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Evaluation of the Anti-Sickle Cell Activity of *Uvaria Chamea* P. Beauv. Roots Aqueous Extract

Lokonon Jacques Ezéchiel[1], SENOU Maximin[1], ABISSI Y. Gloria[1], TCHOGOU Pascal[1], DEHOU René[1], MEDOATINSA Espérance[1], KOUDORO Yaya[3], AGBANGNAN Pascal[3], ANAGO Eugénie[2], AKPOVI D. Casimir[2]

[1] Laboratory of Experimental and Clinical Biology (LaBEC), National School of Applied Biosciences and Biotechnologies (ENSBBA), National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM), R. Benin

[2] Laboratory of Applied Biology (LARBA), Polytechnic School of Abomey-Calavi (EPAC), University of Abomey-Calavi (UAC), R Benin

[3] Laboratory for Study and Research in Applied Chemistry (LERCA); Polytechnic School of Abomey-Calavi / University of Abomey-Calavi (UAC), R. Benin

Correspondence: Sènou M, Experimental and Clinic Biology Laboratory, National School of Applied Biosciences and Biotechnology, National University of Science, Technology, Engineering and Mathematics (UNSTIM), Dassa-Zoumé, R. Benin

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Abstract

Sickle cell disease was a very common hemoglobinosis in tropical countries. Several plants were used in traditional Beninese medicine to relieve sickle cell crises. The present work was carried out to test the efficiency of Uvaria chamea roots aqueous extract in the treatment of sickle cell crises.

Methods: Uvaria chamea roots aqueous extract was preincubated at different concentrations with blood cells from SS red blood cells before or after the Emmel Test. Intra-erythrocyte oxidative stress was measured by methaemoglobin assay after incubation of the extract with hemoglobin. In vivo, the action of the extract on Hemoglobin level, Mean Corpuscular Volume, and platelet count was measured in Wistar rats.

Results: The extract significantly prevented the formation of sickle cells at doses of 40 and 20 mg / ml of blood ($P < 0.05$) and significantly reduced sickle cells to the normal biconcave form at the dose of 40 mg / ml ($P < 0.05$). It lowered the production of methemoglobin at a dose of 10 mg / ml, suggesting antioxidant activity. Hemoglobin level, Mean Corpuscular Volume, and platelet count did not significantly increase in treated rats, indicating that the extract did not stimulate erythropoiesis or thrombopoiesis.

Conclusion: Uvaria chamea extract inhibited dose-dependent sickling of red blood cells. It reduced intraerythrocyte oxidative stress but did not show hematopoietic activity. It could therefore be considered in the preventive or curative management of sickle cell crises, but not against anemia.

Keywords: sickle cell disease, *Uvaria chamea*, anemia, Benin

1. Introduction

Hemoglobinopathies were genetic diseases with inherited abnormalities of hemoglobin. They were divided into two groups : the group of hemoglobinoses presenting structural abnormalities of the globin chain and that of thalassemias characterized by a deficit of one or more chains of hemoglobin. Some pathologies were composite and belong to both groups at the same time (Aubry, 2020). The prevalence of sickle cell trait fluctuated between 20% and 30% in affected countries with a high disease burden (WHO, 2020). In 2016, nearly 5% of the world's population carried a gene responsible for a hemoglobin abnormality and each year, hundreds of thousands of infants were born around the world with thalassemia syndromes (30%) or sickle cell disease (70%). Sickle cell disease was among the most common monogenic diseases worldwide (Fatima et al., 2016). An estimated 312,000 people with SS hemoglobin were born each year worldwide, with the majority of these 236,000 births in sub-Saharan Africa (Piel et al., 2013). The management of sickle cell disease was not easy because the majority of affected countries were poor.

At the same time, traditional medicine was the most widespread form of medicine that people turn to for treatment (WHO, 2002). Traditional medicine was very old. It was the sum of all the knowledge, skills and practices based on the theories, beliefs and experiences of different cultures, whether they were explainable or not, and which were used in the preservation of health, as well as in prevention, diagnosis, amelioration or treatment of physical or mental illnesses (WHO, 2013). Indeed, according to estimates, traditional medicine accounted for 80 to 90% of health care in Africa (WHO, 2002). In recent decades, herbal medicine research became of greater scientific concern (Niyah Njike et al., 2005). It was within this framework that this work aimed to experimentally test the effectiveness of the roots of Uvaria chamea used by traditional therapists in Benin in the management of sickle cell disease.

2. Material and Methods

2.1 Plant Material and Aqueous Extraction

The roots of *Uvaria chamea* were collected in Hêvié in the commune of Abomey-Calavi in Benin. The identification and certification of the plant was made at the National Herbarium of the University of Abomey-Calavi on number YH268 / HNB. The plant was dried at laboratory temperature (20 ° - 25 °) out of direct sunlight and moisture for three weeks. They were then powdered and stored in black sachets (Koudoro et al., 2018 ; Tchogou et *al*., 2021). The technique used to prepare the extracts was that of maceration. After filtration, the extracts were evaporated to dryness at 60 ° C using a Heidolph type rotary evaporator (Koudoro et al., 2018; Tchogou et al., 2021).

2.2 Human Material

Blood samples from ten (10) SS sickle cell patients were taken at the Zou / Collines departmental hospital in Benin with the consent of the patients after approval by the Ethics Committee of the National School of Applied Biosciences and Biotechnologies in Benin.

2.3 Animal Material

The animal material is comprised of six (6) strain albino Wistar female rats from the animal house of IBSA in Benin whose average weight is 143g. These rats were acclimatized to ambient rearing conditions in the animal facility of the Experimental and Clinical Biology Laboratory at the National School of Applied Biosciences and Biotechnologies in Benin. They had access to water and food. They are lit for 12 hours a day and have been put in spacious cages. The cage is cleaned regularly and the water is renewed very often. The behavior of the animals was observed during the two weeks of acclimatization.

2.4 In Vitro Biological Tests

2.4.1 Identification of Secondary Metabolites

The metabolites were identified by coloring and precipitation reactions specific to each metabolite family (Houghton et al., 1998; Agbangnan et *al*., 2012; Dohou et al., 2003; Koudoro et al., 2015).

2.4.2 Hemoglobin Electrophoresis

It is performed to determine the phenotypes of the blood samples taken and to ensure that they were of the SS phenotype. The principle is based on the difference in migration of hemoglobins in an electrophoretic field according to their electrical charges. It was carried out on cellulose acetate gel at pH 8.5 as previously reported (Mpiana et al., 2012).

2.4.3 Anti-sickle Cell Activity

2.4.3.1 Emmel's Test

The principle of the test was that in the absence of oxygen, hemoglobin S polymerizes giving rise to the formation of fibers which deform the blood cell and give it a sickle appearance. Between slide and coverslip, a drop of blood was deposited with 2% sodium metabisulphite. The test was positive if after an hour of time, the red blood cells took the shape of a sickle or banana with pointed, often serrated ends (Mpiana et al., 2013; Sènou et al., 2017).

Emmel's test was performed to assess the anti-sickle cell activity of the extracts. Volume-to-volume mixing was performed between the SS blood sample and physiological water on the one hand to constitute the control and between the blood sample and the extract on the other hand for the test. After 6 hours of incubation at room temperature in the laboratory, a drop of each mixture was mounted between slide and coverslip with a drop of 2% sodium metabisulphite, then the edges were coated with candle wax to prevent drying. The preparations were then read under an optical microscope 4 hours later and the erythrocytes of different shapes observed were counted.

Blood samples of SS phenotypes were mixed with the extract at different concentrations (5, 10, 20 and 40 mg / ml) using physiological saline as a solvent.

2.4.3.2 Emmel Reverse Test

Blood samples of SS phenotypes were mixed with 2% sodium metabisulfite in equal volume and incubated for 2 hours at room temperature. To an aliquot of this mixture was added an equal amount of physiological water for the control or 40 mg / ml extract for the test. After 6 hours of incubation at room temperature, the preparations were read under an optical microscope after mounting between slide and coverslip.

2.4.4 Evaluation of the Ratio of Methemoglobin Production (Fe ++ / Fe +++)

The principle was based on measuring the absorbance of methemoglobin at 540 nm. The methemoglobin profile was a bioindicator of intra-erythrocyte oxidative stress in sickle cell patients (Kambale et al., 2013).

Sickle cell erythrocytes were washed with 0.9% NaCl solution (5 volumes NaCl per 1 volume of well-homogenized whole blood). The mixture was homogenized by successive inversion, centrifuged at 3000 rpm for 10 minutes.

The red blood cell pellet was hemolyzed by adding a double volume in double-distilled water and then centrifuged at high speed. The hemoglobin S solution thus obtained was mixed with the plant extract (10 mg / ml) incubated for 2 hours. For the negative control, the extract was replaced by physiological solution (0.9% NaCl). The absorbances of the solution were read at 540 ηm at time intervals (0, 30, 60, 90 and 120 min) using a UV-visible spectrophotometer: six tubes were available for this (in duplicate) T0 (reading at start time), T30 (reading after 30 min), T60 (reading after 60 min), T90 (reading after 90 min) and T120 (reading after 120 min). The change in optical density (delta OD) over time was calculated to quantify the formation or disappearance of methemoglobin (adapted from Kambale et al., 2013; Mpiana et *al*., 2007a, b, c).

2.5 In Vivo Biological Tests

In vivo, the effect of the extract of the roots of Uvaria chamea on the evolution of hemoglobin, mean corpuscular volume (MCV) and blood platelets was studied in female rats of the wistar strain. for this purpose, two groups of rats of three (3) rats each were formed. The first group being the control received physiological water by gavage and the second group received by gavage the extract of *Uvaria chamea* at 200 mg / Kg of body weight daily for 28 days.

2.6 Blood Tests

The blood of the rats of the two groups was taken at the beginning (D0) and on the twenty-eighth day (D28) by orbital puncture after ether anesthesia. The hemoglobin level and mean corpuscular volume (MCV) and the number of platelets were determined by automated system (Sènou et al., 2016; Agbogba et al., 2019).

2.7 Statistical Analysis

To assess the biological effect of the extract, Dunn's multi-comparison test and Mann Whitney test were used. The significance level was set at 5%. The graphs were drawn using Graphpad software.

3. Results

3.1 The Aqueous Extract of the Root of Uvaria Chamea P. Beauv Inhibited the Sickling of SS Red Blood Cells

Figure 1 showed the mean rate of sickle observed depending on the concentration of the extract. The sickle cell levels were respectively 0.85 ± 0.09 for the controls (0 mg extract / ml); 0.44 ± 0.14 for those treated at 40 mg / ml; 0.60 ± 0.09 for the 20 mg treated; 0.71 ± 0.15 for those treated with 10 mg and 0.72 ± 0.02 for those treated with 5 mg. *Uvaria chamea* P. Beauv extract significantly lowered sickle cell count at 40 mg and 20 mg / ml compared to controls ($P < 0.05$). Inhibition of Sickle Red Blood Cells appears to be dose-dependent.

3.2 The Aqueous Extract of the Root of Uvaria Chamea P. Beauv Reversed the Sickling of SS Red Blood Cells

Figure 2 showed the result of the Emmel reverse test. The average sickle cell count was 0.76 ± 0.11 for the controls and 0.48 ± 0.09 for the 40 mg treated with *Uvaria chamea* P. Beauv extract. The mean sickle cell count decreased significantly with the extract ($P < 0.05$), indicating that the extract reversed sickle cell sickling.

3.3 The Aqueous Extract of the Roots of Uvaria Chamea P. Beauv Reduced Intra-Erythrocyte Oxidative Stress

Figure 3 showed the variation of methemoglobin in the blood of SS patients. After two hours, the absorbance of methemoglobin increased by 0.012 ± 0.004 for the controls while it decreased instead by 0.038 ± 0.004 with the extract of *Uvaria chamea* P. Beauv. at 10 mg/ml. This decrease of methemoglobin indicated a reduction of oxidative stress in red blood cells by the aqueous extract *Uvaria chamea*.

3.4 The Aqueous Extract of the Roots of Uvaria Chamea P. Beauv did not Stimulate Hematopoiesis

Table 1 showed hemoglobin level, mean corpuscular volume and blood platelet count before and after the extract administartion to rats.

