# ABSTRACTS

# Physiologie et Médecine de l'Apnée

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## ENERGETICS OF UNDERWATER SWIMMING IN APNEA

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Dynamic apnea with fins (DYN) involves swimming the longest distance relying solely on body oxygen and anaerobic energy stores. The energy cost per unit distance (C) is therefore an major determinant of DYN performance. Therefore, our aim was to assess the C of DYN and its aerobic ($EO_2$), anaerobic lactic (ELa) and alactic (EPCr) energy contributions. In a 50-m swimming pool, 22 free divers (three females, ten with bi-fins, six with mono-fin, six with both) performed a 50-m DYN, and seven also a 100-m DYN. Net C above resting was calculated from the $O_2$ debt measured at emersion plus ELa (calculated from the blood lactate increase). In nine subjects (six of whom performed also the 100-m DYN), determination of hemoglobin mass and total lung capacity allowed also an estimate of $EO_2$ and, by subtraction, EPCr. C was unchanged between the 100-m and the 50-m DYN ($p=0.81$) and resulted higher with bi-fins than with the monofin (7.4±2.2 vs. 5.5±1.6 J/kg/m, $p=0.02$) due to a higher $O_2$ debt and ELa. DYN personal best correlated better with the distance swum per unit of $EO_2$ at 50 m ($R^2=0.70$) than with C ($R^2=0.25$). From 50 m to 100 m, fractional $EO_2$ decreased (58%±19% to 47%±13%, $p=0.02$), ELa increased (10%±5% to 21%±5%, $p<0.001$) and EPCr was unchanged (31%±20% to 32%±15%, $p=0.83$). The C of DYN seems slightly lower than usually reported for surface swimming with fins at the same speed. At 100 m, ELa and EPCr were disproportionately high for the exercise intensity, possibly due to a diving response. Sparing $EO_2$ is at least as important as C in determining DYN performance.

***Keywords**: Energy cost, dynamic apnea, aerobic.*

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## BLOOD PRESSURE CONTROL DURING BREATH HOLDING

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Cardiovascular responses to breath holding (BH) are influenced by several factors; cease of breathing movements, contact with water, and redistribution of blood during submersion can activate different reflexes. In this context, the arterial baroreflex (BR) still responds to the abrupt blood pressure (BP) changes that occur at BH start. To test the effects of water submersion and face contact with water on the BR responses at BH start we enrolled 16 trained BH divers (6F, 43±13y.o., 72±17Kg, 172±10cm). They performed two maximal BH at rest in: dry in supine position (DS), floating in water in supine position (WS), and in water in prone position (WP). Water temperature was 29.5±0.3◦C. Beat-by-beat BP and pulse interval (PI) were obtained by volume clamp method and BR sensitivity by linear regression analysis. Steady state BP did not differ among conditions ($p=0.92$), whereas PI was higher in WP (1040±171) with respect to WS (924±136, $p=0.004$) and DS (865±178, $p< 0.01$). BP fall at BH start was similar among conditions ($p=0.21$). BR sensitivity fell similarly and reached similar values during BH steady state ($p=0.16$) but recovered faster in WP than in the other conditions. We concluded that only water submersion with face immersion was able

to elicit a greater bradycardic response possibly due to trigeminocardic reflex. BR sensitivity changes during BH were not altered by water submersion even in prone position.

***Keywords:*** *arterial baroreflex, blood pressure, heart rate*

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## DIVING INTO THE UNKNOWN: MUSCLE CHARACTERISTICS OF ELITE BREATH-HOLD DIVERS

