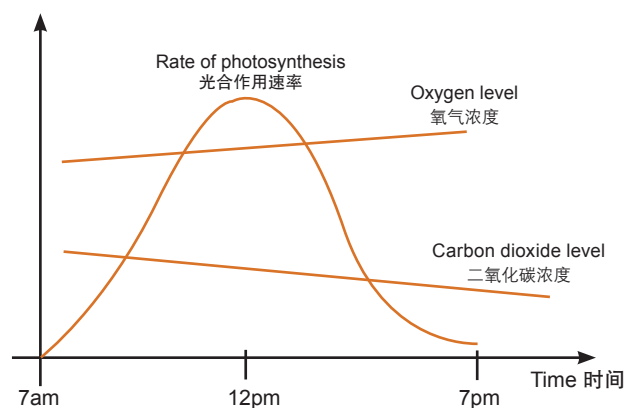


Figure 4 图4

Here we can see a graph that plots the changing rate of photosynthesis against the changing light intensity in an open field. Although the carbon dioxide levels progressively reduce over time (and the oxygen levels

gradually increase) they are quite a stable element and can therefore be treated as a constant for the purposes of any question set.

Figure 1, however, shows significant changes in both the carbon dioxide level and the light intensity inside the greenhouse, which renders the question unfair.

图4显示了一个在开放空间（并非温室）的典型光合作用速率（非二氧化碳和氧气浓度）随光强变化的图谱。在开放空间里，虽然光强、二氧化碳浓度和氧气浓度都随时间而变化，但二氧化碳和氧气浓度都相当稳定。因此，光强被视为唯一的自变量。相反，图1题目所示，在一个隔离的温室，二氧化碳浓度和光强都有相当显著的变化，形成两个自变量，导致实验不公平。

Conclusion 结论

The rate of photosynthesis is an instantaneous effect while the level of carbon dioxide or oxygen is a cumulative effect. 光合作用速率是一种即时效果而二氧化碳浓度则是一种累积效果。

The rate of photosynthesis in an open field is different from that in a greenhouse. In an open field, there is only one variable — the light intensity while in a greenhouse, there are two variables — the light intensity and the level of carbon dioxide. The test cannot be fair with two variables.

开放空间里的光合作用速率和温室里不同。在开放空间里，自变量只有光强一个；在隔离的温室里，光强和二氧化碳浓度两个都是自变量。一个实验中有两个自变量，是不公平的。

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