The mean hemoglobin level was 15.4 ± 0.3 g / dl in control rats and 16.3 ± 0.3 g / dl in rats treated with *Uvaria chamea* P. Beauv. The mean hemoglobin level did not change significantly between control rats and those treated with *Uveria chamea*, indicating that the extract did not stimulate hemoglobin synthesis.

The mean corpuscular volume was 60 ± 2 fL in control rats and 61 ± 1 fL rats treated with Uvaria chamea P. Beauv. Mean corpuscular volume did not change significantly between controls and those treated rats *Uveria chamea*, indicating that the extract did not stimulate release of young red blood cells into the blood.

The mean number of blood platelets was 595 ± 36 G / l in control rats and 574 ± 29 G / l in rats treated with *Uvaria chamea* P. Beauv. The mean blood platelet count did not change significantly between control rats and those treated with *Uveria chamea*, indicating that the extract did not stimulate thrombopoiesis.

3.5 Phytochemical Composition of Uveria Chamea Roots

Table 2 showed the phytochemical screening of *Uveria chamea* roots. The screening revealed the presence of flavonoids, catechesis tannins, leucoanthocyanins and anthocyanins in the roots of Uvaria chamea. We also noted the absence of gallic tannins, saponins, reducing compounds, mucilages and alkaloids.

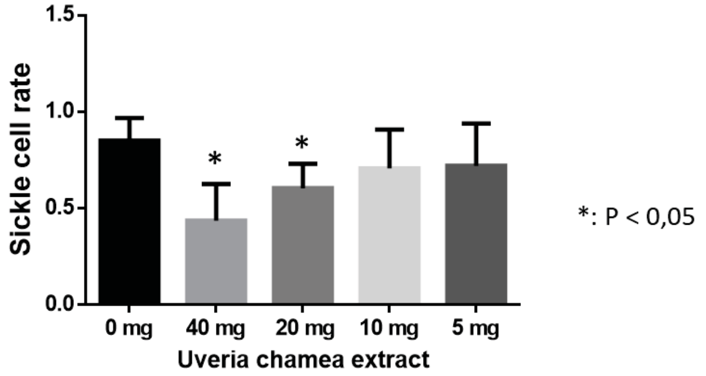

Figure 1. Mean sickle cell count in Emmel's test as a function of the extract concentration

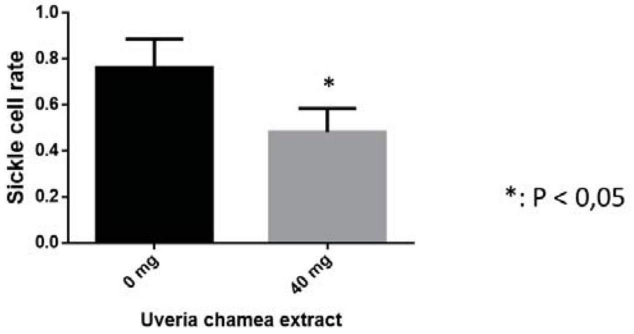

Figure 2. Mean sickle cell count on the Emmel reverse test

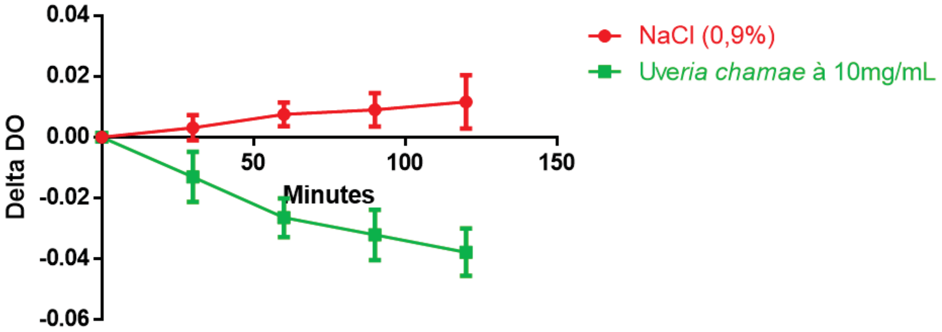

Figure 3. Change in methemoglobin production in SS red blood cells over time

Table 1. Change in rats Hemoglobin level, Mean corpuscular volume and blood platelet count

Rats parameters	Day 0	Day 28	P value
Hemoglobin level (g/dl)	15.4 ± 0.3	16.3 ± 0.3	0.2
Mean corpuscular volume (fl)	60 ± 2	61 ± 1	0.7
Mean blood platelet count (G/l)	595 ± 36	574 ± 29	0.9

Table 2. Phytochemical screening of *Uveria chamea* roots

Métabolites secondaires	*Uveria chamea* P. Beauv.
Flavonoids	+
Catechetical tannins	+
Gallic tannins	-
Leucoanthocyanins	+
Anthocyanins	+
Saponosides	-
Reducing compounds	-
Mucilages	-
Alkaloids	-

4. Discussion

Sickle cell disease was a hemoglobinosis that is most common in tropical countries. This work was part of a search for remedies that can relieve victims of this pathology. *Uvaria chamea* was one of the plants used by Beninese traditional therapists for this purpose. Thus, the present work tested in vitro the effectiveness of the aqueous extract of the roots of the plant in preventing or correcting the sickling of S red blood cells, responsible for sickle cell disease crises.

The aqueous extract of *Uvaria chamea* at concentrations of 20 or 40 mg / ml significantly inhibited the formation of sickle cells by SS red blood cells under hypoxic conditions. The extract therefore prevented the polymerization of hemoglobin S and therefore the sickling of red blood cells, responsible for sickle cell crises (Ngbolua et al., 2013). This polymerization of hemoglobin into a tactoid leads to reduced glycolytic and ionic flow and cell dehydration (Mpiana et al., 2007). In addition to the preventive effect of the sickling of SS red blood cells, at 40 mg / ml the extract induced a conversion of sickle cells into normal biconcave red cells. This result showed that the aqueous extract of *Uvaria chamea* could depolymerize hemoglobin S under hypoxic conditions and therefore reverse the process of sickle cell formation. This suggests that it also has a curative effect and justifies its use in traditional medicine in the treatment of sickle cell crises. This property has also been mentioned in certain plants in Congo which inverted sickle cells into normal biconcave red blood cells (Ngbolua et al., 2013).

In order to explore the mechanism of action of the extract, we tested its effect on the production of methemoglobin. The aqueous extract of Uvaria chamea decreased production of methemoglobin in the SS red blood cells compared to control untreated SS erythrocytes. Indeed, various authors have shown that SS erythrocytes contain a greater concentration of methemoglobin than AA erythrocytes. However, methemoglobin contains oxidized iron (Fe^{3+}) which has less affinity for oxygen than hemoglobin (Fe^{2+}). Oxidation of hemoglobin (Fe^{2+}) to methemoglobin (Fe^{3+}) is due to significant oxidative stress in sickle cells (Mpiana et al., 2010; Ngbolua, 2012). Thus, a plant which would decrease the methemoglobin profile would therefore have an antioxidant effect on sickle cell red blood cells (Kambale et al., 2013). This suggests that the action of the aqueous extract of Uvaria chamea could be through a reduction in intra-erythrocyte oxidative stress. This result is similar to that obtained by et kambale (2013) who showed that *Uapaca heudelotii* Baill would prevent the oxidation of hemoglobin.

In order to elucidate whether the action of the extract did not induce stimulation of hematopoiesis to compensate for sickle cell anemia, we tested it in vivo by chronic administration in Wistar rats. *Uvaria chamea* root extract did not significantly increase hemoglobin level, Mean Globular Volume and blood platelet count in rats, indicating that its action did not involve stimulation of erythropoiesis or thrombopoiesis. This explains why its use in traditional medicine is coupled with other anti-anemic plants. This was the case of *Cocos nucifera* L. (Arecaceae) and *Psorospermum febrifugum* whose root aqueous extracts compensate for anemia by effectively stimulating hematopoiesis (Tchogou et al., 2016 ; Agbogba et *al*., 2019).

Phytochemical screening of the roots of *Uvaria chamea* revealed the presence of several secondary metabolites including anthocyanins. This family of chemical compounds was believed to be involved in inhibiting the polymerization of hemoglobin S, thus preventing the sickling of erythrocytes. It would also act by stabilizing the erythrocyte membrane through its antioxidant properties (Mpiana et al., 2008; Mpiana et al., 2010; Ngbolua, 2012). The biological effects observed in the extract of the roots of *Uvaria chamea* could be due to anthocyanins and perhaps also to other families of compounds.

5. Conclusion

The aqueous extracts from the roots of *Uvaria chamea* prevent and reverse sickling of S red blood cells. It decreases intraerythrocytic oxidative stress without stimulating erythropoiesis and thrombopoiesis. Its action is believed to be due to the secondary metabolites it contains, including anthocyanins. It could therefore be considered in the preventive or curative treatment of sickle cell crises after verification of its safety.

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Seed Germination and Seedling Emergence of *Canavalia Lineata* (Thunb.) DC. (Fabaceae)

Chihiro Ishii[1], Masayuki Shiba[1], Yoshimasa Kumekawa[2] & Tatsuya Fukuda[1]

[1] Graduate School of Integrative Science and Engineering, Tokyo City University, Tokyo, Japan

[2] Minamiawaji City Office, Hyogo, Japan

Correspondence: Tatsuya Fukuda, Graduate School of Integrative Science and Engineering, Tokyo City University, 1-28-1 Tamazutsumi, Setagaya, Tokyo, Japan. E-mail: tfukuda@tcu.ac.jp

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Abstract

Canavalia lineata (Thunb.) DC. (Fabaceae) is a perennial trailing vine that flowers in the summer, and its seeds are sea-dispersed. It grows under various environmental conditions in coastal areas of the temperate and subtropical regions of Asia. Plant species with a wide distribution tend to differentiate in different environmental conditions; therefore, we conducted this study to find whether *C. lineata* has regional differentiation in seed germination and seedling emergence. Seeds of *C. lineata* collected from different areas of Japan were used to compare the seed-floating ability, the effect of low temperature on seed dormancy (0, 2, and 8 months) before germination, and the influence of temperature (4 °C, 15 °C, 20 °C, and 25 °C) on seed germination. Seed-floating tests indicated that many *C. lineata* seeds can float on the sea without losing their germination ability, and there was no associated regional differentiation. In addition, our results showed that this species could germinate without being exposed to low temperatures, but the timing of germination in such cases was different from that in the seeds that experienced low temperatures. The optimal temperature for *C. lineata* germination was 20 °C or higher. These analyses did not reveal any regional differentiation. Our results suggest that sea-dispersed seeds of *C. lineata* that do not lose germination ability for a long period may germinate in relatively warm areas regardless of the presence of low temperature conditions. The study also indicates that as germination of this species requires a relatively high temperature; thus, their distribution has not expanded to the north of Japan.

Keywords: germination, sea, seed, *Canavalia lineata*

1. Introduction

Plants adapt in many ways to biotic and abiotic stresses in their surroundings to survive (Bohnert et al., 1995; Bartels & Sunkar, 2005). In coastal areas, many plants have developed characteristic morphologies to overcome stresses, such as strong winds, seawater droplets, and shifting sands (Greenway & Manns, 1980). Although seawater is often unnecessary for plant growth, it can be used for the seed dispersal by coastal plants. Seed dispersal by ocean currents is considered a long-distance dispersal mechanism and one of the characteristic properties of coastal plants (Nakanishi, 1988; Harwell & Orth, 2002). Many mangrove species have been documented to use seed dispersal by sea currents (Triest, 2008). In Japan, plants with sea-dispersed seeds have been reported in coastal areas. For example, using seed-floating and germination tests, Sawada and Tsuda (2005) reported 14 species of coastal plants, including three alien species, with sea-dispersed seeds. Gene flow had also been observed in the pantropical plants such as *Hibiscus tiliaceus* L. (Malvaceae) and *Ipomoea pes-caprae* (L.) R.Br. (Convolvulaceae) with sea-dispersed seeds (Takayama et al., 2008; Miryeganeh et al., 2014). Recently, Kuroda et al. (2018) suggested that the seeds of *Linaria japonica* Miq. (Plantaginaceae) are dispersed by sea currents as they can float in seawater for more than one month and germinate at an approximate rate of 40%. This indicates that in many plants of coastal areas of Japan, there is no insurmountable reduction in germination ability of seeds that float in seawater due to buoyancy.

