

The Psychology of Entrepreneurship

New Perspectives

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Chapter 5

The Biology of Entrepreneurship

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THE BIOLOGY OF ENTREPRENEURSHIP

Ahmed Maged Nofal, Nicos Nicolaou & Scott Shane

The Biology of Entrepreneurship

Historically, research in entrepreneurship has largely ignored biological factors. However, recently researchers have begun to explore the ways in which human biology affects this phenomenon. This literature has been fragmented, scattered across various outlets, making it difficult for entrepreneurship scholars to aggregate the findings and develop a broad theoretical perspective to describe how biology relates to entrepreneurship (Nofal, Nicolaou, Symeonidou, & Shane, 2018).

In this chapter, we provide a systematic review of the biological perspective in entrepreneurship. Specifically, we systematically review research linking the three biological strands of genetics, physiology, and neuroscience to entrepreneurship. We discuss the findings of this growing literature and how incorporating biology into the study of entrepreneurship can enhance our understanding of various entrepreneurial outcomes. We then discuss the mechanisms through which biology affects entrepreneurship. Finally, we conclude with directions for future research.

Systematic Review

The review strategy is designed to provide a systematic and explicit method for reviewing the research on genetics, physiology, and neuroscience in entrepreneurship.

It adopts the same approach that Nofal et al. (2018) have previously used in their review of the biology of management. First, it uses the same keywords used by Nofal et al. (2018) that are related to the three biological areas (see Table 5.1). Second, it follows the protocols of Tranfield, Denyer, and Smart (2003) for undertaking systematic reviews in the field of management.

Using these protocols, we searched the databases of Thomson ISI Web of Knowledge and Google Scholar. We then reviewed all studies published in journals listed in the Chartered Association of Business Schools' list. We included all papers that were written through the end of July 2019, the stop point for this review. We transferred all the papers to Endnote and screened all the papers using title and abstract analysis to identify the studies that might be relevant to the review. This process resulted in a total of 200 articles. Of these articles, 151 were then excluded according to the exclusion criteria of Nofal et al. (2018) (see Table 5.2), leaving us with a total of 49 articles. We also approached two experts in the area and employed a backward and forward snowballing procedure by manually searching the reference lists of all included studies to make sure that we included all the necessary articles—the approach that yielded 13 more papers on genetics, 8 more papers on physiology, and 11 more papers on neuroscience.¹ After validating the retrieved papers, our overall search shows a total number of 81 papers and 5 books/book chapters (see Table 5.3).

The articles that result from the systematic review are listed in Table 5.3. The journals that make the biggest contribution to the review are the *Journal of Business Venturing*, the *Journal of Applied Psychology*, *Organizational Behavior and Human Decision Processes*, and *Applied Psychology*. We next review the papers in each of the three biological strands. Afterward, we discuss the mechanisms through which biology influences entrepreneurship.

Research on Genetics and Entrepreneurship

Research in the genetics strand has examined the influence of DNA on the propensity to engage in entrepreneurship, the propensity to recognize entrepreneurial opportunities, entrepreneurial intentions, and entrepreneurial performance (Nicolaou & Shane, 2009, p. 2). Two methods are used to examine whether genetics affects entrepreneurship. The first method is called “quantitative genetics”, while the second is called “molecular genetics”. The former builds on natural experiments of twins and adoptees to separate the influences of genes from the effects of environmental factors in an entrepreneurial phenotype. The latter attempts to identify the specific genetic variants that influence entrepreneurial propensities, using candidate gene and genome-wide association studies.

To date, quantitative genetics research has received more attention than molecular genetics research, as evidenced by the number of publications. This research shows that genetic factors explain 48% of the variance in self-employment (Nicolaou, Shane, Cherkas, Hunkin, & Spector, 2008; Zhang, Ilies, et al., 2009), 40%