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**Purpose:** The characterization of skeletal muscle phenotypes in diving populations remains one of the least explored domains of breath-hold physiology, representing a critical gap in our understanding of how skeletal muscle adapts to the unique demands of breath-hold diving. Accordingly, the present study investigated specific markers of skeletal muscle structure and metabolism in elite breath-hold divers.
**Methods:** Twenty males volunteered to participate in this study, matched for age, body size, and whole-body aerobic capacity [10 elite breath-hold divers (EBHD); 10 non-divers (ND)]. A percutaneous skeletal muscle biopsy was obtained from the *m. vastus lateralis* to quantify capillarisation, fibre type distribution (i.e., type I, IIa and II other), and protein content of cytochrome c oxidase (COX) complexes, cytochrome synthase (CS) and monocarboxylate transporters (MCT) isoforms.
**Results:** MCT4 content was 28% higher in EBHD compared with ND ($p = 0.020$), whereas MCT1 and CS showed no between-group differences ($p \geq 0.161$). COX V expression was higher in the ND ($p = 0.049$), while no between group differences were noted in complexes I, II, II and IV ($p \geq 0.253$). Capillary density was significantly higher in EBHD ($p = 0.012$), while fiber type distribution did not differ between groups ($p \geq 0.657$).
**Conclusion:** EBHD exhibit skeletal muscle characteristics indicative of enhanced blood – muscle exchange capacity and augmented lactate efflux potential. Such adaptations may confer an advantage during prolonged breath-holds by preserving glycolytic function and maintaining redox homeostasis. In recovery, these traits likely facilitate more efficient clearance of metabolic byproducts.

***Keywords****: Lactate Transporters, Mitochondrial Complexes, Fibre Type.*

## HYPOXIC CONDITIONING USING VOLUNTARY APNEA TO IMPROVE PERFORMANCE IN SWIMMERS

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Altitude training for athletes is widespread, but the effects are still disputed and debated. Apnea training is an interesting alternative, as it produces beneficial physiological changes for the athlete that could lead to improved performance. To this end, 20 swimmers from the same club, divided into two groups, will undergo training with or without glossopharyngeal insufflation. This type of training should enable them to improve respiratory muscle strength, lung volumes and buoyancy. Next, 20 swimmers divided into 2 groups will undergo apnea training at different lung volumes for 4 weeks. The protocol is expected to improve swimmers' performance through enhanced oxygen transport capacity and reduced ventilatory sensitivity to carbon dioxide. Finally, we will test the impact of mono-ester ketone supplementation in swimmers to reduce hypercapnic stimulation and oxygen consumption, ultimately to improve performance during apnoeic efforts in swimmers.

***Keywords:*** *Hypoxia, Apnoea, Pulmonary function, Hypoxic dose, nutrition*

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## EFFECTS OF FREEDIVING ON LUNGS

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The presentation will address the various effects of freediving on the lungs, ranging from the surface to the ocean floor. Through the implementation of ventilatory training, freedivers enhance the strength of their ventilatory muscles, thereby enabling them to achieve greater volumes. Furthermore, they have the capacity to utilise specific techniques, such as glossopharyngeal breathing, which serve to augment the volume of air inhaled. It is evident that this phenomenon is accompanied by consequences for the respiratory system. With diving and the increase in pressure, a number of known mechanisms such as blood shift and probably others enable freedivers to descend to depth. We will look at these mechanisms in more detail and present the potential risks induced by these pressures.

***Keywords****: pulmonary function, depth, pressure*

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## FROM MODELING TO VALIDATION: A CRITICAL OVERVIEW OF DECOMPRESSION IN BREATH HOLD DIVING

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The likelihood of developing decompression sickness (DCS) after repetitive breath-hold (BH) dives was considered only after the first case studies by Paulev (Decompression sickness following repeated breath-hold dives. J Appl Physiol. 1965; 20(5): 1028-1031.) With increasing depths reached during competitions and the use of sea scooters the threat of DCS in breath-hold diving became more relevant. Despite the undocumented algorithms used by the dive computer manufacturers to prevent ”taravana”; the efforts in prevention of DCS in BH diving by mathematical modeling are not abundant. This communication reviews the existing models for DCS in BH. This study proposes the validation of models by using the DCS cases in the literature; this validation modality is applied to selected models. Moreover, an alternative method of validation based on the conversion of Doppler scores to the probability of DCS is discussed alongside with the optimal time window for Doppler detection as well as detection sites.