Long-distance seed dispersal influences many key aspects of plant biology. It could spread invasive species in plant communities (Hovestadt et al., 1999). In particular, long-distance seed dispersal from south to north leads to the invasion of areas with significant climatic differences and temperature changes. Plant species undergo regional differentiation to adapt to these conditions. Some species of genus *Canavalia* (Fabaceae) have buoyant and impermeable seeds that can drift for long periods over great distances (Sauer, 1964); the genus *Canavalia* comprises approximately 60 species in subtropical and tropical regions (Sauer, 1964). Snak et al. (2016) explained that *Canavalia* achieved its present-day distribution through recent transoceanic dispersal of buoyant and impermeable seeds. Based on chloroplast and nuclear

DNA sequences, Vatanparast et al. (2011) suggested that Hawaiian *Canavalia* species arose by the colonization of sea-dispersed seeds. In Japan, three species of this genus are found: *Canavalia lineata* (Thunb.) DC., *C. rosea* (Sw.) DC., and *C. cathartica* Thouars (Ohashi, 1981). *C. lineata* is a perennial trailing vine that grows in coastal areas from in temperate and subtropical regions of Asia (Ohashi, 1981). Its leaves are compound, and leaflets are roughly circular; the flowers are small and reddish-purple, ranging from 2.5 to 3 cm in diameter (Figure 1). It blooms with great intensity between June and August and produces large fruits that are 6–12 cm long and 3-4 cm wide (Ohashi, 1981). The seeds are sea-dispersed (Nakanishi, 1987), and the distribution area is spread across the north of the three Japanese *Canavalia* species. Its distribution is limited to the north at Chiba Prefecture on the Pacific Ocean side and Shimane Prefecture on the Sea of Japan side (Tateishi, 1997) (Figure 2).

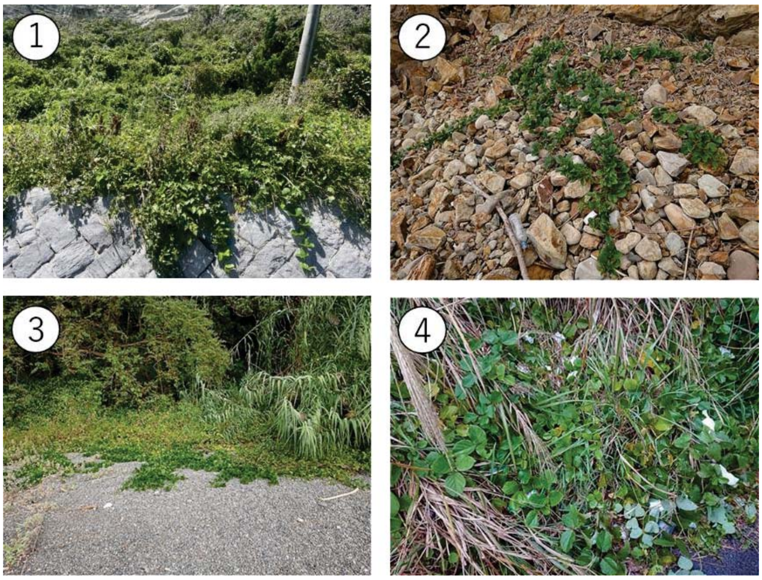

Figure 1. *Canavalia lineata*

1: Chiba; 2: Minamiawaji; 3 Aki; 4: Kochi. Figure numbers and locality names are corresponded in Table 1.

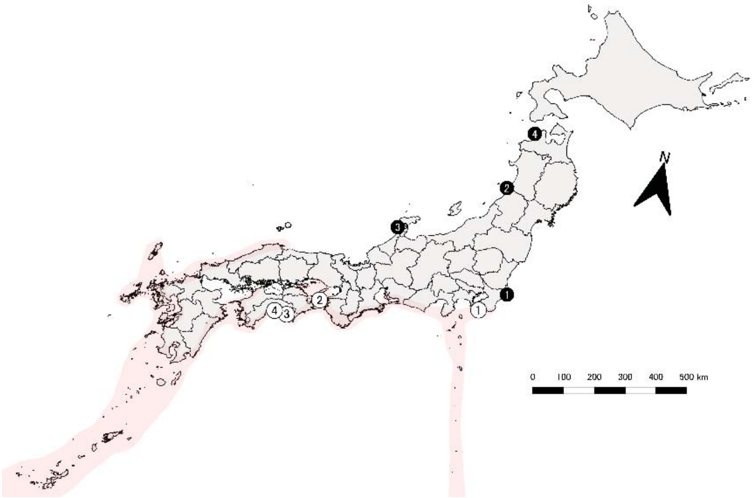

Figure 2. Distribution of *Canavalia lineata* based on Tateishi (1997)

Collecting localities indicate open circles. Numbers in the open circles are corresponded in Table 1. The localities where seedlings of this species were reported are indicated by solid circles. The numbers in the solid circle are based on the following reports; 1: Wada (1980), 2: Mori (1954), 3: Nakanishi (1980), 4: Nakanishi (2016).

However, some reports have suggested that *C. lineata* has expanded ahead of these northern limits. For example, Nakanishi (1987) observed *C. lineata* to be distributed in Ibaraki Prefecture located north of the Chiba Prefecture. Moreover, Mori (1954) and Nakanishi (1980) showed them to be present in Yamagata Prefecture and Ishikawa Prefecture, located at the north of Shimane Prefecture, on the Sea of Japan side. Tateishi (1997) suggested that the northern limit of *C. lineata* on the Sea of Japan side was Shimane Prefecture because seedlings that colonized Yamagata and Ishikawa Prefectures did not reach their reproductive phase. A recent report indicated the presence of *C. lineata* seedlings in Aomori Prefecture on the Sea of Japan side, which is the northernmost part reported to date to have these seedlings (Nakanishi, 2016); however, this seed population also lacked reproductive ability. Based on these reports, the northern limits of this species remain unclear. Environmental constraints in the northern limits at early life-history stages of seed dispersal or seedling establishment may be critical in restricting the colonization of this species. Compared to the center of the distribution, the species distribution in the north may be limited by several biotic and abiotic environmental factors and differences in available resources, such as light, soil water, and nutrients. In addition, the wide distribution from south to north was expected to cause regional differentiation in *C. lineata*.

Understanding reproductive biology traits, seed germination behavior, and the influence of environmental factors on germination is crucial to conserve and manage coastal plant species (Evans et al., 2003; Heywood & Iriondo, 2003). The function of a seed is to establish a new plant, but it can do this once because the completion of germination is essentially an irreversible process. The specific environmental sensitivity of seeds may have implications for dispersal, colonization, plant demography, speciation, and extinction (Wills et al., 2014). The timing of seedling emergence is a crucial event in a plant's life cycle, affecting its chances of becoming established and reaching the reproductive phase (Vandelook & Van Assche, 2008; Donohue et al., 2010). Therefore, various plant species have evolved several dormancy mechanisms to optimize the seed germination time (Foley, 2001). Seedlings of most species emerge shortly after germination. The timing of seedling emergence is mainly regulated by dormancy breaking and the germination requirements of the seed. Various legumes have seeds that are physically dormant because of the development of water-impermeable seed coats (Baskin et al., 2000). This type of defense is also present in the wild progenitors of cultivated legumes (Abbo et al., 2014). The legume seeds exit dormancy in response to temperature changes in the habitat, by making the seed coat water-permeable (Smýkal et al., 2014). Temperature is one of the most important abiotic factors affecting seed germination (Baskin & Baskin, 1985; Milbau et al., 2009); it also controls germination timing in seasonal climates (Shafii & Price, 2001; Rajasekaran et al., 2002). Each plant species has a base and ceiling temperature that represent the extremes at which germination can occur (Finch-Savage & Leubner-Metzger, 2006). Seed characteristics generally remain highly conserved within a species, but even small changes in these characteristics can affect almost every aspect of their morphology, ecology, and physiology (Harper et al., 1970). However, some studies have examined variations in seed characteristics within species (Buckley et al., 2003). The germination response to temperature can vary among populations across the distribution range of a species (Seguí et al., 2021). Understanding how populations vary in their sensitivity to temperature along climate gradients is important for determining their vulnerability to climate variability and change. As *C. lineata* has a wide distribution area ranging from south to north, its seeds may show differentiation in ecological and physiological characteristics to regulate germination time along climate gradients. Therefore, this study aimed to elucidate and compare seed germination and seedling emergence in *C. lineata* seeds from different areas.

2. Method

2.1 Plant Material Collection

Seeds of *Canavalia lineata* were collected from four allopatric populations during November 2020 and September 2021. Seed populations used in our study were named after locations (Chiba, Minamiawaji, Kochi, and Aki) (Table 1). The seed collecting localities are shown in Table 1. Seeds were manually separated from inflorescences. Then, healthy seeds were selected and placed in envelopes. Germination tests without subjecting to low temperatures began immediately after seed collection. The remaining seeds were dry-stored in a refrigerator (MPR-312D, SANYO, Japan) at 4 °C until further use.

Table 1. Sampling localities used in this study. Locality numbers are corresponded in Figure 2

Locality name and number		Locality	Latitude and longitude	
Chiba	1	Iwaifukuro, Kyonan-machi, Awa-gun, Chiba Prefecture	35°10'N	139°82'E
Minamiawaji	2	Nadanigoro, Minamiawaji City, Hyogo Prefecture	34°19'N	134°74'E
Aki	3	Akano, Aki City, Kochi Prefecture	33°51'N	133°84'E
Kochi	4	Nino, Haruno-cho, Kochi City, Kochi Prefecture	33°47'N	133°50'E

2.2 Seed-Floating Test Followed by Germination Experiment

Floating tests were performed in the summer of 2021 using the seeds incubated at low temperatures in a refrigerator for eight months. Four groups (Chiba, Minamiawaji, Kochi, and Aki) of thirty *C. lineata* seeds were placed in glass basins (30 cm depth × 30 cm diameter) three-quarter filled with saline water (3.45 % NaCl solution) and subjected to three weeks floating period. During the floating test, sunken seeds were removed from the glass basins. After the floating period, the seeds were washed with water, and the integrity of the water-impermeable seed coat was breached by artificially cutting a hole in the seed coat. These seeds were then used for subsequent germination experiments. The germination experiments were carried out in flowerpots (10 cm depth × 10 cm diameter) filled with three-quarters of vermiculite (KA09, Kohnan Co., Japan) in distilled water. The seeds were sown in the flowerpots and then the pots were placed in an incubator (A5501, AS ONE, Japan) at 25 °C. All four groups of floating seeds (Chiba, Minamiawaji, Kochi, and Aki) were treated in this way. Seeds were considered germinated at the seedling emergence. The percent germination was recorded every day for two weeks. All values were expressed as mean ± SD. Tukey's multiple comparison test was used to determine significant differences in germination between floating tests done on seawater and distilled water, for seed collected from different areas; p-values < 0.05 were considered significant.

2.3 Germination Experiments After Different Low-Temperature Incubation Periods

In general, a temperature around 5 °C is considered optimum for breaking seed dormancy. This temperature is often used in experiments involving pre-chilling treatments (Baskin & Baskin, 2014). However, in some cases, temperatures below 5 °C can be more effective in breaking dormancy. To reveal the effect of low temperature on the dormancy, *C. lineata* seeds were placed in a refrigerator at 4 °C for three different periods: 0 months (non-dormancy), 1 month, and 8 months. Thirty seeds collected from Chiba Prefecture were used in this experiment. The seeds were then taken out from the refrigerator and their seed coats were pierced. Then, the germination experiments were performed in flowerpots (10 cm depth × 10 cm diameter) filled three-quarters with vermiculite (KA09, Kohnan Co., Japan) and distilled water. The pots were kept in an incubator (A5501, AS ONE, Japan) at 25 °C. The percent germination was recorded daily for two weeks. All values were expressed as mean ± SD. Tukey's multiple comparison test was used to determine significant differences in germination among different incubation periods of low temperature and p-values < 0.05 were considered significant.

