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Biological Framework of Psychological Resilience: Literature Review

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Abstract: *Resilience, as a multi-dimensional psychological construct, is considered in the context of mental health. Many authors understand resilience as a psychobiological phenomenon which determines an individual's response to adverse life events or stress. The connection between psychological resilience and stress as a bio-psycho-social reaction is the topic of numerous empirical research studies and theoretical analyses. This paper focuses on the biological components and framework of psychological resilience. Based on the internet search in general research open access repositories (Google Scholar, DOAJ) and specialized repositories (MEDLINE and PSYCHINFO), the interest of the research community to investigate connections between biological factors and psychological resilience is confirmed. The following biological factors and components, which are most frequently considered and connected with psychological resilience, are: multiple phenotypic levels including stress response systems, neural circuitry function, and immune responses, in interaction with genetic factors; neurogenesis in the hippocampus or reactive up-regulation of ion channels in ventral tegmental area (involved in resilience against stressful conditions); temporal axis; genes encoding serotonin transfer; etc. By choosing specific terms as internet search filters, only a few papers were selected. The factors that form the biological framework of psychological resilience are systematized. An overview of the interventions likely to promote resilience and resilient brain function is included. The main conclusion emphasizes the importance of a holistic approach to psychological resilience as a construct supported by and affecting the social dimension as well as the biological dimension of personal functioning.*

Keywords: *psychological resilience; stress; biology of resilience.*

1. INTRODUCTION

Resilience is a positive psychological adaptation to changes and challenges. It is a multi-dimensional construct. And, it is both a capacity and an active process encompassing a person's flexibility in response to changing situational demands and the ability to bounce back from negative emotional experiences [1]. In the Oxford Advanced American Dictionary online the word 'resilience' is defined both as "the ability of people or things to feel better quickly after something unpleasant, such as shock, injury, etc." and "the ability of a substance to return to its original shape after it has been bent, stretched, or pressed" [2]. The psychological community understands resilience as a psycho-socio-biological phenomenon which determines an individual's response to adverse life events or stress.

The popularity of the concept of resilience in recent years is based on shifting the cultural focus on positive outcomes [3]. Psychological resilience is a topic of research in many sciences and scientific disciplines: different disciplines of psychology, biology and neurobiology, neurophy-siology, neuroscience, cognitive neuroscience, medical sciences, etc. Some of the authors used the construct neuropsychobiology of resilience [4]. A holistic approach to resilience science must include a neurobiological perspective [3]. Current scientific approach and technological tools and means are enabling a "true biopsychosocial approach to the study of resilience in humans" [5]. The research into the neuroscience of resilience is relatively new [6, 7].

However, in this paper, we consider the basic topic of resilience from the standpoint of positive psychological approaches and look for biological frameworks of established, manifested, and strengthened psychological resilience.

1.1. Psychological Resilience

According to the American Psychological Association, "resilience is the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands"[8].

Psychological resilience can be considered from two perspectives [1]:

- Resilience is the **process** of successfully adapting to difficult or challenging life experiences.
- Resilience is an **outcome** of successfully adapting to difficult or challenging life experiences.

Two crucial conditions for consideration some behaviour as resilient are: "(1) exposure to significant threat or severe adversity; and (2) the achievement of positive adaptation despite major assaults on the developmental process" [9].

Researchers have identified three related uses of the term resilience [1, 6, 10]:

1) Recovery is a form of resilience which refers to the return to a normal, pre-stressor level of functioning (health and psychosocial wellbeing).
2) Resistance is a form of resilience which occurs when a person displays minimum or no signs of disturbance (low distress, normal functioning) following a challenging event.
3) Reconfiguration (or redirecting) is a form of resilience which occurs when a person returns to homeostasis in a different formation with key aspects of that individual changing as a result of their experience.

Some of the indicators of a resilient person are the following [1, 11, 12, 13, 14, 15]: able to show positive adaptation in the face of adversity; able to rebound; able to function despite prolonged exposure to stressors and disadvantages; flexible; able to make and maintain supportive relationships; reflective; has problem-solving skills; able to plan; seeks to help; able to act independently; has goals; persistent; takes risks; optimistic; able to regulate his or her emotions and interact more effectively in social environments; has a higher sense of control and internal locus of control; the ability to withstand or recover quickly from difficult conditions. Resilience emerges through complex interactions of internal and external factors.