TABLE 5.1 Keywords and Search Terms

	<i>Genetics</i>	<i>Physiology</i>	<i>Neuroscience</i>
Business	<ul style="list-style-type: none"> ✓ Biology and business ✓ Gene and business 	<ul style="list-style-type: none"> ✓ Biology and business ✓ Hormone and business ✓ Testosterone and business ✓ Dopamine and business ✓ Cortisol and business ✓ Oxytocin and business ✓ Serotonin and business ✓ Physiology and business ✓ Biology and management ✓ Hormone and management ✓ Testosterone and management ✓ Dopamine and management ✓ Cortisol and management ✓ Oxytocin and management ✓ Serotonin and management ✓ Physiology and management ✓ Biology and leadership ✓ Hormone and leadership ✓ Testosterone and leadership ✓ Dopamine and leadership ✓ Cortisol and leadership ✓ Oxytocin and leadership ✓ Serotonin and leadership ✓ Physiology and leadership 	<ul style="list-style-type: none"> ✓ Biology and business, ✓ Neuroscience and business
Management	<ul style="list-style-type: none"> ✓ Biology and management ✓ Gene and management 		<ul style="list-style-type: none"> ✓ Biology and management ✓ Neuroscience and management
Leadership	<ul style="list-style-type: none"> ✓ Biology and leadership ✓ Gene and leadership 		<ul style="list-style-type: none"> ✓ Biology and leadership ✓ Neuroscience and leadership

(Continued)

TABLE 5.2 Exclusion Criteria

<i>N</i>	<i>Criteria</i>	<i>Reason for Exclusion</i>
1	Organizational evolution papers	Examine how organizations evolve but do not look at the relationships between biology and entrepreneurship
2	Metaphor papers	Compare organizational activities to biology only metaphorically and do not look at the relationships between biology and entrepreneurship
3	Biological contexts papers	Examine the relationships between different management variables in biology-related contexts such as hospitals, pharmacies, biotech companies but do not look at the relationships between biology and entrepreneurship
4	Proxy papers	Use proxies such as age, gender, and ethnicity for biology
5	Marketing papers	Do not capture entrepreneurship-related phenotypes
6	Accounting, Economics and Finance papers	Do not capture entrepreneurship-related phenotypes

Source: Adapted from Nofal et al. (2018)

of the variance in starting a new business, and 43% of the variance in engaging in the firm start-up process (Lindquist, Sol, & Van Praag, 2015; Nofal et al., 2018; Zunino, 2016). The majority of those papers used self-employment and business ownership as proxies to measure entrepreneurship, which are less likely to capture the explorative dimensions of entrepreneurship (Henrekson & Sanandaji, 2014). Attempting to address this issue, other studies have examined the influence of genes on other entrepreneurial outcomes, such as opportunity recognition and entrepreneurial intentions. For instance, there is evidence that genetics contribute to 45% of the variance in opportunity recognition (Shane & Nicolaou, 2015b) and 42% of the variance in entrepreneurial intentions (Nicolaou & Shane, 2010).

While research shows that genetic factors explain a significant part of the variance in entrepreneurship, research trying to detect the specific genes influencing the tendency to engage in entrepreneurship has been less informative compared to quantitative genetics research. In this regard, Nicos Nicolaou et al. (2011) found a single nucleotide polymorphism in the dopamine receptor genes to be associated with entrepreneurship using a candidate-gene study.

However, candidate gene studies (in most settings) have suffered from a lack of replication (Duncan, Ostacher, & Ballon, 2019; van der Loos et al., 2011) and have been superseded by genome-wide association studies (GWAS). GWAS

TABLE 5.3 Publications Included in the Systematic Review (sorted by year)