***Keywords:*** *Taravana, Decompression Sickness (DCS), Apnea, Venous Gas Emboli (VGE)*

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## DOPING IN BREATH-HOLD DIVING COMPETITIONS: PHARMACOLOGICAL AND ETHICAL PERSPECTIVES

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Unlike in endurance or strength sports, the pharmacological landscape in apnea focuses on reducing oxygen consumption, anxiety, and cardiac workload, rather than on enhancing energy output.

However, as the 2025 Škerbi´c et al. analysis of the Vertical Blue case demonstrates, the line between medical use and doping is often blurred. **Benzodiazepines** may reduce anxiety and promote relaxation, favoring bradycardia and oxygen conservation. However, sedation impairs cognitive control, increasing blackout risk. **Propranolol**, a beta-blocker, decreases heart rate and myocardial oxygen consumption, theoretically extending dive time. Excessive bradycardia, however, can induce syncope. **Acetaminophen and NSAIDs** can blunt pain and thermal discomfort, masking distress signals. their misuse raises questions about the meaning of fair play in sport. **Hormones** such as erythropoietin (EPO), corticosteroids, or testosterone may enhance oxygen transport or recovery. Mechanism and potential use: Erythropoietin (EPO) to enhance oxygen transport; testosterone for recovery/erythropoiesis; corticosteroids for metabolic modulation. Risks: Increased hematocrit/viscosity (thrombosis risk) with EPO; immunosuppression with corticosteroids. **Sildenafil**: a phosphodiesterase-5 inhibitor that augments nitric-oxide–cGMP signaling, producing pulmonary vasodilation and reduced pulmonary

artery pressure. In high-altitude settings. Human studies demonstrate attenuation of altitude-induced pulmonary hypertension and improved gas exchange . A direct transfer of what is potentially useful in HAPE to free-diving is inconsistent. More, despite physiologic rationale, animal data from Blatteau and colleagues indicate no bene- fit for diving safety and, importantly, a potential harm signal: in a rat model, sildenafil pre-treatment increased the incidence and severity of neurological decompression sickness (DCS).

***Keywords:*** *Ethics, performance enhancement, risks*

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**Guillaume Néry, World Champion**

L'idée de cette présentation est d'expliquer en détail ce qui se passe pendant une plongée et de partager tous les obstacles que je dois surmonter, à la fois physiquement et mentalement, afin de voir s'il existe des similitudes avec les projets et les défis que nous rencontrons tous dans la vie.
Je suis comme fil conducteur une plongée, de la surface jusqu'au fond, puis la remontée. Tout au long de la présentation, je propose de courts exercices de respiration et d'apnée afin que le public puisse vivre une expérience et pas seulement écouter un discours.
Je divise la présentation en plusieurs parties :
Je commence bien sûr par une introduction au monde de l'apnée et un bref aperçu de ma carrière.
Ensuite, la partie principale de la présentation est divisée en quatre : la surface, la descente, le fond et la remontée. Chaque partie est associée à un verbe clé, et je développe plusieurs points essentiels.

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## BRAIN ADAPTATIONS TO FREEDIVING: LESSONS FROM SOUTHERN ELEPHANT SEAL AN EXTREME DIVER

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Human brain is highly vulnerable to the absence of oxygen, hypoxia. Repeated hypoxic events are reported in various brain pathologies and represent a risk factor for neurodegener- ative diseases. Marine mammals, such as pinnipeds, are naturally adapted to daily repeated hypoxic events during foraging dives. How do pinniped brains cope with repeated severe hypoxic events?
Southern Elephant Seal (SES) represents a unique mammalian model for better understand- ing of management of oxygen capabilities, as they alternate between terrestrial and aquatic habitats. SES is the most extreme diver, with a record of 2h and 2000m deep, dives all day at sea even for sleeping (”1h per day). SES showed significant modifications for cerebral vascularization between pups and adults, while the animals transition from terrestrial to marine life: 1) in the grey matter, the vascular volume fraction was ”62% higher in adults;
2) the vessels were significantly more ramified and tortuous in adults (e.g. 6% more tortuous in the white matter). These cerebrovascular adaptations would facilitate access to oxygen during SES dives.
Interestingly, adult SES vessels share similar phenotypes to pathological cerebral-blood ves-