1.2. Resilience and Stress

The connection between psychological resilience and stress as a bio-psycho-social reaction is the topic of numerous empirical research studies and theoretical analyses. Resilience is analyzed as the outcome of successful stress adaptation [4]. Resilient individuals are changed by their own experiences. Consideration of resilience in relation to allostasis (adaptation through change) [6] or allostatic state (allostatic state is reflected by the adjustment or maintenance of physiological and behavioral systems in order to adapt to challenging or stressful situations) [16] and in relation to vulnerability are current topics as well.

Sometimes, the researchers use the words stress and resilience as one concept "stress resilience". The ability to manage own stress effectively enables the impact of stressors to develop resilience.

The effects of eustress and distress, and effects of the actual stress and chronic stress, and connections with resilience are not considered in this paper.

1.3. Biology of stress and resilience as psychological phenomena

The importance of the interdisciplinary approach to stress and resilience research is emphasized [17]. However, the researchers focused more on the stress than on the resilience. Early work has focused on the physiological stress response [16]. Resilience research has mainly focused on the contribution of psychosocial and environmental factors, with limited attention to the potential role of intraindividual biological factors [3].

A wide range of physiological and behavioural reactions developed as a response to stress, enable quick recovery or adaptation to the change. Borell [18] emphasized that the neuroendocrine and immune systems have been studied regarding stress effects at the cellular or neural level during the last decade. All these studies were often conducted in an isolated manner without considering that the neuroendocrine and immune systems are communicating with each other and are ultimately influenced by the perception of a stressor." Based on the analogy between the animal world and the human world, Borell's discussion on the neurobiological integration of stress emphasized a systematic and holistic approach to stress as a bio-psychosocial phenomenon based on the communication between the central nervous system, endocrine system, and immune system.

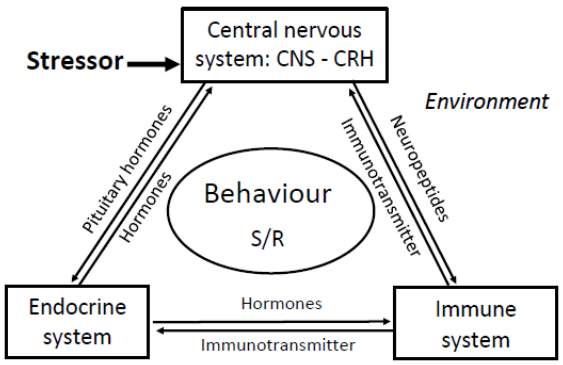

Figure 1. *Neurobiological integration of stressful or resilient behaviour (adapted according to [18])*

Current stress research considers the central nervous system, endocrine system, and immune systems as key systems for stress and resilience, and emphasises their interactions.

2. RESEARCH METHODOLOGY

The problem of the analysis: This paper focuses on the representation of the biological approach to psychological resilience in scientific and professional articles, other publications, and different types of work presentations, as well as the biological components and framework of psychological resilience.

The research goals:

- Overview of the presence of topics on the connection between psychological resilience and biological factors from the perspective of holistic approaches to sciences and scientific branches (example: biology of psychological resilience; neuroscience of psychological resilience).
- A systematic overview of the biological factors (causes and consequences) of psychological resilience based on the prior analysis.

A general browser was used to find and analyze the resources on the connections between psychological resilience and biological framework, in two general databases and two specialized databases: Google Scholar as general citation repositorium, DOAJ as general open access repositorium, and MEDLINE and PSYCHINFO as specialized repositories using the following terms (concepts) as filters (see Table 1). The internet search was performed on May 2, 2024, and control search June 11, 2024.

3. RESULTS

In the first step of this research, an examination of how many topics on biological frameworks of psychological resilience are represented in scientific periodicals available in online repositories was performed, and an overview of resources based on internet searches was given. In the second step of the research, there is an overview of biological components (factors, systems) related to resilience.

3.1. Repository search results

Based on the internet search in general open access registries and repositories (Google Scholar and DOAJ), and in specialized repositories (MEDLINE and PSYCHINFO), focusing on the articles (Table 1).