<i>Genetics</i>	<i>Physiology</i>	<i>Neuroscience</i>
1. Nicolaou, Shane, Cherkas, Hunkin, et al. (2008)	1. White, Thornhill, & Hampson (2006)	1. Frank et al. (2009)
2. Nicolaou, Shane, Cherkas, & Spector (2008)	2. Tomasino (2007)	2. Collins & Karasek (2010); Shane (2009)
3. Frank, Doll, Oas-Terpstra, & Moreno (2009)	3. Weis, Firkner, & Hennig (2007)	3. Laureiro-Martínez, Brusoni, & Zollo (2010)
4. W. Johnson (2009)	4. White, Thornhill, & Hampson (2007)	4. Arvey & Zhen (2012)
5. Nicolaou & Shane (2009)	5. Shane (2009)	5. de Holan (2013)
6. Nicolaou, Shane, Cherkas, & Spector (2009)	6. Unger, Rauch, Narayanan, Weis, & Frese (2009)	6. Nejati & Shahidi (2013)
7. Shane (2009)	7. Sundararajan (2010)	7. Nicolaou & Shane (2013)
8. Zhang, Iliès, & Arvey (2009)	8. Trahms, Coombs, & Barrick (2010)	8. Tracey & Schluppeck (2013)
9. (Zhang, Zyphur, et al., 2009)	9. Guiso & Rustichini (2011b)	9. Krueger & Welpe (2014)
10. Koellinger et al. (2010)	10. Guiso & Rustichini (2011a)	10. McMullen, Wood, & Palich (2014)
11. Nicolaou & Shane (2010)	11. Arvey & Zhen (2012)	11. Laureiro-Martínez et al. (2014)
12. (Shane, 2010)	12. van der Loos, Haring, et al. (2013)	12. Arvey & Zhang (2015)
13. Shane, Nicolaou, Cherkas, & Spector (2010b)	13. Alrajih & Ward (2014)	13. Laureiro-Martínez, Brusoni, Canessa, & Zollo (2015a)
14. Shane, Nicolaou, Cherkas, & Spector (2010a)	14. Greene, Han, Martin, Zhang, & Wittert (2014)	14. Laureiro-Martínez, Venkatraman, Cappa, Zollo, & Brusoni (2015)
15. van der Loos, Koellinger, Groenen, & Thurik (2010)	15. Rietveld, van Kippersluis, & Thurik (2014)	15. Massaro (2015)
16. Nicolaou & Shane (2011)	16. Arvey & Zhang (2015)	16. Shane & Nicolaou (2015a)
17. Nicolaou, Shane, Adi, Mangino, & Harris, (2011); van der Loos et al. (2010)	17. (Bönte, Procher, & Urbig (2015)	17. de holan & Couffe (2017)
	18. Shane & Nicolaou (2015a)	18. Nofal et al., (2017)
	19. Unger, Rauch, Weis, & Frese (2015)	19. Pérez-Centeno (2017)
	20. Nofal et al. (2017)	20. Nofal et al. (2018)
	21. Wolfe & Patel, (2017)	21. S. K. Johnson et al. (2018)

18. van der Loos et al. (2011)
19. Arvey & Zhen (2012)
20. Quaye, Nicolaou, Shane, & Harris (2012)
21. Quaye, Nicolaou, Shane, & Mangino (2012)
22. Wermerfelt, Rand, Dreber, Montgomery, & Malhotra (2012)
23. Shane & Nicolaou (2013)
24. van der Loos, Rietveld, et al. (2013)
25. Arvey & Zhang (2015)
26. Lindquist et al., 2015)
27. Shane & Nicolaou (2015a)
28. Schermer, Johnson, Jang, & Vernon (2015)
29. Shane & Nicolaou (2015b)
30. Arvey, Li, & Wang (2016)
31. Zumino (2016)
32. Nofäl, Nicolaou, & Symeonidou (2017)
33. Nofäl et al. (2018)
34. Guedes, Nicolaou, & Patel (2019)
35. Kuechle (2019)
22. Nicolaou, Patel, & Wolfe (2017)
23. Nofäl et al. (2018)
24. Diallo (2019)
25. Patel & Wolfe (in press)
26. Wolfe & Patel (2018)
22. Pérez-Centeno (2018)
23. Lahti, Halko, Karagozogu, & Wincent (2019)
24. Nicolaou, Lockett, Ucbasaran, & Rees (2019)
25. Shane, Drover, Clingsmith, & Cerf (2019)

Note. Some papers span more than one category and accordingly appear in more than one column.

aim to identify small effect-size genes influencing entrepreneurial phenotypes by examining the entire genome without the need for a priori hypotheses.

GWAS suffer from their own limitations. In particular, GWAS require very large samples (Koellinger et al., 2010; van der Loos et al., 2010) and genome-wide significance levels of 5×10^{-8} . In other words, due to the large number of statistical tests conducted, a Bonferroni correction is needed to adjust the alpha values from $p < 0.05$ to $p < (0.05/\text{number of statistical tests})$. For GWAS, the adjusted Bonferroni correction corresponds to $p < 5 \times 10^{-8}$. Meanwhile, the highest significance values achieved for GWAS in entrepreneurship were 6×10^{-7} for the rs10791283 of the OPCML gene (Quaye, Nicolaou, Shane, & Mangino, 2012), and 1.25×10^{-7} for the rs6738407 located in the HECW2 gene (van der Loos, Rietveld, et al., 2013). As a result, the GWAS are largely inconclusive. There might be a very large number of genes involved in entrepreneurship, each with such a small individual effect size that the effects are difficult to detect.