sels described in human neurodegenerative diseases. Using blood biomarkers of brain health, we observed increase of brain proteins in the plasma of the SES after dives. Then, abnormal vessel-morphologies and presence of brain proteins in the blood raise the question of the potential pathological situation of repeated severe hypoxia for adult SES.
*Contributors* Erwan Piot, Baptiste Picard, Laura Charlanne, Christophe Dubois, Christophe Guinet, Caroline Gilbert

*Funding supports*: CNRS, ANR and IPEV
***Keywords:*** *hypoxia, pinniped, Brain*

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**HUMAN THERMOREGULATORY FUNCTION DURING UNDERWATER ACTIVITIES IN COLD WATER**

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During dives in cold water, body core temperature is preserved via the seamless recruitment of cold-defence thermoeffectors, viz. peripheral vasoconstriction attenuates heat loss to the surroundings, and shivering and non-shivering processes augment endogenous heat production. Inefficient activation of any of these thermoregulatory mechanisms may result in hypothermia, degrading divers' physical and cognitive performance, and, in some instances, threatening their life during protracted exposure. For instance, it is well established that whole-body cold stress decreases apneic duration, and impairs manual dexterity, accuracy, attention and decision-making. Interestingly, cross-sectional studies performed in Japanese and Korean divers, have shown that, at least before the introduction of protective suits and gloves, prolonged repeated cold-water dives may lead to the induction of thermal adaptation, characterized by augmented cold-induced vasoconstriction (i.e., "insulative" adaptation), and perhaps by increased thermogenesis associated with the increased activation of non-shivering processes (i.e., "metabolic" adaptation). Furthermore, aside from the low temperatures encountered underwater, divers' thermal balance and performance may also be compromised, via non-thermal pathways, by alterations in the partial pressure of metabolically-active (e.g., carbon dioxide) and/or of inert (e.g., nitrogen) gases inhaled at great depths. A summary of the current state of human-based evidence on the independent and combined effects of cold stress and the diving-specific gaseous environment on thermoregulation and cognition will thus be presented.

***Keywords*** **: cold, cold injury, shivering, cold adaptation, gaseous environment**

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## CROSS-ADAPTATION BETWEEN HEAT AND HYPOXIA: A PROMISING CONCEPT TO MAXIMIZE BREATH-HOLDING PERFORMANCE?

**Guillaume Costalat**

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Cross-adaptation refers to the process by which acclimation to one environmental stres- sor, such as heat, enhances tolerance and physiological responses to another stressor, such as hypoxia. Traditionally, breath-hold divers have relied on cold water immersion, though evidence supporting its efficacy in improving breath-holding (BH) performance is limited. In contrast, heat stress, applied either passively or combined with exercise, has been shown to induce beneficial physiological adaptations. Recent studies indicate that heat acclimation may improve physiological responses under hypoxic exposure, including increased arterial oxygen saturation and reduced heart rate. These changes may result from heat-induced reductions in renal blood flow, which trigger erythropoietin release and ultimately lead to an increase in haemoglobin mass. Given that BH performance partly relies on delaying tis- sue hypoxia, repeated heat exposure could prolong BH duration by postponing the onset of hypoxemia. Additionally, heat acclimation has been associated with decreased energy cost during submaximal exercise, making heat exposure a potentially favorable strategy for im- proving dynamic apnea performance. At the cellular level, cross-adaptive effects are thought to involve shared molecular pathways, particularly the upregulation of heat shock proteins (HSPs) and hypoxia-inducible factors (HIFs), which help maintain cellular homeostasis and protect against stress-induced damage. While most of the current literature focuses on aero- bic performance under traditional hypoxic environments (normobaric or hypobaric hypoxia), further work is needed to explore these adaptations in the context of apnea-induced hypox- emia. Overall, heat could offer a promising strategy to boost performance in challenging environments such as during prolonged voluntary breath-holding.