Table 1. *Number of sources with key terms searched in e-databases*

Phrases and words	Google	Google Scholar: articles	DOAJ: articles	MEDLINE: articles	PSYCHINFO articles
Biological framework of psychological resilience	24.800.000[a] (0)[b]	493.000 (0)	11 (0)	89 (0)	0 (0)
Biological basis of psychological resilience	15.500.000 (7)	518.000 (2)	8 (0)	97 (0)	174 (0)
Biological fundaments of psychological resilience	3.970.000 (0)	18.600 (0)	0 (0)	7 (0)	0 (0)
Biology of psychological resilience	213.000.000 (2)	389.000 (2)	8 (0)	72 (0)	151 (0)
Neurobiology of psychological resilience	1.210.000 (10.400)	104.000 (25)	7 (0)	32 (0)	61 (0)
Neuroscience of psychological resilience	26.400.00 (4)	281.000 (1)	52 (0)	44 (0)	278 (0)
Endocrinology of psychological resilience	1.190.000 (0)	67.100 (0)	4 (0)	26 (0)	31 (0)
Biology of resilience	76.000.00 (203.000)	2.120.00 (165)	378 (1)	137 (0)	152 (0)
Neurobiology of resilience	2.150.00 (81.500)	138.000 (1940)	96 (3)	51 (0)	61 (0)
Neuroscience of resilience	28.700.000 (53.500)	403.000 (236)	230 (2)	61 (0)	292 (0)
Endocrinology of resilience	7.630.000 (3)	98.800 (0)	11 (0)	30 (0)	32 (0)
	N[1] – number of results with some words/part of phrases (N)[2] – number of results with the whole phrases				

Based on the internet search in registries and repositories, focusing on the articles, the interest of the research community to investigate connections between biological factors and psychological resilience is confirmed.

The following biological factors and components, which are most frequently considered and connected with psychological resilience, are: CNS, brain, ANS, multiple phenotypic levels including stress response systems, neural circuitry function, and immune responses, in interaction with genetic factors; neurogenesis in the hippocampus or reactive up-regulation of ion channels in ventral tegmental area (involved in resilience against stressful conditions); temporal axis; genes encoding serotonin transfer; etc.

3.2. Results of searching by specific term

By choosing specific terms as internet search filters "biological basis of psychological resilience", "biology of resilience", "neurobiology of resilience", and "neuroscience of resilience" (in the title and in the text), only a few papers were selected in open access area (Table 2). For the content analysis 12 papers were considered.

Table 2. *The articles which included the phrase "biological basis of psychological resilience" or combination of words in open databases*

Title of the paper	Year of publishing	Google Scholar	DOAJ	Research Gate
The Biological Basis of Psychological Resilience as a Consequence of Active Processes. [19]	2012	+	no	no
The Neuroscience of Resilience. [6]	2018	+	no	+
Differences in Neural Recovery from Acute Stress Between Cortisol Responders and Non-responders. [16]	2018	+	+	+
Biological and Psychological Perspectives of Resilience: Is It Possible to Improve Stress Resistance? [15]	2018	+	+	+
Visual Analysis of Psychological Resilience Research Based on Web of Science Database. [20)	2023	+	+	+
Bringing a neurobiological perspective to resilience [3]	2021	+	no	+
The Biology of Human Resilience: Opportunities for Enhancing Resilience Across the Life Span. [5]	2019	+	no	+
Psychobiological Mechanism of Resilience and Vulnerability: Implications for Successful Adaptation to Extreme Stress. [21]	2004	+	no	+
Resilience in mental health: linking psychological and neurobiological perspectives. [22]	2013	+	no	+
Cognitive neuroscience of psychological resilience: State of research and unresolved issues. [4]	2021	+	no	+
The Molecural Basis of Resilience: A Narrative Review. [24]	2022	+	no	+
The Role of Epigenetics in Psychological Resilience. [25]	2021	+	no	+

4. AN OVERVIEW OF BIOLOGICAL CORRELATES OF THE PSYCHOLOGICAL RESILIENCE

Based on the content analysis of the articles searched from repositories and registry, the biological framework of psychological resilience is presented.

4.1. Neurochemical and neuroanatomic correlates of psychological resilience

The factors that form the biological framework of psychological resilience (causes and consequences), or neurobiological contributors to resilience [3], are systematically presented based on the holistic research articles and review papers.

Primary biological systems that are involved in stress responsivity and, by extension, resilience, are the following: the central nervous system, the endocrine system, and the immune system, as key organic systems connected with resilient behaviour. It is based on the organic and behavioural dimensions of stress which are considered in the research on resilience [3, 5, 6, 7, 15, 16, 17, 21, 22, 24].

According to [15] "the growing understanding of the neurobiological mechanisms of resilience should result in the development of novel interventions that specifically target neural circuitry and brain areas that enhance resilience and lead to more effective treatments for stress-induced disorders."