Research on Physiology and Entrepreneurship

Physiology is the second strand in the literature on the biology of entrepreneurship. This strand has mainly focused on the influence of hormones. Among the key findings are that testosterone influences the tendency of people to engage in self-employment (White et al., 2006; Greene et al., 2014). Testosterone is suggested to influence risk-taking which in turn affects the tendency to become self-employed (Bönte et al., 2015; White et al., 2006). Nicos Nicolaou, Patel, and Wolfe (2018) utilized three different studies using serum testosterone levels, prenatal testosterone exposure using the 2D:4D ratio, and testosterone transfer in opposite-sex and same-sex twins to show that testosterone is associated with a higher propensity of engaging in entrepreneurship. Jens M. Unger et al. (2015) also found a significant interactive effect between prenatal testosterone and need for achievement on the number of jobs created by an entrepreneur.

Testosterone is not the only hormone examined. Other research shows a significant interactive effect of the stress hormone “cortisol” and epinephrine on the tendency to become an entrepreneur (Wolfe & Patel, 2017). Individuals with elevated epinephrine levels are more likely to engage in risky decision-making when their cortisol levels are low.

Research on Neuroscience and Entrepreneurship

The third strand of the biological theory of entrepreneurship examines the relationship between neuroscience and entrepreneurship (de Holan, 2013; Nicolaou & Shane, 2013). Examining neural activity in the brain can help us better understand how human beings function (Hannah, Balthazard, Waldman, Jennings, & Thatcher, 2013; Lee, Butler, & Senior, 2008). For instance, incorporating

neuroscience methods into the study of entrepreneurship has allowed “researchers to obtain more truthful data” about numerous “psychological functions such as brain reward systems and judgement” (Lahti, Halko, Karagozoglu, & Wincent, 2018, p. 17). Capturing the neural activity has also helped in revealing various neuropsychological antecedents to individuals’ strategic decisions, including emotions and cognitions (Laureiro-Martínez et al., 2015).

Nicos Nicolaou et al. (2019) propose four complementary mechanisms through which neuroscience can enhance our understanding of entrepreneurship: (1) capturing hidden mental processes that are unlikely to be revealed using other techniques, (2) confirming discriminant and convergent validity of entrepreneurship constructs, (3) investigating the underlying antecedents and temporal ordering of variables, and (4) refining theoretical perspectives.

Unfortunately, to date, most of the work on the neuroscience of entrepreneurship is conceptual (Nicos Nicolaou et al., 2019). Nevertheless, the few empirical papers in this area have uncovered some patterns for the study of entrepreneurship. For example, Lahti et al. (2018) argue that entrepreneurs’ bonding with their ventures activates the same brain regions as parents’ bonding with children, suggesting that entrepreneurs exhibit strong bonding, intimacy, caregiving dispositions, and affective emotions when thinking about their ventures—which resembles the relationship between parents and their children. Laureiro-Martínez et al. (2014) show that entrepreneurs have greater decision-making efficiency than managers and stronger activation in the frontopolar cortex, which has been associated with exploration. In a recent functional magnetic resonance imaging study Shane et al. (2019) found that founders with high passion trigger investors’ neural engagement by 39% and investors’ interest in the venture by 26% compared to founders with low passion.

Mechanisms Explaining the Biological Basis of Entrepreneurship

An understanding of the mechanisms relating biology to entrepreneurship can augment our ability to understand various entrepreneurial outcomes (Colarelli & Arvey, 2015; Nicolaou & Shane, 2011). As (Shane et al., 2019, p. 6) explain, understanding the mechanisms relating biology to entrepreneurship is novel, but not easy, and “human beings are too complex biologically for there to be a single mechanism”. Research has presented a number of mechanisms to explain how biology impacts the tendency of people to engage in entrepreneurship.

First, biology may impact the tendency of people to engage in entrepreneurship through psychological characteristics. Prior work shows, for instance, that agreeableness, openness to experience, and extraversion mediate the relationship between genetic factors and entrepreneurial performance (Shane & Nicolaou, 2013). Extant literature also shows that testosterone affects entrepreneurial intentions through risk-taking (Bönte et al., 2015).