2.4 Germination Experiments at Different Incubation Temperatures

To determine the effect of temperature, seeds were germinated in incubators under two temperature regimes: 20 °C and 25 °C (20 °C: THS-020DB, ADVANTEC, Japan; 25 °C: A5501, AS ONE, Japan). In this experiment, the seeds collected from Chiba Prefecture (n=30) or Minamiawaji (n=10) were pre-exposed to 4 °C for one month and one week, respectively. Then, they were taken out from the refrigerator, and their seed coats were pierced. Germination experiments were conducted using the method described above, and the percent germination was recorded every day for two weeks.

Similarly, additional experiments were performed on seeds collected from Minamiawaji (n=10) in the incubator at 4 °C and 15 °C (4 °C: MPR-312D, SANYO, Japan; 15 °C: THS-020DB, ADVANTEC, Japan). Two weeks later, the temperature was raised to 25 °C, and the germination rates were measured. All values were expressed as mean ± SD. Tukey's multiple comparison test was used to determine significant differences in germination at different incubation temperatures, and p-values < 0.05 were considered significant.

3. Results and Discussion

Legumes have soft-to-hard seed coats that play a critical role in the lateral transfer of assimilates and other nutrients before their release into the developing embryo (Lush and Evans, 1980; Offler & Patrick, 1984, 1993). Ma et al. (2004) reported that small cuticular cracks, which are consistently correlated with seed coat permeability to water, are not present in the hard seed coat. *Canavalia* species also have a water-impermeable seed coat (Mendoza-González et al., 2014). Dalling et al. (2011) hypothesized that the hard seed coat should depend on the likelihood of seed predation and that non-hard coats might evolve as part of a predator avoidance strategy. Bean weevils are seed predators that feed on legumes; their adults deposit eggs on seeds, then the larvae chew their way into the seed and feed on the bean endosperm and embryo (Janzen, 1977). The perforation of the seed coat by bean weevils is considered to play an important role in water permeation into the embryo and endosperm, and trigger germination of legume seeds (Fox et al., 2012). Therefore, in our study, we used an artificial method to break the seed coat. The integrity of the water-impermeable seed coat was compromised by cutting a hole in the seed coat; the floating tests and the tests after incubating seeds at low temperatures were performed without modifying the seeds.

3.1 Seed-Floating Ability of Seeds From Different Collecting Areas

The floating test in saline water indicated that seeds of *C. lineata* collected from various areas had a high probability to continuously float for three weeks or more (Table 2). Moreover, no significant differences were found between seeds collected from the different localities (Table 2).The question remains: how far could the seeds of *C. lineata* disperse in the floating period of three weeks or more? Although the speed of movement of seeds in the sea is unknown, an interesting phenomenon in 2021 provided clues regarding the movement of floating objects in the ocean current. Pumice stones were ejected from Fukutoku-Oka-no-Ba, which is an undersea volcano on the Ogasawara Islands, in an eruption in mid-August (Geological Survey of Japan, 2021). The pumice stones were found in Okinawa in mid-October and along the coast of Chiba Prefecture in early November (Geological Survey of Japan, 2021). Although the movement of pumice and seeds cannot necessarily be the same, it was shown that the distance from Okinawa to Chiba could be covered by floating objects in the ocean current in approximately a few weeks, suggesting that seeds of *C. lineata* floating on the sea for more than three weeks can be dispersed at long distances.

Table 2. Comparison of seed floating ratio in saline water among collecting localities

	localities							
days	Chiba		Minamiawaji		Aki		Kochi	
0	100.0±0.00	a, A	100.0±0.00	a, A	100.0±0.00	a, A	100.0±0.00	a, A
5	95.24±4.76	ab, A	100.0±0.00	a, A	100.0±0.00	a, A	82.61±8.08	b, A
10	95.24±4.76	ab, A	100.0±0.00	a, A	100.0±0.00	a, A	78.26±8.79	b, A
15	95.24±4.76	ab, A	100.0±0.00	a, A	100.0±0.00	a, A	73.91±9.36	b, A
20	85.71±7.82	ab, A	100.0±0.00	a, A	100.0±0.00	a, A	73.91±9.36	b, A
23	85.71±7.82	ab, A	100.0±0.00	a, A	93.33±6.67	ab, A	73.91±9.36	b, A

Locality names are corresponded in Table 1. Columns marked by different letters differ significantly according to the Tukey's HSD test ($p < 0.05$). Small alphabets indicate the results of tests among localities, and large alphabets indicate the results of tests among days within localities.

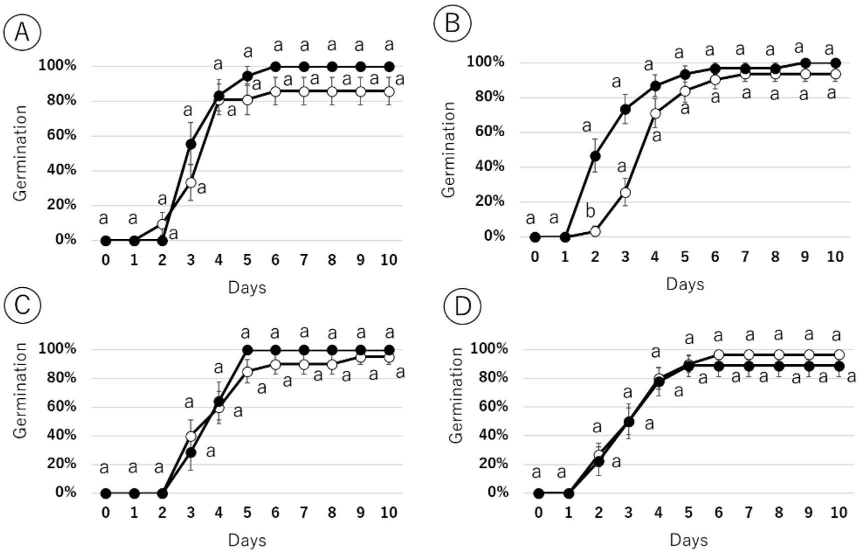

Figure 3. Percentage of seed germination of *Canavalia lineata* versus days in saline water (solid circle) and distilled water (open circle)

A: Chiba; B: Minamiawaji; C: Aki; D: Kochi. Locality names are corresponded in Table 1.

However, even if the seeds float in seawater for a long time, seed dispersal by sea currents cannot be effective if the seeds do not retain their germination ability. Our germination tests revealed that the seeds that floated on seawater had high germination rates; however, these rates were slightly lower than those of the seeds that floated on pure water (Figure 3). This finding suggested that invisible scratches on the seed coat may affect the penetration of saline water into the seed. Our results indicated that most seeds could germinate after floating in saline water, indicating that seeds of *C. lineata,* long which have dispersed by sea currents, maintain their germination ability. Moreover, no significant difference was observed between the seeds collected from different regions in floating experiments (Tables 3, 4), indicating that there was no regional differentiation in seed germination ability. These results suggested that *C. lineata* seeds could be dispersed over long distances, but the lack of differentiation between regions may inhibit the expansion of the distribution area.

Table 3. Comparison of seed germination ratio floated in saline water among collecting localities

	localities							
days	Chiba		Minamiawaji		Aki		Kochi	
0	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A
1	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A
2	0.00±0.00	b, A	46.67±9.26	a, AB	0.00±0.00	b, A	22.22±10.08	ab, AB
3	55.56±12.05	ab, AB	73.33±8.21	a, BC	28.57±12.53	b, B	50.00±12.13	ab, BC
4	83.33±9.04	a, BC	86.67±6.31	a, CD	64.29±13.29	a, C	77.78±10.08	a, CD
5	94.44±5.56	a, C	93.33±4.63	a, D	100.00±0.00	a, D	88.89±7.62	a, D
6	100.00±0.00	a, C	96.67±3.33	a, D	100.00±0.00	a, D	88.89±7.62	a, D
7	100.00±0.00	a, C	96.67±3.33	a, D	100.00±0.00	a, D	88.89±7.62	a, D
8	100.00±0.00	a, C	96.67±3.33	a, D	100.00±0.00	a, D	88.89±7.62	a, D
9	100.00±0.00	a, C	100.00±0.00	a, D	100.00±0.00	a, D	88.89±7.62	a, D
10	100.00±0.00	a, C	100.00±0.00	a, D	100.00±0.00	a, D	88.89±7.62	a, D

Locality names are corresponded in Table 1. Columns marked by different letters differ significantly according to the Tukey's HSD test ($p < 0.05$). Small alphabets indicate the results of tests among localities, and large alphabets indicate the results of tests among days within localities.

Table 4. Comparison of seed germination ratio among collecting localities

	localities							
days	Chiba		Minamiawaji		Aki		Kochi	
0	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A
1	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A	0.00±0.00	a, A
2	9.52±6.56	ab, A	3.23±3.23	b, AB	0.00±0.00	b, A	26.67±8.21	a, B
3	33.33±10.54	a, A	25.81±7.99	a, B	40.00±11.24	a, B	50.00±9.28	a, B
4	80.95±8.78	a, B	70.97±8.29	a, C	60.00±11.24	a, BC	80.00±7.43	a, C
5	80.95±8.78	a, B	83.87±6.72	a, C	85.00±8.19	a, CD	90.00±5.57	a, C
6	85.71±7.82	a, B	90.32±5.40	a, C	90.00±6.88	a, CD	96.67±3.33	a, C
7	85.71±7.82	a, B	93.55±4.49	a, C	90.00±6.88	a, CD	96.67±3.33	a, C
8	85.71±7.82	a, B	93.55±4.49	a, C	90.00±6.88	a, CD	96.67±3.33	a, C
9	85.71±7.82	a, B	93.55±4.49	a, C	95.00±5.00	a, D	96.67±3.33	a, C
10	85.71±7.82	a, B	93.55±4.49	a, C	95.00±5.00	a, D	96.67±3.33	a, C

Locality names are corresponded in Table 1. Columns marked by different letters differ significantly according to the Tukey's HSD test ($p < 0.05$). Small alphabets indicate the results of tests among localities, and large alphabets indicate the results of tests among days within localities.

3.2 Germination Rate With and Without Low-Temperature Stress

The low-temperature tests for various periods indicated that *C. lineata* seeds did not require low-temperature exposure for germination (Figure 4), and have the potential to germinate as soon as they were washed ashore in coastal areas. However, it remains unclear why *C. lineata* seeds do not need low temperatures for germination, despite being restricted to relatively seasonal environments, where favorable conditions occur over most of the year. However, it was very interesting to note that germination rates were significantly different among the low-temperature periods after seeds had absorbed water (Figure 4). Seeds that experienced low temperatures showed faster germination, implying that *C. lineata* seeds could select the time of germination to adapt to the optimal period for seedling emergence. Plants develop dormancy to overcome long periods of unfavorable growth conditions, such as dry hot summers and cold winters (Vegis, 1964). In general, dormancy is considered a mechanism for avoiding periods that are favorable for germination but unfavorable for subsequent seedling establishment (Vleeshouwers et al., 1995). For example, Langens-Gerrits et al. (2003) indicated that the longer the cold storage, the faster and more uniform leaf emergence occurred in lily, indicating that low temperature not only affects the number of sprouted bulblets but also the time of emergence. The most favorable period for seedling establishment varies according to geographical distribution and climatic conditions. Therefore, different climatic conditions are often reflected in the dormancy-breaking requirements of seeds (Skordilis & Thanos, 1995). Habitat preference and the life cycle of the species are other factors that determine the optimal period for seedling emergence and thus affect seed behavior (Nikolaeva, 1999). Snak et al. (2016) revealed the molecular phylogenetic relationships in *Canavalia* species, he observed that *C. lineata* was closely related to *C. rosea* (Sw.) DC., *C. cathartica* Thouars, *C. gladiata* (Jacq.) DC., and so on, which have a wide distribution range in the tropics without winters. Although *C. lineata* has a wide distribution area, each region has a winter season. We hypothesized that *C. lineata* has gained the ability to recognize low temperatures to improve fitness in the temperate zone, regardless of whether this species could germinate without exposure to low temperatures. To verify this hypothesis, it is necessary to conduct germination experiments on seeds of tropical *Canavalia* species exposed to low temperatures, in the future.