Neurocircuitries (any control mechanism that regulates neural activity), as mediators of the stress response and reward experience, are considered crucial in the neurobiology of resilience [22], and in the context of mental health.

The major neural systems that govern the stress response are the hypothalamus-pituitary-adrenal axis (HPA axis), the sympathetic nervous system (SNS) and the dopaminergic and serotonergic neurotransmitter systems [22].

Analyzing the neurobiological pattern for resilience, Charney [21] found "eleven possible neurochemical, neuropeptide, and hormonal mediators of the psychobiological response to extreme stress were identified and related to resilience or vulnerability: cortisol, DHEA, CRH, locus coeruleus norepinephrine system, neuropeptide Y, galanin, dopamine, serotonin, benzodiazepine receptors, testosterone, and estrogen (Table 3).

These neurochemical response patterns to stress help establish a framework for developing a measure of psychobiological allostatic load, and it may relate to resilience and vulnerability to the effects of extreme psychological stress [21].

Table 3. *Biological framework and response linked with resilience: neurochemical and/or endocrine responses - adapted to Charney [21]; additional overview [3, 16, 22]*

Neurochemical response to acute stress	Associations with Resilience
Cortisol	✓ Stress/induced increase constrained by negative feedback by means of glucocorticoid receptor and mineral corticoid receptors. ✓ Mobilizing energy, enhancing alertness, facilitating memory formation, and deploying the physiological resources needed to adequately respond to stress. ✓ Crucial in processes of memory consolidation, facilitating learning of emotional information. ✓ Has important regulatory function to amygdala.
Glucocorticoids (GCs), generally	✓ GCs plays very heterogeneous role in stress: they can serve permissive, stimulative, suppressive, and preparative functions. ✓ Crucial in processes of memory. ✓ Consolidation, facilitating learning of emotional information.
Dehydroepiandosterone (DHEA)	✓ High DHEA-cortisol ratios may have preventive effects regarding PTSD and depression. ✓ Inhibition of HPA axis.
CRH	✓ Reduced CRH release, adaptive changes in CRH-1 and CRH-2 receptors.
Locus coeruleus-norepinephrine system	✓ Reduced responsiveness of locus coeruleus-norepinephrine system.
Neuropeptide Y	✓ Adaptive increase in amygdala neuropeptide Y is associated with reduced stress-induced anxiety and depression.
Galanin	✓ Adaptive increase in amygdala galanin is associated with reduced stress-induced anxiety and depression.
Dopamine	✓ Cortical and subcortical dopamine systems remain in optimal window of activity to preserve functions involving reward and extinction of fear.
Serotonin (5-HT)	✓ High activity of postsynaptic 5-HT1A receptors may facilitate recover.
Benzodiazepine receptors	✓ Resistance to stress-induced down-regulation of benzodiazepine receptors.
Testosterone	✓ Increase in testosterone may promote increased energy and active coping and reduce depression symptoms.
Estrogen	✓ Short-term increase in estrogen may attenuate effects of stress-induced HPA axis and noradrenergic system activation.
Epinephrine (adrenaline)	✓ Infront the stress and challenge, epinephrine stimulates the nervous system to prepare the body for a quick response.
Norepinephrine	✓ Enhanced memory consolidation of emotional information and directly influence the activation of brain structures supporting memory. ✓ Decrease connected with the resilience, increase connected with the stress.

How can we describe the individuals with the highest index for psychobiological allostatic load and resilience?

According to the results of Charney's overview [21] a resilient individual will be described as person in the highest quartile for measures of DHEA, neuropeptide Y, galanin, testosterone, and 5-HT1a receptor and benzodiazepine receptor function and the lowest quartile for HPA axis, CRH, and locus coeruleus-norepinephrine activity.

Neuroendocrinological networks of resilience consist of the limbic-cortical network of the stress response, the meso-cortico-striatal network of reward processing, and the default mode network of interoceptive processing" [15].

The current state of research on the neurobiological framework of resilience focuses on the connections between psychological resilience and the stress and reward systems of the brain [22], how the brain regulates reward and motivation (hedonia, optimism, learned helpfulness), learns, remembers, and responds to fear (effective behaviour despite fear), and develops adaptive social behaviours (altruism, bonding and team work), and how these neural mechanisms relate to resilience and courage [21].

Current approaches describe how multiple biological systems work together in a complex, integrated manner to promote the body's adaptation to a threat or challenge [3], and to maintain resilience; some factors promote resilience in one domain, but may not promote resilience in another or all other domains [3]. Other biomarkers and components relevant to reaction to stress and establishing resilience involve: immune functioning, cellular aging, epigenetic modification of DNA, etc.