Second, biology may moderate the relationship between environmental factors and the tendency to engage in entrepreneurship. Empirical evidence, for example, indicates that genetics and social environments play an interactive role in influencing the propensity toward entrepreneurship (Zhang, Ilies, & Arvey, 2010; Zhang, Zyphur, et al., 2009). Further work proposes an interactive influence of genetic factors and education on the likelihood of self-employment (Quaye, Nicolaou, Shane, & Harris, 2012).

Third, biology may influence the propensity towards entrepreneurship by affecting the likelihood of people to select certain environments that, in turn, affect their likelihood of engaging in entrepreneurship. For instance, the genetic makeup of individuals may enable them to self-select environments that give them better access to business angels and venture capitalists which in turn increases the likelihood that they engage in entrepreneurship (Shane & Nicolaou, 2015a).

Fourth, interactions between biological factors may affect the tendency of people to become entrepreneurs. Research shows, for instance, that cortisol and epinephrine have an interactive effect on the probability of becoming self-employed (Wolfe & Patel, 2017). Cortisol has been commonly labeled as the stress hormone, and epinephrine is widely known as adrenaline—which triggers the decision to fight rather than withdraw. Bringing these arguments to entrepreneurship, Wolfe and Patel (2017) propose that individuals who have high levels of epinephrine (i.e., adrenaline) are more likely to fight and engage in entrepreneurship provided that they possess low levels of stress as expressed by their decreased levels of cortisol.

In the same line, studies show that the anterior cingulate cortex interacts with the orbitofrontal cortex and the locus coeruleus to affect exploration and exploitation (Aston-Jones & Cohen, 2005; Laureiro-Martínez et al., 2010; Nofal et al., 2018). This evidence shows that exploration and exploitation are associated with interactions between the two brain regions that are responsible for reward-seeking and attentional control (Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015b). While showing the complexity of entrepreneurial behavior, those interactive influences of biological factors on entrepreneurship could also partly explain why prior studies have failed to detect the specific genetic variants influencing the tendency to engage in entrepreneurship. For example, there could be interactions between genetic factors contributing to the variance of who engages in entrepreneurship.

Future Research

There are a number of research gaps that future studies need to address. For instance, further entrepreneurship variables need to be examined, such as the influence of biology on entrepreneurial biases, entrepreneurs' thinking styles, and their fear of failure. Researchers are also urged to provide further empirical evidence on how biology and environmental factors interact to influence the

tendency of people to engage in entrepreneurship (Quaye, Nicolaou, Shane, & Harris, 2012). More empirical work is also needed on how people's biological makeup can drive them to self-select into certain environments to engage in entrepreneurship (Nicolaou & Shane, 2009).

Research pertaining to the specific biological strands is also needed. For example, extant work trying to identify specific genes influencing entrepreneurship has been less successful, with detected genes explaining a very low percentage of the variance of entrepreneurship (Quaye, Nicolaou, Shane, & Mangino, 2012; van der Loos, Rietveld, et al., 2013). These unsuccessful attempts are believed to be due to a number of reasons. First, genes can influence entrepreneurship by interacting with other biological and environmental factors (Nicolaou & Shane, 2009). Second, the effect of genes on complex variables, such as entrepreneurial outcomes, is characterized by being polygenic in nature (Plomin, DeFries, Knopik, & Neiderhiser, 2012). It is unlikely that a single gene would have a large effect on entrepreneurial outcomes but rather that a combination of genes each of a small effect size combine to affect the tendency of people to engage in entrepreneurial outcomes (Quaye, Nicolaou, Shane, & Massimo, 2012). Research on polygenic risk scores may be a useful avenue in this endeavor (e.g. Belsky et al., 2016)).