***Keywords:*** *Cross, adaptation, Heat, Hypoxia, Breath, holding, Training*

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## PULMONARY EDEMA AND BREATH-HOLD DIVING

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Immersion pulmonary edema is likely to occur in various immersed activities such as swimming, scuba diving, and breath-hold diving. It combines the effects of immersion and central blood shift with the constraints of the practiced immersed activity and individual risk factors.

Apnea diving, and specifically deep diving, exposes the athlete's cardiorespiratory system to exceptional constraints, leading to specific pathophysiological and clinical aspects of these pulmonary edemas, including the diving response and the mechanical constraints on the lungs due to pressure. Unlike scuba divers, who often describe respiratory distress with acute dyspnea, free deep divers typically report hemoptysis and mild respiratory discomfort.

Free divers must be aware of specific preventive measures aimed at reducing mechanical constraints on the lungs, particularly during descent and at the bottom. Although these accidents

seem common, they must be taken seriously, as they are likely to increase the risk of loss of consciousness and death during apnea.

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## WHAT DID WE LEARN ABOUT DECOMPRESSION SICKNESS

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Over the past decade, SCUBA decompression research has shifted from prescriptive, one-size-fits-all tables toward risk-stratified and potentially personalized strategies grounded in venous gas emboli (VGE) monitoring, epidemiology, and modeling. Large cohort anal- yses from the DAN Europe DSL database clarified diver-, environment-, and profile-level predictors of DCS and VGE, reinforcing that similar profiles can yield markedly different bubble loads across and within individuals. Controlled and observational studies compar- ing algorithms refined understanding of gradient factors (GF) and stop distribution, with accumulating evidence arguing against overly deep stops and favoring more efficient shallow time reallocation. Parallel work explored preconditioning to blunt endothelial dysfunction and bubbles (e.g., short bouts of mini-trampoline exercise). Emerging machine-learning approaches show promise for predicting post-dive bubble grades from profile features, a po- tential step toward individualized decompression. Recent basic and applied studies also examined modifiers such as CO exposure, temperature, and workload, highlighting complex interactions that may amplify risk despite ”safe” profiles. Overall, contemporary evidence supports decompression strategies that (i) prioritize efficient shallow stops over deep-stop loading, (ii) account for substantial inter- and intra-diver variability, (iii) integrate smarter monitoring beyond VGE alone, and (iv) rigorously evaluate adjuncts (preconditioning, exer- cise timing) before routine adoption. The field is moving toward data-driven, individualized decompression while underscoring the need for high-quality randomized and longitudinal studies to link physiologic markers with clinical outcomes. All this will open a necessary new way of understanding that the DCI like symptoms experienced in freediving are not only related to a ”classic” understanding of decompression mechanisms.

***Keywords:*** *DCS Perspectives, Supersaturation, Adverse effects*

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## EARLY RECOGNITION OF DCI SYMPTOMS IN FREEDIVING: A MEMORY TOOL FOR FREEDIVERS BY FREEDIVERS

**Juan Valdivia Valdivia**

UNU Freediving Foundation – 26 S Treasure Dr, É tats-Unis

Early Recognition of DCI Symptoms in Freediving: A Memory Tool for Free-divers by Freedivers.

**Background:** Decompression illness (DCI) is increasingly observed among elite and recreational freedivers, particularly at greater depths and during repetitive deep dives. Early recognition of neurological symptoms is crucial for timely intervention, yet freedivers often lack a simple, practical tool for symptom identification in the field. To address this gap, we

developed a mnemonic acronym-**MFSCO**, ”Mask, Fins, Snorkel, CO2”.

**Methods:**A review of clinical presentations from documented freediving-related DCI cases over the past five years was conducted. The acronym was created in 2017 and approved by AIDA in 2018. Neurological and systemic features were identified and categorized into a concise acronym, to facilitate recall and recognition by athletes and safety teams in remote areas.