However, the most important and "principal" organ for identification of and (resilient) response to stress is the brain, as a target of stressful events [5]. The neuroanatomic basis of resilience is the topic of numerous research studies. Based on the methodology of research article selection (Chapter 2), only eight papers were used for the review of the neuroanatomic basis of resilience [3, 4, 5, 13, 15, 16, 21, 22].

Table 4. *Biological framework and resource linked with the resilience: neuroanatomic framework*

Neuroanatomic basis	Associations with Resilience
Brain regions	✓ Some of the key brain structures involved in the neurochemical response patterns following acute psychological stress.
Prefrontal cortex: medial prefrontal cortex lateral prefrontal cortex	✓ Stimulation promotes resilience. ✓ Selective activation enhances resilience. ✓ With amygdala have impact to quick attenuate learned fear and to function more effectively in dangerous situation.
Hippocampus, hippocampal complex, CA3 neurons in hippocampus	✓ It is modulated by the stress hormone. ✓ Important for spatial learning and memory. ✓ Most sensitive to stress, regulated HPA axis. ✓ Stimulation of the hippocampus decreases glucocorticoid secretion. ✓ Hipoccampus lesions increase basal glucocorticoid levels, especially during the stress recovery phase. ✓ Function to learn behaviour.
Amygdala	✓ Inhibition amygdala activity mediated by the medial prefrontal cortex have impact to quick attenuate learned fear and to function more effectively in dangerous situations. ✓ May reduce the strength of the original traumatic memory. ✓ Interacts with the hippocampus in mediating the effects of stress on the consolidation of contextual information. ✓ Interaction between amygdala and medial PFC are essential for successful emotion regulation. ✓ Emotional behaviour.
Hypothalamus HPA axis: Hypothalamic-pituitary-adrenalin axis	✓ Adequately response to stress. ✓ Lower ANS or HPA axis reactivity /often buffered from risk and show protection ✓ HPA axis enacts a more delayed, longer-term response to stress through a cascade of hormonal processes that culminates in the release of cortisol. ✓ HPA axis leads to the release of glucocorticoids.
Ventral tegmental área Potassium channel in the ventral tegmental area	✓ Regulating motivated behaviour. ✓ One of the components of brain reward circuits. ✓ Important mediator of active stress, a channel to enhance resilience.
Locus coeruleus	✓ The locus coeruleus–norepinephrine system globally. LC activated by stressors Modulates arousal, alerting and orienting functions. ✓ Have a powerful effect on the regulation of multiple memory systems. ✓ Reduced responsiveness of locus coeruleus norepinephrine system.
Nucleus accumbens	✓ Reward seeking, production resilience through self-care, and seeking social support.
Autonomic nervous system	
PNS Parasympathetic nervous system	✓ Reducing arousal and promoting restoration ("rest and digest"). ✓ lower ANS or HPA axis reactivity / often buffered from risk and show protection
SNS Sympathetic nervous system	✓ Mobilize the body to respond to stress through psychological activation. ✓ lower ANS or HPA axis reactivity. Often buffered from risk and show protection.

4.2. Selected molecular correlates of psychological resilience

It is believed that psychological resilience is moderately heritable, and influenced in equal parts by both environment and genetic factors [5], which would lead to the conclusion that the stable component of resilience is 50% heritable [24]. Ryan and Ryznar [24] analyzed the molecural basis of resilience. Many gene variants, oftentimes in association with corresponding protein biomarkers, are thought to be involved in development and modulation of resilience, their impact either positive or negative on the final outcome. They considered *PRTFDC1* gene, *DCLK2* and *KLHL36* genes, *NR3C2* gene, *NPY* gene, *FKBP5* gene, etc.

Phosphorybosil Transferase Domain Containing 1 (*PRTFDC1*) gene is regarded as a possible novel PTSD gene. It codes phosphorybosil transferase domain-containing protein 1, a member of a protein family important in purine salvage pathway, which allows for bases coming from in DNA and RNA catabolism to be converted back into nucleotides [24]. The brain is amongst those organs that cannot synthesize nitrogen bases de novo, and relies heavily on this pathway [25].

Certain alleles of *DCLK2* and *KLHL36* genes have also been connected to resilience. The former might be crucial for developing positive social skills and is thought to play a part in regulation of *NR3C2* gene, which has previously been associated with resilience [24].