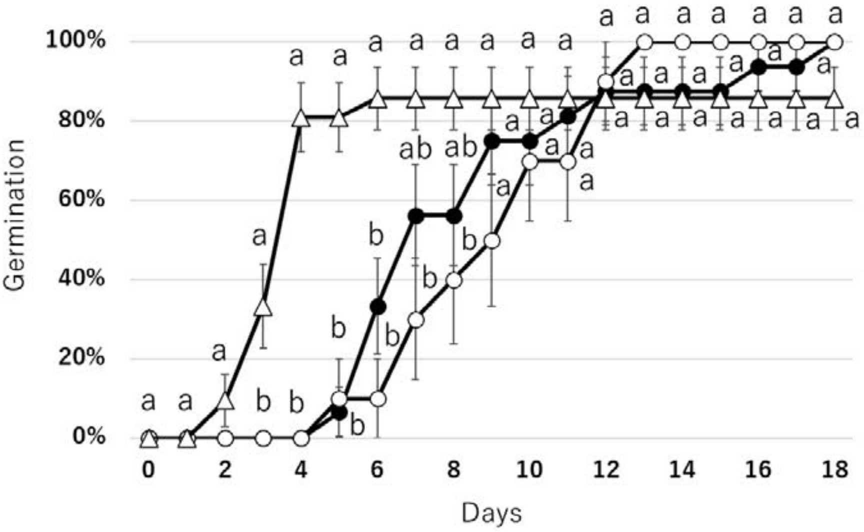

Figure 4. Influence of low temperature periods before seed germination of *Canavalia lineata* (0 month [solid circle], 1 month [open circle] and 8 months [open triangle])

3.3 Effect of Temperature on Seed Germination

Temperature is the most important driving force influencing plant development rate; for example, the effects of temperature on plant development are the basis for models used to predict germination timing. Although all of the above germination experiments on *C. lineata* seeds were performed at 25 °C based on the methods of Butler et al. (2014), it is unclear whether the temperature change could affect the germination and seedling emergence. Thus, the results of germination experiments at multiple temperatures using *C. lineata* seeds with holes cut revealed that they could germinate at temperatures 20 °C or above, but not at 15 °C or below (Figures 5, 6). Moreover, the increase in the temperature significantly accelerated the seedling emergence (Figure 6). Although their germination occurred at 20 °C, not all individuals germinated (Figure 5), suggesting that this temperature was unlikely to be the optimum temperature for germination. These results suggest that *C. lineata* seeds require relatively high temperatures for germination and seedling emergence; therefore, this species occurs in warmer areas and is not distributed in the northern regions of

Japan. In addition, *C. lineata* seeds that could not germinate at 4 °C and 15 °C, germinated at 25 °C (Figure 6), indicating that the seeds did not die even if they were left at low temperature for a certain period. Therefore, *C. lineata* seeds may be present as drifting seeds and buried seeds along the coast of Japan, as seeds can only remain ungerminated in the ground if they are affected by predation or pathogenic infection or both.

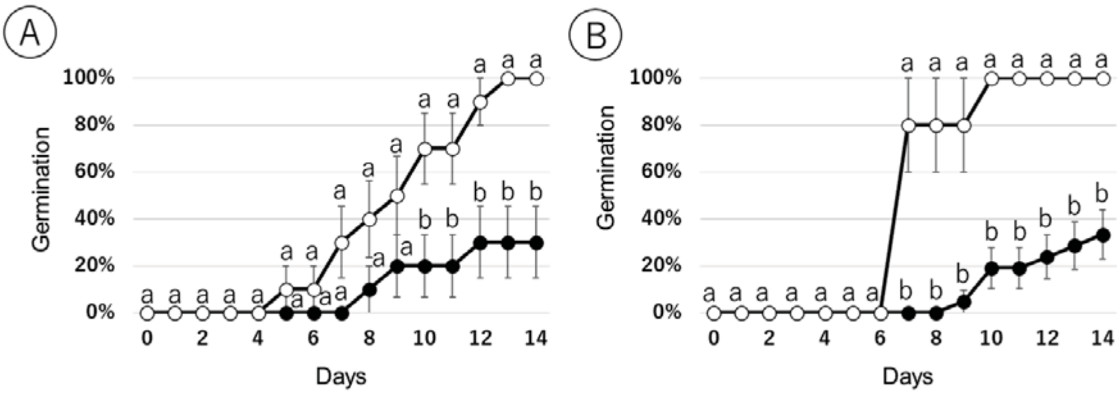

Figure 5. Comparison days of seedling appearance between 20 °C (solid circle) and 25 °C (open circle)

A: Chiba; B: Minamiawaji. Locality names are corresponded in Table 1.

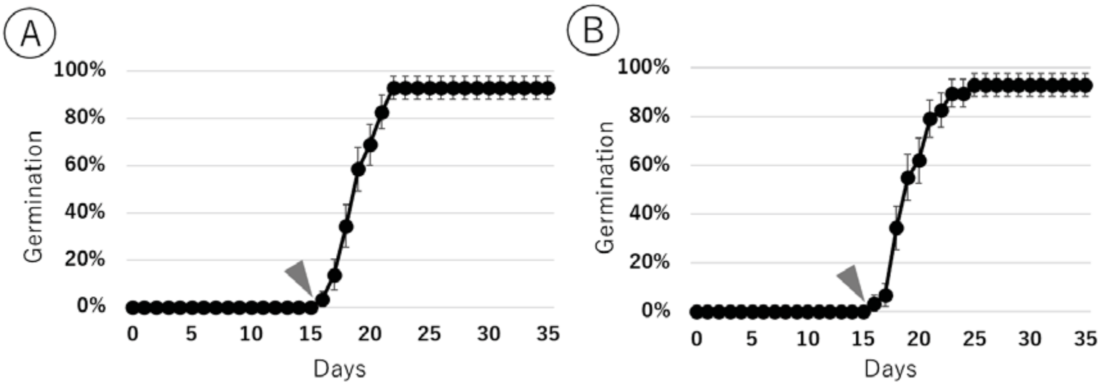

Figure 6. Cumulative seed germination percentage of *Canavalia lineata* after transferred (14 days) from 4 °C or 15 °C into 25 °C used in the seeds collected from Minamiawaji

Arrowheads indicate the day when the temperature was transferred from 4 °C. Locality name is corresponded in Table 1. A: from 4 °C into 25 °C; B: from 15 °C into 25 °C.

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Weight at First Calving and Its Relationship With Productive Indicators in Nelore Cows in a Grazing System of the Bolivian Tropics

Atsuko.Ikeda[1] , Pablo.R. Marini [2]

[1] PhD student, Faculty of Veterinary Science, Universidad Nacional de Rosario, Casilda, Argentina

[2] Career of the Scientific Researcher (CIC-UNR), Universidad Nacional de Rosario, Casilda, Argentina

Correspondence: Atsuko Ikeda, Universidad Nacional de Rosario. Av. Ovidio Lagos y Ruta 33, S2170HGJ, Casilda, Argentina

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Abstract

Considering only selection for increased weight gain until after one year could cause adult cow weight gain that would not be desirable depending on the production system. To evaluate the relationship of weight at first calving and its relationship with productive indicators in Nelore cows in a grazing system of the Bolivian tropics. Retrospective data from the years 1992 to 2019 were used, which were part of two cooperatives: Agropecuaria Integral San Juan de Yapacaní and the Centro Tecnológico Agropecuario located in Santa Cruz de la Sierra, Bolivia. The data corresponding to 1052 Nelore primiparous cows were used for the research work. The lightest cows had the same calf weight at birth as the rest of the heaviest cows, weaned a lighter calf, arrived the first calving rapidly, showed no differences with the Accumulated Production and the Calf Index with the heaviest cows, but had the highest stock efficiency. Identifying the group of lightest cows as the most efficient was considered a positive tool to recommend producers to take into account at the time of selection. The study shows that the age at first calving is related to indicators of productive efficiency in Nelore cows in a grazing system of the Bolivian tropics and that their use would have a greater impact in identifying the most efficient cow for each production system.

Keywords: Nelore cows, Efficiency, Accumulated production, Calf index, Grazing system

1. Introduction

The use of Nelore cattle to the Bolivian production systems constitutes an advance to obtain heavier animals with high daily weight gain at a lower cost, that is, more efficient (Flores and Ortiz, 2010). Although, the selection only for greater weight of calves at weaning can increase adult weight due to the medium to high genetic correlation between final weight and weight at different ages (Boligon *et al*., 2009). In the same way, the elimination of cows due to their low weight gain can reduce their age at first calving. However, considering only selection for increased weight gain until after one year could cause adult cow weight gain that would not be desirable depending on the production system (Boligon *et al.,* 2010). The efficiency of animal production systems is an objective to be achieved, not only from an economic-productive point of view but also from a socio-environmental point of view (Hegarty *et al.,* 2007). Many of the efforts to improve efficiency in livestock have focused on different measures of feed efficiency (variations in amount of feed consumed and rate of weight gain) determined during the growth phase. While this approach provides pertinent information on efficiency during the growth phase, the relationship to cow efficiency has yet to be determined (Ikeda *et al*., 2019). An increase in body growth and a decrease in food consumption would be the main measures to consider in an improvement program whose objective is to improve dietary efficiency using traits described for this purpose as selection criteria (Grion *et al.,* 2014). Mature weight (MW) can be used as an indicator of animal size, mainly due to its easy measurement and inclusion in management practices (Silveira *et al.,* 2015). Consequently, the objective of this study was to evaluate the relationship of weight at first calving and its relationship with productive indicators in Nelore cows in a grazing system of the Bolivian tropics.

2. Method

In this work, retrospective data from the years 1992 to 2019 were used, which were part of two cooperatives: Agropecuaria Integral San Juan de Yapacaní (16 ° 59 ′ 0 ″ south latitude, 63 ° 58 ′ 0 ″ west longitude) and the Centro Tecnológico Agropecuario (17 ° 13 ′ 12 ″ south latitude, 62 ° 53 ′ 39 ″ west longitude) located in the Japanese communities of San Juan and Okinawa in Santa Cruz de la Sierra, Bolivia. The area has a tropical climate and rains for much of the year (986-1805 mm) and a short dry season, at a height of 286 meters above sea level. The average annual temperature is 24.3 °C.

2.1 Animals

The data corresponding to 1052 primiparous Nelore cows were used. The calving months of the cows were May and July of each year. Weaning occurs between seven and eight months depending on body condition and general condition. The gynecological and sanitary control is carried out by a technical advisor on a routine basis.

2.2 Feeding and Management

The herd was fed grazing managed in intensive conditions, with cultivated pastures *Brachiaria decumbens* (8 to 12 t / ha / year of DM), *Brachiaria humidicola* (8 to 10 t / ha / year of DM), *Brachiaria dictyoneura* (8 to 10 t / ha / year of DM*), Cynodon dactylon* (10 to 20 t / ha / year of DM) and *Panicum maximum cv mombaza* (20 to 28 t / ha / year of DM), (ESCASAN, 2020).

$$PAC = \frac{P_d * n_p * C_a}{EVP_n - C_i}$$

2.3 Body Weight Record

The cows had at least two individual weight checks. The weighing of the animals was always carried out at the same time (8:00 am). The calves were weighed with a brand manual scale (POCKET BALANCE; Made in Germany) the same day of birth. From two months of age, calves and mothers were weighed with a brand electronic scale (ICONIX New Zealand Ltd.).

2.4 Variables to Analyze

Cow live weight (LW) in kg: average live weight of each cow of the weights made in its first lactation.

Calf weight at birth (CWB) in kg: average calf weight at birth for all calvings.

Calf weight at weaning (CWW) in kg: Average calf weight at weaning of all calvings.

Age at first calving (AFC) in months: The age of first calving (date of birth - date of first calving).

Longevity (L) in days: Date of discard or death - date of birth in days.

Calf Index (CI) in kg: Total production of weaned calf / longevity in days (Date of discard or death - date of birth in days).

Accumulative Productivity (PAC) in kg (Lôbo *et al.,* 2000).

PAC: Pd = average live weight of all weaned calves (kg); np = total number of calves given birth by the cow; Ca = constant equal to 365 days, making it possible to express fertility on an annual basis; EVPn= age in days of the cow at the last calving; Characteristics were analyzed using Ci = constant equal to 550 days approximately 18 months, which represents age at first conception.