**Results:** The **MINI Neuro Exam** is a simplified, field-adaptable neurological screening tool specifically designed for **freedivers in remote or resource-limited environments**. Its components are structured around the easily memorized acronym representing key domains of neurological function:

**M – Motor Function/Memory**

**F – Fine Motor Skills and Feeling S – Speech**

**C – Coordination O – Orientation**

– Vision (”Two Eyes”)

This enables rapid identification of gross **neurological abnormalities** associated with **DCI**. Offers a field-adapted, practical tool for rapid recognition.

**Conclusion:** The **MFSCO** acronym provides freedivers with an accessible memory tool to recognize potential DCI symptoms early. By empowering divers and safety teams to identify warning signs, it encourages earlier intervention, reinforces a culture of safety. Further validation of this tool in larger cohorts is warranted.

***Keywords:*** *neuro exam, mini neuro exam, DCI, physical exam, Freediving.*

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**APNEE, UNE AVENTURE DE LA CONSCIENCE**

**Audrey Palma**

Dans « Apnée, une aventure de la conscience » (L’Harmattan, 2024), Audrey Palma propose une lecture originale de la plongée en apnée, envisagée comme une expérience transformatrice mobilisant corps, souffle et psyché. À la croisée des sciences humaines et de la pratique sportive, son essai interroge les effets physiologiques et psychologiques de l’apnée dans une société marquée par l’accélération, la fragmentation des repères et la perte du lien au vivant.

Loin de se limiter à une approche technique, l’auteure explore les états modifiés de conscience induits par la suspension volontaire de la ventilation, et les mécanismes de régulation émotionnelle qu’elle active. Elle questionne notamment la place du souffle dans la construction de l’identité, la gestion du stress, et la quête de sens. L’apnée devient ainsi un outil d’introspection, de reconnexion à soi, et potentiellement, un levier thérapeutique.

Audrey Palma met également en lumière les risques liés à la survalorisation de la performance, les dérives addictives et les enjeux de sécurité, en particulier autour des syncopes. Elle propose une typologie de ces épisodes, en lien avec les dynamiques psychiques du dépassement de soi.

Fruit de douze années de pratique, de recherche et d’enseignement, ce livre s’inscrit dans une perspective transdisciplinaire, articulant physiologie, psychologie et spiritualité. Il offre aux professionnels de santé, aux chercheurs et aux pratiquants une grille de lecture sensible et critique de l’apnée contemporaine.

***Mot clés*** *: psychologie, conscience, émotions*

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# ”PHENOMENOLOGY OF THE DEPTHS: THE FREEDIVING GESTURE AT THE THRESHOLDS OF WORLD AND CONSCIOUSNESS”

**Inès Leferme**

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Inès Leferme’s PhD in Philosophy (Institut de Recherches Philosophiques, Université Paris Nanterre) explores deep freediving as a unique practice of boundary exploration-those of the sensible world, the living body, and consciousness itself. By examining both the physiological effects of hypoxia and pressure on the human organism, and the shifts in perception and self-awareness they generate, the project aims to describe the freediving experience in its full sensory, bodily, and subjective dimensions.

Drawing on data from physiological studies and qualitative investigations into lived experience (including interviews and freedivers’ personal accounts), the research seeks to bridge embodied experience with the biological constraints of extreme immersion. Supervised by Natalie Depraz (Université Paris Nanterre) and Frédéric Lemaitre (Université de Lorraine), this thesis adopts a dual perspective that questions the limitations of conventional scientific tools in accessing lived subjectivity. To address this challenge, it turns to methods drawn from experiential phenomenology-particularly microphenomenology-as well as contributions from contemporary cognitive science.

Through this philosophical research program, we aim to offer a renewed understanding of what it means to engage in deep freediving-not merely as an athletic performance, but as a singular way of relating to the world.

***Keywords*:** Phenomenology, freediving, self, awareness, extreme, subjective, qualitative investigation, philosophy, micro, phenomenology