It is important to note that while genomes across all somatic cells of an individual remain mostly the same throughout the life, the expression of genes varies immensely thanks to an intricate system of epigenetic markers, which include DNA[1] methylation, histone modifications, and non-coding RNAs (ncRNAs)[2]. These can be involved in both heritable silencing and activation. Epigenome is inherited mitotically and can be modified in response to a variety of changes in the environment, as well as during normal development and cell differentiation. The genome can directly affect the epigenome, thanks to the fact that changes in the genetic sequence can alter methylation sites and influence the efficacy of sequence-dependent functions of ncRNAs. Also noteworthy is the fact that the majority of research of the epigenetic component of resilience is focused on inheritance of adversity. In other words, epigenetic markers which correlate with diminished resilience are better known and researched than those that might be present in individuals with increased resilience [26].

The components of hypothalamic-pituitary-adrenal (HPA) axis can also be observed on the genomic scale. FK506 binding protein 51, coded by the *FKBP5* gene, inhibits the glucocorticoid receptor, which results in a decreased negative feedback inhibition of the HPA axis [24]. A series of studies of this gene were aimed at understanding the interactions between the genotype, epigenetic markers and exposure to childhood trauma [5]. The T-allele of rs1360780 polymorphism this gene shows delayed cortisol recovery after exposure to psychological stress, thus resulting in HPA axis dysregulation. The C-allele, on the other hand, allows for faster cortisol recovery. The intron 7 CpGs (DNA regions of cytosine followed by guanine in the linear sequence of bases) of T risk allele are also demethylated in individuals who report significant early trauma exposure. The protective C-allele might then also be activated through demethylation, positively impacting individual's stress response. This differs significantly from the study of Holocaust survivors, who exhibit high methylation of *FKBP5* [24].

A single nucleotide polymorphism within the *NPY* gene, which codes for neuropeptide Y, has also been linked with psychological resilience. The T-allele of the said polymorphism (rs16147) correlates with increased resilience, whereas the C-allele is associated with poorer overall resilience ("anxiety and depressive symptoms after experiencing childhood adversity") [24].

MicroRNAs (miRNAs) are small non-coding RNAs involved in gene expression. They inhibit messenger RNAs (mRNAs) by inducing their degradation or translational repression [27]. MiRNAs, a part of the intricate system of epigenetic regulation themselves, can be modified as a result of DNA methylation, histone modifications and chromatin remodeling. It is important to note that miRNAs have been found in all bodily fluids, and as such, they might have a widespread role in communication within the entire organism [27]. It has been shown that milder symptoms of anxiety disorder correlate with higher levels of certain miRNAs, namely miR-4505 and miR-663, which are present in blood. Another potential biomarker miRNA is miR-29c, found in peripheral blood lymphocytes of individuals exposed to stress through an arithmetic task. This miRNA has also been in correlation with increased survival rate in breast cancer through inhibition of particular genes involved in pathogenesis, which implies that it could play an important role in stress altogether, both physical and psychological [24].

4.3. Interventions to support resilience and biological feedback

APA emphasized that "psychological research demonstrates that the resources and skills associated with more positive adaptation (i.e., greater resilience) can be cultivated and practiced" [28]. Resilience also moderates the negative effects of stress and promotes adaptation, and it has been associated with increased psychological well-being [1, 29].

Current approaches to mental health are focusing on resilience rather than pathophysiology. This focus in many ways represents a paradigm shift in clinical-psychological and psychiatric research that has great potential for the development of new prevention and treatment strategies; the guiding idea is "Investigating health, not disease" [30].

In the research study of impact of psychological, social and biological mechanism on shaping resilience towards mental health [31], researcher suggested implication for action in enhancing children resilience. Based on this analysis, researchers recognized that these three types of mechanisms are all important for the development of resilience, but the social mechanisms are much more influential, and they can determine the role of biological and psychological mechanisms in resilience development.

There are a number of interventions likely to promote resilience and resilient brain function, including parenting and community-based interventions for children and adolescents, hardiness training, mediation and mindfulness approaches, and aerobic exercise [5].

[1] DNA — deoxyribonucleic acid.

[2] RNA — ribonucleic acid.

What is the impact of educational interventions on the biological phenomena linked to stress management and resilience?

Based on the understanding of the biological process that is connected with resilience, the overview of the treatment to enhance and promote resilience suggests using supportive factors (dyadic support, educational support) that have an impact on adaptive regulatory activity within the ANS and HPA axis, and stress and resilience physiology [3].