2.5 Statistical Analysis

The criteria used in previous work (Marini and Oyarzabal, 2002a; Marini and Oyarzabal 2002b) were applied to divide the cows in categories. The cows were ordered from lowest to highest weight, and they were divided into three groups of equal numbers, forming three categories: low (l), medium (m) and high (h) weight at weight calving. To check whether this criterion differentiated three age levels at the first delivery, the means and standard deviations were estimated and the Tukey Analysis of Variance and comparison of means ($p < 0.05$) tests were applied (Sokal and Rohlf, 1979). Averages were obtained by category and for all variables based on weight at first calving. It was analyzed by ANOVA and the comparison of means was made through Tukey's tests ($P < 0.05$). Statistical analyzes were performed with the JMP software package in version 5.0 for Windows (JMP®, SAS Institute, 2003).

3. Results and Discussions

The growth of animals is related to the ability to gain body mass, being affected by diet, weather conditions, health and genetics. Knowledge of this process is very important for meat production systems, because it is possible to identify phases of the animal's life that describe different growth rates (Lopes *et al.,* 2011; Malhado *et al.,* 2009). The live weight (average ± standard error) of the first lactation cows was 465 ± 62 kg for the total of the cows analyzed. Significant differences were found between the calving years analyzed and the weight ($p \leq 0.001$), with 1994 being the year with the lowest weight of the cows 447 ± 61 kg and 1998 with the heaviest weight of the cows 524 ± 13 kg. The weights found in the cows analyzed are higher than those cited by Rosa *et al., (*2001) where the general average adult weight was 447 kg, with a coefficient of variation of 11%, and from those reported by Lopes *et al.,* (2016) of 555 ± 71 kg in adult cows and the

425.8 ± 3 kg reported by Segura-Correa *et al.,* (2013). And they were found below the 577 ± 5 kg obtained by Foianini *et al.,* (2010).

The cows were grouped by calving decades and the average weights were obtained: Decade I (1992-2000), Decade II (2001-2010) and Decade III (2011-2019), showing significant differences ($p \leq 0.001$), in the average weights of the cows belonging to the same: Decade I (157) 508 ± 4.9 kg, Decade II (462) 497 ± 2.8 kg and Decade III (433) 487 ± 2.9 kg. It should be noted that in the last Decade III group there are many of the cows analyzed that have not yet reached adult weight, and possibly this could have modified the average weight of the decade. Obviously, there is a variation in the weight of Nelore cows that can be the effect of several factors (management, feeding, genetics, environment) that cause this difference in weight. When seeing the results of the weights of the cows between decades, these have been decreasing, although the weights continue to be above the cited authors. Since the late 1980s, cooperatives have been working with cattle herds with the aim of providing pure Nelore breeders to their associates. The selection criteria in these cooperatives was to achieve animals that have increased average daily weights that would allow having a calf as heavy as possible at weaning (Ikeda y Marini, 2021).

Table 1. Productive variables y weight categories at first calving

	LW (kg)	CWB(kg)	CWW (kg)	AFC (days)
1 (353)	426 ± 1.6^{c}	34.5 ± 0.2^{a}	200 ± 1.9^{b}	1045 ± 11^{a}
2 (353)	495 ± 0.9^{b}	34.5 ± 0.2^{a}	209 ± 1.9^{a}	1096 ± 11^{b}
3 (346)	564 ± 1.6^{a}	35.3 ± 0.2^{a}	210 ± 1.9^{a}	1114 ± 11^{b}

Different letters in the column indicate significant differences $p \leq 0.05$

All values correspond to the arithmetic mean ± standard error

Live weight (LW): Average cow weight of all the weights of its life

Calf weight at birth (CWB) in kg

Calf weight at weaning (CWW) in kg

Age at first calving (AFC) in days

Table 1 shows that three categories of cows were found with significant differences ($p \leq 0.05$) between them, according to weight at first calving. The three categories do not differ in calf birth weight, although they do differ in weaning weight ($p \leq 0.05$) where the medium and high weight categories have the highest calf weaning weight values. The same behavior is observed with age at first delivery, where the medium and high weight categories reach their first delivery at an older age than those of the low weight category ($p \leq 0.05$).

In general, zebu cattle have an average birth weight (BW) of 30 kg (Reynolds *et at.,* 1980; Paschal *et al.,* 1991).
More recent works showed that the birth weight in Nelore cattle was between 29 and 32 kg on average (Silva *et al.,* 2008; Santana *et al*., 2012; Boligon *et al.,* 2013; Chud *et al.,* 2014). A study by Chirinos *et al.,* (2017) using first calving cows showed that the average weight of the calves was 27.0 ± 4.9 kg less than those found by Silva *et al.,* (2008) in rodeos of Paraná, Santa Catarina and Río Grande do Su with average of 30.4 ±2.4; 29.1 ± 2.9 and 29.8 ± 2.9 kg. The weights found in the different categories in this work are grater than those previously mentioned. It is important to note that the average weight determined in this study was well above parameters that the Asocebu-Colombia (2016) refers to for Nelore cattle, which is between 26 to 28 kg. One of the explanations could be that the weight at birth is commonly considered as a selection criterion in cattle for beef, the growth traits (expressed as body weight) are easily measurable, highly correlated from birth to adulthood, and respond well selection due to heritability estimates that are moderate to high (Yokoo *et al.,* 2007; Boligon *et al.,* 2009; Zuin *et al.,* 2012) and therefore the search for calves heavier at calving. Weaning weight is often used as a correlated trait in genetic evaluation programs and is used for decision-making on replacement selection (Guidolin *et al.,* 2012). Alfonso *et al.,* (2001) showed that the live weight of calves was 145 kg average for Nelore calves weaned at seven months of age for four consecutive years (1994-1999), in the same sub region. However, Santos *et al.* (2004) found lower values in extremely dry years for Nelore calves at 12 months of age, with an estimated mean weight of 146 kg. Itavo *et al.,* (2008) found that Nelore calves weaned at eight, nine and ten months of age with an average of 181.5 kg LW for animals raised in cultivated pastures. These higher weights, the authors attributed it to the diversity of the grass and the possibility of diet selection. The values found in this work respond to calf weights in cultivated pastures, where the heaviest and intermediate cows in the group have the calves with the highest weaning weight. This result would coincide with the previous explanation where a greater possibility of selection of the diet with quantity and quality of pasture would cause a greater weight of the calves. Table 1 shows that the age at first delivery found significant differences ($p \leq 0.05$)

between them according to weight at first delivery.

Cows in the high and medium weight categories take longer to have their first calving than cows in the low weight category. This could be because high and medium weight cows need more time to reach their optimum weight and more time for the development of the reproductive system. The results of age at first calving are below that reported by Duitama *et al.,* (2013) where it showed that the average in Brahman cows was 1226 days. Although being similar to the values found in Nelore cattle (Lôbo *et al.,* 2000), at 1180 days reported by García *et al.,* (2003) and at 1086 ± 268 days presented by Flores and Ortiz (2010) in the ranch Parabano (Cordillera Province, Santa Cruz Department).

Table 2 shows that the three categories do not differ in the Accumulated Production nor in the Calf Index. However, they show a significant difference ($p \leq 0.05$) in Stock efficiency where the underweight categories are the ones with the highest values.

Table 2. Variables of productive efficiency by age categories at first calving

	PAC (kg)	CI	SE
1 (353)	103 ± 1.3^a	0.158 ± 0.001^a	0.471 ± 0.004^a
2 (353)	102 ± 1.3^a	0.159 ± 0.001^a	0.422 ± 0.004^b
3 (346)	100 ± 1.3^a	0.158 ± 0.001^a	0.373 ± 0.004^c

Different letters in the column indicate significant differences $p \leq 0.05$

All values correspond to the arithmetic mean ± standard error

Accumulated Production (PAC): Accumulated Productivity in kg of weaned calf per year

Calf Index (CI) in kg

Stock Efficiency (SE) in kg

Table 2 shows that the Accumulative Production results show that the cows in the three categories do not show significant differences. The results obtained in this work are similar to the 96.7 kg ± 46.7 kg of Accumulated Production weight reported by Azevedo *et al.,* (2005) and lower than those of Rosa (1999), working with data from herds of the Genetic Improvement Program of the Nelore Breed in Brazil, with an average of 144 kg for PAC and Schwengber (2001), also working on the information generated in the herds of the Nelore Breed Genetic Improvement Program in Brazil showed an average of the Accumulated Production of 130 kg of calves. The Calf index (Table 2) assesses the kg of calf produced from birth to discard, it is an indicator that involves various stages of the cow's life, not only production, longevity and reproduction, but also the rearing stage of the cows. The results showed that there were no significant differences between the groups of cows, that is, the three groups from birth generated the same amount of kg of calf per day.

In Table 2 the results of the stock efficiency by category are observed, where there were significant differences between the categories ($p \leq 0.05$), with the cows of less weight obtaining the highest efficiency in kg of calf. In other words, the lightest cows were the ones that produced the highest kg of calf per kilo of cows kept. Normally, one of the criteria used is to achieve a greater weight of the cow at the first calving, because it would achieve a better productive behavior, among them a greater weight of the calf at weaning, which according to the results obtained in this work would be achieved. However, it does not mean that these cows are the most productive efficient, since the lightest cows show equal weight at birth, younger age at first calving, the same efficiency in the indicators of Accumulated Production (PAC) and Calf Index (IT) and have the highest stock efficiency. This means that the 10 kg of weaning calf achieved by the heaviest cows is not enough to achieve a stock efficiency similar to that of the lightest cows, the difference in kg between both categories should be not less than 70 kg with respect to the lightest to achieve the same stock efficiency. These results could be explained by the search for greater weights of the calf at weaning that both cooperatives have had, this has not allowed an integral selection but directed to the search for a single element with greater weight. It is necessary to use various indicators for measurements and subsequent decision-making to search for the most efficient cows in the evaluated systems.

4. Conclusion

It is concluded that the age at the first calving is related to indicators of productive efficiency in Nelore cows in a grazing system of the Bolivian tropics and that their use would have a greater impact in identifying the most efficient cow for each productive system.

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Association, in an Ant, of a Quantity of an Element with the Time Period of Its Learning

Marie-Claire Cammaerts[1], Roger Cammaerts[2]

[1] Independent researcher, retired from the Biology of Organisms Department, University of Brussels, Belgium

[2] Independent researcher, retired from the Natural and Agricultural Environmental Studies Department (DEMNA) of the Walloon Region, Belgium

Correspondence: Marie-Claire Cammaerts, independent researcher, 27, Square du Castel Fleuri, 1170 Bruxelles, Belgium. E-mail: mccammaerts@gmail.com

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Abstract

The workers of the ant *Myrmica sabuleti* detain numerosity abilities, have a notion of the running time, and can acquire operant conditioning. The present work examines if, according to these skills and through conditioning, the workers of this ant can associate a learned quantity of a given element with the time period of its occurrence. We collectively trained such ants from 8 to 19 o'clock to a stand bearing a given quantity of an element and from 20 o'clock to 7 o'clock next day to a stand bearing another quantity of the same element, and we tested them in front of these two amounts at 16 o'clock and 4 o'clock next day. At 16 o'clock, the ants reacted essentially to the amount presented during training from 8 to 19 o'clock, and at 4 o'clock to the amount presented during training from 20 o'clock to 7 o'clock. They thus associated the learned quantity of an element with the period of the day during which this learning occurred. It may be argued that this association simply results from the three cognitive capabilities cited here above, and does not require any other more complex skill. In addition, the ants appeared to have better learned from 20 to 7 o'clock than from 8 to 19 o'clock, i.e., during the time of day corresponding to their period of highest natural activity.

Keywords: quantity assessment, *Myrmica sabuleti*, operant conditioning, periods of activity, running time

1. Introduction

The aim of the present work was to examine if the workers of the ant *Myrmica sabuleti* Meinert, 1861 can associate the sight (the learning) of a quantity of an element with the time period during which this quantity was learned. Here below, we successively briefly report information about the numerosity abilities and the sense of running time of *M. sabuteli* ants, then of other animal species.

