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# Why Sustained Effort is Important in Research: A Geometric Explanation

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**Abstract**

In a book aimed at young researchers, a renowned biologist E. O. Wilson advises them to be persistent, to continuously follow the same research direction. While this advice is supported by his (and others') experience of mentoring young scientists, it seems to contradict the experience of many famous scientists of the past who moved from one research direction to another and still achieved great success. In this paper, we provide a geometric explanation for Wilson's advice – and we explain why this explanation was not applicable in the past.


**Keywords:** persistence in research, geometric model, expanding knowledge

## 1 Introduction

**Sustained effort, persistence are important: an advice.** In his book [1], the renowned biologist E. O. Wilson advises to young scientists on how to do research. One of his main pieces of advice is the need for sustained effort, the need to persist, to keep going despite obstacles, losses or setbacks, to continue moving forward until one have completed his/her goals.

**Why this advice?** On the one hand, this advice makes sense, and it is supported by the experience of mentoring young researchers.

On the other hand, this advice seems contrary to the general spirit of creative research: instead of continuing to go in the same direction, why not try different things?

The history of science seems to support the advantages of going in different directions, this is how most researchers succeeded in the past: Newton invented calculus, discovered Newton's laws of mechanics, studied optics, and make comments on the Bible. Why not advise young researchers to follow Newton's example?

**What we do in this paper.** In this paper, we use a simple geometric model of expanding knowledge to show that – while creativity is important – the optimal scientific strategy is indeed to be persistent.

## 2 How to Describe Expanding Knowledge: A Natural Simple Geometric Model

**Expanding knowledge: a natural description.** We as a civilization have started with the basic knowledge, and we have been expanding this knowledge in all directions. At each moment of time, we have expanded our knowledge only so far, and we continue expanding as time goes on.

It is therefore reasonable to characterize our state of knowledge at each moment of time by the distance $R$ from the basic knowledge that we have reached by this moment.

**The resulting geometric description.** As a result, we arrive at the following description of our current state of knowledge:

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- the set of all possible pieces of knowledge is a multi-dimensional space;
- in this space, there is a fixed point $O$ that represents the basic knowledge;
- at each moment of time $t$, the civilization's state knowledge is represented by a number $R$; crudely speaking, we know all the pieces of knowledge whose distance from the point $O$ does not exceed $R$.

The value $R$ increases with time, meaning that, as we learn new things, the radius $R$ of our "sphere of knowledge" increases.

This is the model that we will use in our analysis.

# 3 What is the Best Research Strategy: Analysis of the Problem and the Resulting Conclusions

**The main objective of research reformulated in terms of the geometric model.** Our goal is to expand the knowledge, i.e., increase the "radius of knowledge" $R$ as much as possible.

For that purpose, numerous scientists are positioned at the edge of this sphere of knowledge. Each of these scientists moves ahead into the unknown territory. As a result, the sphere of knowledge expands.

**Limitations.** As a scientist progresses, he or she moves from the original sphere of science into the unknown. The rate with which a scientist can uncover new knowledge is limited. In geometric terms, this means that there is a bound $B$ on the speed with which a scientist can move.

Because of this bound, the farthest a scientist can move during the time period $T$ is the distance $B \cdot T$.

**In which direction should a scientist go?** Our goal is to expand the sphere of knowledge as much as possible. With researchers positioned all over the current border of knowledge (i.e., at the distance $R$ from the point $O$), the expansion is determined by how far each researcher will go.

If each researcher who is originally at a point $S$ on the sphere of radius $R$ continues along the straight line $OS$ past the point $S$, then after the period $T$, this researcher will reach a new point $S'$, at the distance $R' \stackrel{\text{def}}{=} R + B \cdot T$ from the point $O$. If all researchers follow this strategy, our radius of knowledge will increase from $R$ to $R' = R + B \cdot T$.

Let us show that this "following the straight line" idea is the optimal research strategy. Indeed, it is well known that the straight line is the shortest of all the paths connecting two points. Thus, if a researcher's trajectory of the overall length $B \cdot T$ is not a straight line, then the distance between the starting point $S$ and the final point $S'$ is smaller than $B \cdot T$: $d(S, S') < B \cdot T$. As a result, due to the triangle inequality

$$d(O, S') \le d(O, S) + d(S, S'),$$

we get

$$d(O, S') < R + B \cdot T.$$

In other words, in this case, the sphere of knowledge expands less that in situation where each researcher follows a straight line.

**We arrive at the desired explanation.** We therefore conclude that an optimal way to increase knowledge is for each scientist to follow a straight line, to go in the same direction all the time – i.e., to be persistent. Thus, *a natural geometric model of expanding knowledge indeed provides an explanation of why persistence (= sustained effort) is important.*

**What about Newton?** So why did Newton (and many other famous scientists of the past) not follow this strategy? Why are our arguments not applicable to Newton?

The main difference between now and Newton's times is that in the past, we did not have researchers positioned all over the border of knowledge. The reason for this difference is simple: in the past, there were much fewer researchers. For example, in the time of Newton, in addition to Newton himself, there was only one other person in the world working on calculus – Leibniz.

As a result, in the past, to expand knowledge in all areas, the same researcher had to enhance the knowledge's expansion in several areas – thus deviating from the straight line trajectory.

Nowadays, in each area of research, no matter how narrow, there are dozens of researchers. As a result, the most efficient way to collectively expand knowledge is for each of them to be persistent.

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## References

[1] Wilson, E.O., *Letters to a Young Scientist*, Liveright, New York, 2013.