Recommended interventions (strategies and procedures) to enhance resilience [3, 5, 15, 32]:

- Psychological and behavioural therapy: it can be used to enhance resilience and mental flexibility and to reduce the symptoms of mental disorders; it should be kept in mind that psychotherapy generally takes place over a long period, and works slowly;
- Active adaptations largely impact resilience.
- Psychological cognitive therapies;
- Life skills education-based programme;
- Intensive mindfulness meditation training;
- Stress inoculation training;
- Enhancing early functional attachment relationship and parenting quality;
- A physically and emotionally safe and enriched environment creates the basis to down-regulate stress activation, and enhances neural proliferation towards the prefrontal cortical regions;
- Specific resilience enhancing interventions: promoting peer relationship and prosocial behaviours in adolescence; enhancing a person sense of control in early adulthood.

5. CONCLUSION

The main conclusion emphasizes the importance of a holistic approach to psychological resilience as a construct supported by and affecting the social dimension as well as the biological dimension of personal functioning. There are no uniform indicators of biological functions included in resilient functioning. Consideration of the biological framework of resilient functioning demands analysis of different contexts and collaborative interactions between them and resilient persons as a bio-psycho-social system.

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REFERENCES

[1] DigiPsyRes team (2024). *Manual: Step by Step from trainees to trainers and supporter in student peer support network*. Kragujevac: University of Kragujevac and ERASMUS+ project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crisis – DigiPsyReS".

[2] Oxford Advanced American Dictionary online. Resilience. https://www.oxfordlearnersdictionaries.com/definition/american_english/resilience?q=resilience

[3] Bush, N., & Roubinov, D. S. (2021). Bringing a neurobiological perspective to resilience. In M. Ungar (Ed.), *Multisystemic resilience: Adaptation and transformation in contexts of change* (pp. 35–56). Oxford University Press. https://doi.org/10.1093/oso/9780190095888.003.0003 Available from https://oxford.universitypressscholarship.com/10.1093/oso/9780190095888.001.0001/oso-9780190095888-chapter-3

[4] Wackerhagen, C., Reppmann, Z., Riepenhausen, A., Veer, I. M., & Valter, H. (2021). Cognitive neuroscience of psychological resilience: State of research and unresolved issues. *Nervenheilkunde*, 40(4), 249-258. DOI: 10.1055/a13719465

[5] Feder, A., Fred-Torres, S., Soutwick, S. M., & Charney, D. S. (2019). The Biology of Human Resilience: Opportunities for Enhancing Resilience Across the Life Span. *Biological Psychiatry,* 86, 443–453. https://doi.org/10.1016/j.biopsych.2019.07.012.

[6] Hunter, R. G., Gray, J. D., & McEwen, B. S. (2018). The Neuroscience of Resilience. *Journal of the Society for Social Work and Research*, 9(2). 305–339.

[7] Watanabe, N., & Takeda, M. (2021). Neurophysiological dynamics for psychological resilience: A view from the temporal axis. *Neuroscience Research*, 175(2022), 53–61. https://doi.org/10.1016/j.neures.2021.11.004

[8] APA Dictionary of Psychology: Resilience. American Psychological Association. https://dictionary.apa.org/resilience

[9] Luthar, S. S., Cicchetti, D., & Becker, B. (2000). The Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. *Child Development*, 71(3), 543–562.

[10]Lepore, S. J., Revenson, T. A. (2006). Chapter 2. Resilience and Posttraumatic Growth: Recovery, Resistance, and Reconfiguration. In L. G. Calhoun & R. G. Tedeschi (Eds.). *Handbook of Posttraumatic Growth: Research and Practice* (pp. 24-46). New Jersey – London: Lawrence Erlbaum Associates Publishers.

[11]Bjekić, D., & Stojković, M. (2022). University teachers' resilience. In I. Milićević (Ed.). *Proceedings TIE2022* (p. 461–469). Čačak: Faculty of Technical Sciences.

[12]Boon, H. J. (2021). Teachers' resilience: conceived, perceived or lived-in. In: Mansfield, C.F. (eds). *Cultivating Teacher Resilience.* Springer, Singapore.