The workers of the ant *M. sabuleti* have many cognitive abilities. Among others, they detain numerosity abilities summarized, for the readers' convenience, in Cammaerts & Cammaerts (2020d, 2020e, 2022a). Briefly, *M. sabuleti* workers can add and subtract one visual or olfactory cue to and from other ones when perceiving the results of the operation; they natively possess a left to right oriented number line with a logarithmic mental positioning of the quantities on this line. Through experiences, they acquire a concrete notion of zero. They can acquire numerical symbolisms and use the symbols for adding. They can expect the following element in an increasing or decreasing arithmetic or geometric sequence when being in presence of the sequence. They add two numbers of elements if these elements are identical, and if they are sighted simultaneously, i.e., if they are located from one another at a horizontal distance not exceeding 5 cm and at a vertical distance not exceeding 4 cm, as well as if they are not perceived after a time gap longer than 7 minutes and 45 seconds between them (Cammaerts & Cammaerts, 2019a, 2019b, 2021c, 2021d, 2022c).

Myrmica sabuleti ants have a notion of the running time (Cammaerts, 2010). This was revealed through several experimental works (Cammaerts 2004, 2010, 2013a), and was particularly obvious when demonstrating that these ants can expect the time o'clock of the occurrence of an event on the basis of previous occurrences of this event (Cammaerts & Cammaerts, 2016b). However, young ants do not yet detain this ability (Cammaerts, 2013b; Cammaerts & Cammaerts, 2015c). In addition, the workers of *M. sabuleti* natively detain a circadian rhythm (Cammaerts et al., 2011).

Similar abilities have been found in many vertebrates and invertebrates. A non-exhaustive list of these abilities is here below reported and much more information can be found in the references here above cited.

Numerosity abilities can be ranked in four successive steps: evaluating amounts of elements, counting the number of elements, adding and subtracting elements, acquiring numerical symbolisms. Evaluating amounts of elements has been observed for instance in fishes (Agrillo et al., 2017), rats (Cox & Montrose, 2016), and spiders (Rodriguez et al., 2015). Counting elements has been shown for instance in frogs (Rose, 2018), birds (Pepperberg, 2012) and monkeys (Beran, 2008). Adding and subtracting elements is an ability detained for instance by birds (Rugani et al., 2009) and monkeys (Flombaum et al., 2005). Birds (Xia et al., 2000) and chimpanzees (Biro & Matsuzawa, 2001) can acquire numerical symbolisms. New born chicks were even shown to possess a number line (Rugani et al., 2015). The notion of zero was showed to be acquired by birds (Pepperberg & Gordon, 2005) and chimpanzees (Biro & Matsuzawa, 2001). Learning a sequence of numbers or of other elements has been observed in several animal species (Kershenbaum et al., 2014). Expecting the following element of a sequence was observed e.g., in monkeys (Brannon & Terrace, 2000).

Expectative behavior requires having a notion of the running time. Such a notion has been found to be detained by, e.g., great apes (Osvath & Osvath, 2008). Bees, according to their navigation system, also detain this notion (Eban-Rothschild & Bloch 2012). In addition to their notion of the running time, most of animal species including humans detain an innate circadian rhythm. The trait and properties of such a rhythm are explained for instance in the reviews of Murphy and Campbell (1996) and of Rivkees (2007). These authors focus on mammalians and provide information on the physiological mechanisms which act in accordance with a circadian rhythm. Forager honeybees possess an obvious circadian rhythm ruled by a molecular clock that is more similar to that of mammals than to that of fruit flies (Eban-Rothschild and Bloch 2012). Using anesthesia, an experimental work on the clock time behavior of the honeybees showed that the circadian clock of these insects is ruled by mRNA oscillations of two genes, *cryptochrome-m* and *period* (Cheeseman et al., 2012).

Workers of the ant *M. sabuleti* aged of about 2 years have a notion of the running time and are able to acquire conditioning (as shown in all of our here above cited references). They might thus be able to associate a given quantity of elements with its time period of occurrence. The ability to associate elements with their time period of occurrence could possibly be acquired thanks to conditioning. Indeed, it is nowadays admitted that during a conditioning process, the individuals not only associate the reward with the conditional stimulus, but also associate the reward and the conditional stimulus with several other parameters such as events occurring at the same time, environment characteristics, and time o'clock. The latter parameter is probably the main one memorized (Enquist et al., 2016)

Therefore, for *M. sabuleti* workers, detaining the ability to associate a learned quantity of an element with the time period during which this quantity has been learned is not a meaningless hypothesis. This hypothesis is all the more plausible since these ants can associate visual cues (squares, circles, stars) with the part of the day corresponding to their learning (Cammaerts & Cammaerts, 2022b). We here investigate about the potential ability of the workers of the ant *M. sabuleti* to associate learned quantities of elements with the time period during which these quantities were learned.

2. Materials and Method

2.1 Collection and Maintenance of Ants

We experimented on four colonies of *Myrmica sabuleti,* Meinert 1861 (labelled A, B, C, D) collected in May 2021 from an abandoned quarry located in the Aise valley (Ardenne, Belgium). The colonies lived under stones, and contained about 600 workers, brood and a queen. In the laboratory, each colony was maintained in one to three glass tubes half-filled with water, a cotton plug separating the water from the ants. The tubes were covered with transparent red paper for providing the ants with a low lighting inside their nest. The nest tubes of each colony were deposited in a tray (34 cm x 23 cm x 4 cm) the borders of which having been slightly covered with talc to prevent ants from escaping. These trays served as foraging areas in which food was delivered, namely pieces of *Tenebrio molitor* larvae (Linnaeus, 1758) provided three times per week, and sugar water continuously provided in small cotton-plugged tubes. The lighting of the laboratory was provided by a window (natural daytime light) and by the low artificial lighting (night-time light) of annexed rooms. Artificial lightning equaled *ca* at least 330 lux while testing the ants (during about 10 minutes), and about 110 lux during the other night-time periods. The temperature equaled *ca* 20°C, the humidity *ca* 80%, and the electromagnetic field *ca* 2 μWm^2. These conditions were suitable to the used species, *M. sabuleti*. Ants are here often named 'workers' or 'nestmates' or 'congeners' as usually do researchers on social insects.

2.2 Experimental Planning and Design

The figures 1 and 2 help to understand the following subsections.

Two experiments were performed, a first one on colonies A and B, a second one on colonies C and D. Each time, the ants were trained during four successive days and tested eight times over these training days. More precisely, the ants of colonies A and B were trained to 1 black rectangle from 20 o'clock until 7 o'clock and to 3 black rectangles from 8 o'clock until 19 o'clock, the ants being thus deprived of any stimulus from 7 to 8 o'clock and from 19 to 20 o'clock. The ants of colonies C and D were trained to 2 black circles from 8 o'clock until 19 o'clock and to 4 black circles from 20 o’clock until 7 o’clock, these ants being thus deprived, such as those of colonies A and B, of any stimulus from 7 to 8 o’clock and from 19 to 20 o’clock. The 1 and 3 black rectangles as well as the 2 and 4 black circles are described in the following paragraph. This planning allowed managing a time interval of 16 hours between the experiments I and II. Let us add that we choose such kinds of graphical elements because we know that the workers of the ant *M. sabuleti* can discriminate them (Cammaerts, 2008). Over their training, the ants of colonies A, B, C, and D were tested each day at 4 and 16 o’clock (in total, eight times) in front of the two kinds of stimuli used during training. The training and testing protocols as well as the analysis of the recorded data are detailed in the paragraphs below.

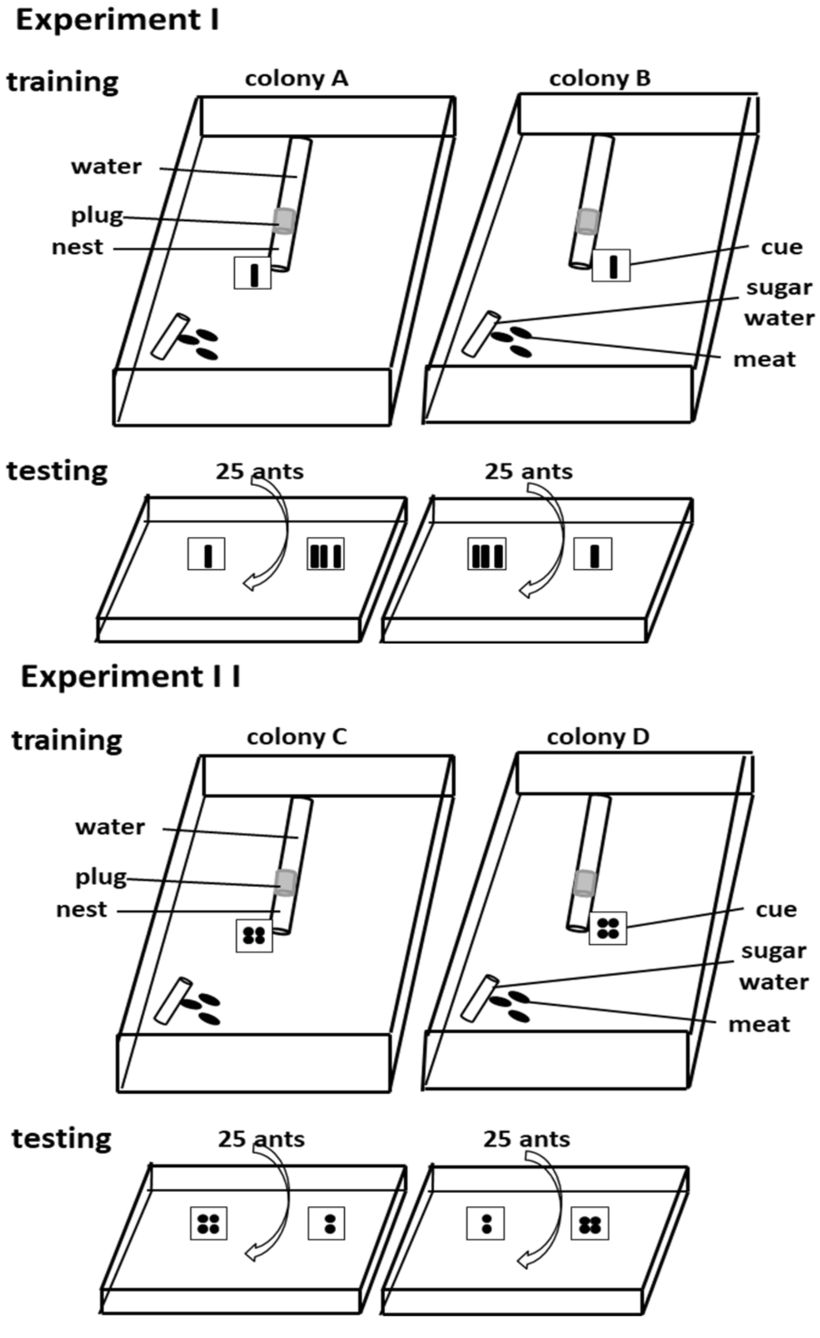

Figure 1. Schematized experimental design and protocol

During four days, the ants were trained to a given number of an element during a defined time period and to another given number of an element during another time period. The ants were tested in front of these two quantities of elements twice each day, at two o’clock times corresponding to the two training time periods, in order to see if they could associate each of the two quantities with the time period during which they were trained to them.

2.3 Cues

The cues presented to the ants were 1 or 3 black rectangles for experiment I (colonies A and B) (1.1 cm x 0.25 cm) as well as 2 or 4 black circles for experiment II (colonies C and D) (diameter: 0.45 cm). These cues were drawn using Microsoft Word® software inside a white square (2 cm x 2 cm), these squares being then printed and cut. Using extra transparent sticky paper, each square was tied on the front face of a stand constructed in strong white paper (Steinbach®, Malmedy, Belgium, 250g/m^2), presenting a vertical part (2 cm x 2 cm; on which the cue was tied), as well as a duly folded horizontal part [2 x (1 cm x 0.5 cm)] for ensuring the vertical maintenance of the stand. The cues were tied on the stands three days before starting the experiments in order to avoid any remaining odor. The cues and stands used to test the ants were identical to those used for training them, but were new, never used.

2.4 Experimental Protocol

The ants were trained in their foraging area to each cue during its allocated time period of presence, the cue being set close to the nest entrance which served as a reward, on the left of the entrance for colonies A and C, and on its right for colonies B and D. The ants underwent so operant conditioning to the cue. Colonies A and B (experiment I) were provided with 1 black rectangle from 20 o'clock to 7 o'clock and with 3 black rectangles from 8 o'clock to 19 o'clock, while colonies C and D (experiment II) were provided with 2 black circles from 8 o'clock to 19 o'clock and with 4 black circles from 20 o'clock to 7 o'clock. This difference between experiments I and II aimed to avoid any possible link between the time period and the size (smaller or larger) of the presented amounts of elements. The two cues were presented during four successive days according to the above cited planning, which includes a gap of one hour between the presentations of each of the two cues. A gap of sixteen hours existed between the last test made during Experiment I and the first cue deposit made for Experiment II.