In addition, empirical studies on hormones and entrepreneurship have only focused on a few hormones, such as testosterone, cortisol, and epinephrine (Nofal et al., 2018; Wolfe & Patel, 2017). Researchers are encouraged to examine the influence of serotonin, dopamine, and oxytocin on entrepreneurship. Serotonin and dopamine contribute to the formation of various personality traits and psychological attitudes, which have been previously related to entrepreneurship, such as sensation-seeking, risk-taking, novelty-seeking, and job satisfaction (Song, Li, & Arvey, 2011). Oxytocin is commonly known as the social bonding and/or the trust hormone as it promotes social networking abilities, with people high in oxytocin more likely to establish trusted social networks and bonds (Algoe, Kurtz, & Grewen, 2017), and therefore more likely to engage in entrepreneurship (Shane & Nicolaou, 2015a). Oxytocin is also famous for its impact on stress regulation (Olf et al., 2013).

Additional research on the neural correlates of entrepreneurship is also required. For instance, although studies have reported that entrepreneurs exhibit distinctive activity in certain regions of the brain relative to their counterparts, we need to know more about the implications of this neural activity for entrepreneurship (Laureiro-Martinez et al., 2014; Nofal et al., 2018; Shane et al., 2019).

Discussion

The goal of this chapter is to bring together research examining the role of genetics, physiology, and neuroscience in entrepreneurship. This literature has been highly fragmented, limiting our ability to comprehensively understand the mechanisms governing the relationship between biology and entrepreneurship (Nofal

et al., 2018). Our systematic review shows that the past decade has witnessed a significant rise in work examining the influence of biology on entrepreneurship as well as calls for research in this area. For instance, our review shows that six journals in the past 10 years have called for special issues on the role of biology and/or mental conditions in management: *Academy of Management Perspectives* (Phan & Wright, 2018), *Applied Psychology* (Arvey & Zhen, 2012; Arvey & Zhang, 2015), the *Journal of Business Venturing* (Wiklund, Nikolaev, Shir, Foo, & Bradley, 2019), *Entrepreneurship Theory & Practice* (Nicolaou, Phan, & Stephan, in press), *Leadership Quarterly* (Lee, Senior, & Butler, 2012), and *Organizational Behavior and Human Decision Process* (Shane, 2009). There have also been some special issues calls in nonmanagement journals, such as *Frontiers in Human Neuroscience* (Waldman, 2013).

Studies on the biology of entrepreneurship demonstrate that entrepreneurship is a function not only of environmental factors but also of biological factors. In fact, as researchers argue, “we are all biological creatures and our biology affects all aspects of our behavior, including our work” (Nofal et al., 2018, p. 23). Entrepreneurial outcomes, such as opportunity recognition (Shane et al., 2010a), entrepreneurial intentions, entrepreneurial performance (Patel & Wolfe, in press; Shane & Nicolaou, 2013; Wolfe, Patel, & Drover, 2018), crowdfunding performance (Anglin, Wolfe, Short, McKenny, & Pidduck, 2018), business ownership (Nicolaou, Shane, Cherkas, Hunkin et al., 2008), self-employment, and the tendency to engage in entrepreneurship (Shane & Nicolaou, 2015b; Wolfe & Patel, 2017), have all been shown to be influenced by both biological and environmental factors. These biological factors often play a role in affecting people’s psychological traits and attitudes, which, in turn, affect their tendencies to engage in entrepreneurship. These traits include sensation-seeking, openness to experience, creativity, and extraversion.

Moreover, our systematic review shows that different biological strands can jointly play a role in entrepreneurship, such as evidence of gene–gene interactions, gene–hormone interactions (Frank et al., 2009; Quaye, Nicolaou, Shane, & Harris, 2012), and hormone–psychological variables interactions (Unger et al., 2015). Furthermore, evidence of the influence of biology on entrepreneurship suggests that the effect of biology on entrepreneurship is less likely to be direct but likely to partially manifest through other psychological factors and attitudes, such as risk-taking, openness to experience, and sensation-seeking (Bönte et al., 2015; Nicolaou, Shane, Cherkas, & Spector, 2008; Shane et al., 2010a; White et al., 2006).

Conclusion

The biological theory of entrepreneurship is becoming an increasingly important area in the field. This chapter has examined how genetics, physiology, and neuroscience influence the tendencies of people who become entrepreneurs.

This growth is parallel to the growth in the biological perspective in management, where more than 133 journals worldwide have published at least one article on the biological perspective in management during the past few years (Nofal et al., 2018). Yet many gaps still exist and further research is required to boost our understanding of the biological underpinnings of entrepreneurship.

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Note

1. Some articles and book chapters are included in more than one biological strand because they examine more than one biological factor.

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