[13] Cherry, K. (2021). *Resilience*. Verywellmind. https://www.verywellmind.com/what-isresilience-2795059

[14]Tait, M. (2008). Resilience as a contributor to novice teacher success, commitment, and retention. *Teacher Education Quarterly*, Fall 2008, 57–75. https://files.eric.ed.gov/fulltext/EJ838701.pdf

[15]Liu, H., Zhang, C., Ji, Y., & Yang, L. (2018). Biological and Psychological Perspectives of Resilience: Is It Possible to Improve Stress Resistance? *Frontiers in Human Neuroscience, Section Brain Health and Clinical Neuroscience*, 11, https://doi.org/10.3389/fnhum.2018.00326

[16]Dimitrov, A., Demin, K., Fehiner, P., Walter, H., Erk, S., &Weer, I. M. (2018). Differences in Neural Recovery from Acute Stress Between Cortisol Responders and Non-responders. *Frontiers in Psychiatry*, 9, A631, 1-13. doi:10.3389/fpsyt.2018.00631

[17]Contrada, R. J., & Baum, A. (Eds.) (2011). *The Handbook of Stress Science: Biology, Psychology and Health*. New York: Springer Publishing Company.

[18]Borell, E. H. von (20001. The biology of stress and its application to livestock housing and transportation assessment. *Journal of Animal Science,* 79(E.Suppl.), E260-E267. DOI: 10.2527/jas2011.79E-SupplE260x

[19]Takata, A. (2012). The Biological Basis of Psychological Resilience as a Consequence of Active Processes. *Japanese Journal of General Hospital Psychiatry*, 24(1), 18–24.

[20] Su, P., Yi, J., Chen, X., & Xiao, Y. (2023). Visual Analysis of Psychological Resilience Research Based on Web of Science Database. *Psychology Research and Behavior Management,* 16, 465–481. https://doi.org/10.2147/PRBM.S394693

[21]Charney, D. S. (2024). Psychobiological Mechanism of Resilience and Vullenability: Implications for Successful Adaptation to Extreme Stress. *American Journal of Psychiatry*, 161(2), 195-215. doi:10.1086/697956

[22]Rutten, B. P. F., Hammels, C., Geschwing, N., Menne-Lothmann, C., Pishva, E., Schruers, K., van den Hove, D., Kenis, G., van Os, J., & Wichers, M. (2013). Resilience in mental health: linking psychological and neurobiological perspectives. *Acta Psychiatrica Scandinavica*, 128, 3 – 20. DOI: 10.1111/acps.12095

[23] Sun, X., Song, Z., Si, Y., & Wang, J-H. (2018). MicroRNA and mRNA profiles in ventral tegmental area relevant to stress-induced depression and resilience. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 86, 150–165. https://doi.org/10.1016/j.pnpbp.2018.05.023

[24]Ryan, M., & Ryznar, R. (2022). The Molecural Basis of Resilience: A Narrative Review. *Frontiers in Psychiatry*, May 6; 13:856998. doi: 10.3389/fpsyt.2022.856998

[25]Ipata- P. L. (2011). Origin, utilization, and recycling of nucleosides in the central nervous system. *Advances in Physiology Education*, 35(4), 342–346. DOI: 10.1152/advan.00068.

[26]Smeeth, D., Back, S., Karam, E. G., Pluess, M. (2021). The Role of Epigenetics in Psychological Resilience. *Lancet Psychiatry*, 8(7), 620–629. doi: 10.1016&S2215-0366(20)30515-0.

[27]Wiegand, C., Savelsbergh, A., & Heusser, P. (2017). MicroRNAs in Psychological Stress Reactions and Their Use as Stress-Associated Biomarkers, Especially in Human Saliva. *Biomedicine Hub*, 2:481126, DOI: 10.1159/000481126

[28]APA. Resilience. American Psychological Association. Available on https://www.apa.org/topics/resilience

[29]Pidgeon, A.M., Rowe, N.M., Stapleton, P., Magyar, H.B., & Lo, B.C.Y. (2014). Examining characteristics of resilience among university students: An international study. *Open Journal of Social Sciences*, 2, 14-22. doi:10.4236/jss.2014.211003

[30]Kalish, R., Müller, M. B., & Tuescher, O. (2015). A conceptual framework for the neurobiological study of resilience. *Behavioral and Brain Sciences,* 38(1), 1-79. DOI: 10.1017/S0140525X1400082X

[31]Mu, Y (2023). Building Resilience to Reduce Mental Health Illnesses: Guidelines for Government Actions. *Journal of Student Research,* 12(4). 1-6. DOI: 10.47611/jsrhs.v12i4.5861

[32]Rossouw, P. J. (2015). Resilience: A Neurobiological Perspective. *Neuropsychotherapy in Australia*. 31, 3-8. Mediros.com.au. Author self-archived in ResearchGate.