Over these four days, the ants were tested at 4 and 16 o'clock, thus eight times in total, each time in a separate tray, each colony having its own tray devoted to testing. Each tray measured 21 cm x 15 cm x 7 cm, had its borders slightly covered with talc, and contained the two kinds of cues to which the ants have been conditioned. These two quantities (the smaller and the larger) of elements were randomly set on the left or the right in the tray. To make a test on a colony, 25 ants of this colony were transferred into their tray devoted to testing, and half a minute later the number of visits made by the ants when approaching each of the two presented cues at a distance less than 2 cm were counted 20 times over 10 minutes. After that, the ants were returned to their foraging area. For each test, each colony and each kind of cue, the sum of the 20 counts was established. These sums, i.e. the total numbers of ants sighted near each cue during each test on each two colonies of an Experiment are given in Table 1.

Adding the corresponding sums obtained for each test made on the two colonies used for an Experiment allowed calculating the proportions of ants having visited each two presented cues (i.e., the ants' conditioning scores). These proportions are given in the text. The variability of the numbers of ants sighted during testing near the stands bearing the quantities they saw during the time of the day corresponding or not to the time of the day of their learning is shown in Figure 3.

There was no statistical difference between the conditional scores of the ants of colonies A and B, nor between those of the ants of colonies C and D, regarding the correspondence between the time of the test and the daily period of the training (Mann-Whitney tests). The scores of colonies A + B (experiment I) and of C + D (experiment II) were thus pooled for further statistical analyses.

During the first testing session in each of these two experiments, the ants were faced to a cue to which they had already been trained and to another cue which was new for them. This first testing session was thus not taken into account in the following statistical analysis. The effect of the predictors 'training period' (day-time or night-time), 'time of testing' (4 or 16 o'clock) and 'colony' (A, B, C or D, 'colony' set as a block effect) and of the interaction between training and testing time on the workers' response (i.e., the total number of sighted workers near each cue) was analyzed by a GLMM regression based on the 'car' package in R software (function glm, formula: 'total number of workers ~ training period*time of testing + colony'). Likelihood-ratio tests were made for each predictor. The link function was chosen by comparing the median, mean and variance of the worker's responses in each case of a training period corresponding to a time of testing. All 8 cases, each containing 6 to 8 response values depending on whether the first counting session could or could not be taken into account, showed a variance very different from the mean which, in turn, was similar to the median, what means that a Gaussian family link function appeared to be the best choice.

3. Results

3.1 Experiment I

Numerical and statistical results are given in Table 1, photos are shown in Figure 2, and a graphical synthesis of the variability of the results can be seen in Figure 3.

Table 1 shows that the ants of colonies A and B very significantly associated the learned quantities of elements and the time period of the day during which they were presented to them. Their responses at 4 or 16 o'clock were strongly correlated to the time periods 20 to 7 or 8 to 19 o'clock (P = 2.095E-9).

The mean response of the ants of colonies A and B to one black rectangle to which they were trained during the night and tested at night (at 4 o'clock) equaled 89.26%, and their mean response to 3 of these rectangles to which they were trained during the day and tested at day (at 16 o'clock) equaled 86.11%. Trained at night and tested at day, their mean response equaled 13.97% while when trained during the day and tested at night, their mean response equaled 10.74%.

Figure 3 shows that, when tested, the number of visits made by the ants to a cue (a quantity) at a time of the day corresponding to that of its learning was higher and did not overlap with the number of visits they made to a cue (a quantity) at a time of the day not corresponding to that of its learning.

Table 1. Results of two experiments made for knowing if ants can associate through conditioning a given number of elements with the time period during which it was learned. *: the learning period corresponding to this test having not yet taken place, the first counting session was not taken into account in the statistical analysis

Experiment I.	N° of ants of colonies A and B		Predictor's effect
	trained during		on the workers' response
Days 1 to 4,	20h to 7h and	8h to 19h	
	and sighted in front of		(GLM, likelihood ratio test)
Testing time	1 element	3 elements	
1, 4h	35 and 40	13* and 1*	Training period:
16h	8 and 5	31 and 46	$\chi^2 = 0.030$; df = 1; P = 0.8634
2, 4h	34 and 20	4 and 3	Time of testing:
16h	7 and 8	36 and 53	$\chi^2 = 0.155$; df = 1; P = 0.6935
3, 4h	112 and 29	14 and 2	Colony:
16h	6 and 5	22 and 49	$\chi^2 = 0.821$; df = 1; P = 0.3648
4, 4h	45 and 40	2 and 3	Interaction, training and test time:
16h	9 and 4	49 and 33	$\chi^2 = 35.884$; df = 1; P = 2.095E-09
Experiment II.	N° of ants of colonies C and D		Predictor's effect
	trained during		on the workers' response
Days 1 to 4,	8h to 19h and	20h to 7h	
	and sighted in front of		(GLM, likelihood ratio test)
Testing time	2 elements	4 elements	
1, 16h	54 and 53	14* and 5*	Training period:
4h	3 and 5	49 and 38	$\chi^2 = 8.088$; df = 1; P = 0.0045
2, 16h	57 and 48	10 and 7	Time of testing:
4h	11 and 0	58 and 42	$\chi^2 = 0.398$; df = 1; P = 0.5280
3, 16h	27 and 32	1 and 9	Colony:
4h	3 and 3	36 and 42	$\chi^2 = 0.002$; df = 1; P = 0.9661
4, 16h	33 and 27	5 and 7	Interaction, training and test time:
4h	4 and 4	26 and 61	$\chi^2 = 108,101$; df = 1; P < 2.2E-16

Experiment I: when the number of elements they saw was 1 (presented from 20 to 7 o'clock) or 3 (presented from 8 to 19 o'clock), the ants went essentially to 1 element at 4 o'clock and to 3 elements at 16 o'clock. They have thus associated each learned amount with its time period of occurrence. Experiment II: when 2 elements were presented on a stand from 8 to 19 o'clock, and 4 from 20 to 7 o'clock, the ants mostly reacted to 2 elements at 16 o'clock and to 4 elements at 4 o'clock. They have thus also associated the two learned quantities with their time period of occurrence.

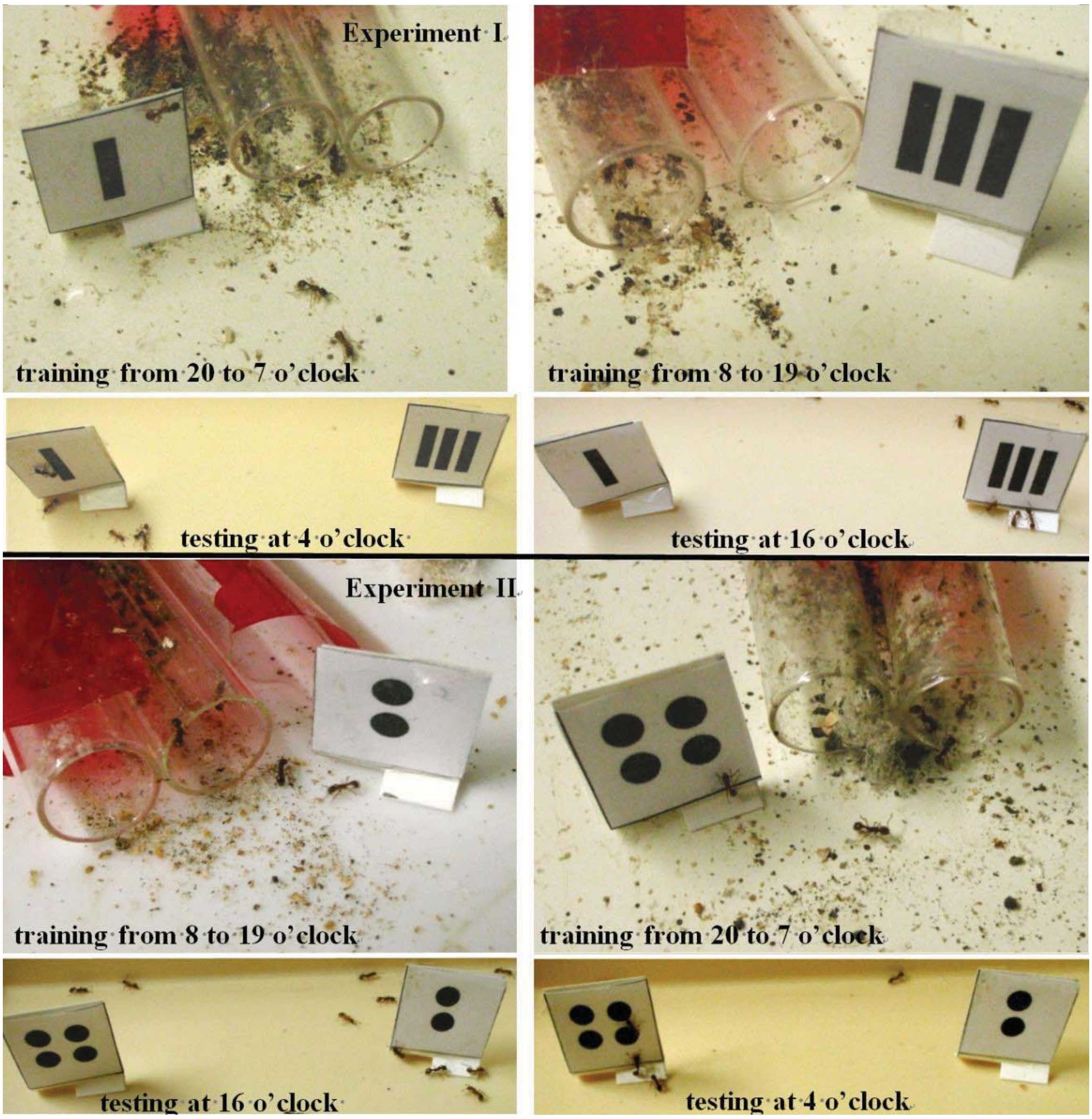

Figure 2. Some views of the experiments

For Experiments I and II, the upper photos show the ants' training and the lower photos show the ants' testing. Experiment I: trained to 1 black rectangle from 20 to 7 o'clock, the ants responded mostly to that cue when tested at 4 o'clock (i.e. during the time period of their training to 1 rectangle); trained to 3 black rectangles from 8 to 19 o'clock, the ants responded mostly to that cue when tested at 16 o'clock (i.e. during the time period of their training to 3 rectangles). Experiment II: in the same way, trained to 2 black circles from 8 to 19 o'clock, the ants responded essentially to that cue when tested at 16 o'clock (i.e. during the time period of their training to 2 circles), and trained to 4 black circles from 20 to 7 o'clock, they responded essentially to that cue when tested at 4 o'clock (i.e. during the time period of their training to 4 circles). The ants associated thus the correct numbers of elements with the time periods during which they were conditioned to them.

3.2 Experiment II

Numerical and statistical results are given in Table 1, photos are shown in Figure 2, and a graphical synthesis of the variability of the results can be seen in Figure 3.

Table 1 shows that the ants of colonies C and D also duly associated the learned quantities of elements with the time periods of the day during which they were trained to them. A strong correlation again existed between the ants' responses at 16 or 4 o'clock and the time periods 8 to 19 or 20 to 7 o'clock ($P < 2.2E-16$). In this experiment, the time of day when the training took place had some influence on the ants' response (P = 0.005), but not much compared to the relation between training period and test time.

The mean response of the ants of colonies C and D to 2 black circles, to which they were trained during the day and tested at day, i.e., 16 o'clock, equaled 84.96%, and their mean response to 4 of these circles, to which they were trained during the night and tested at night, i.e., 4 o'clock, equaled 91.53%. Trained during the day and tested by night, their mean response equaled 8.47% while when trained during the night and tested by day, their mean response equaled 15.04%.

Figure 3 shows again that, when tested, the number of visits made by the ants to a cue (a quantity) at a time of the day corresponding to that of its learning was higher and did not overlap with the number of visits they made to a cue (a quantity) at a time of the day not corresponding to that of its learning.

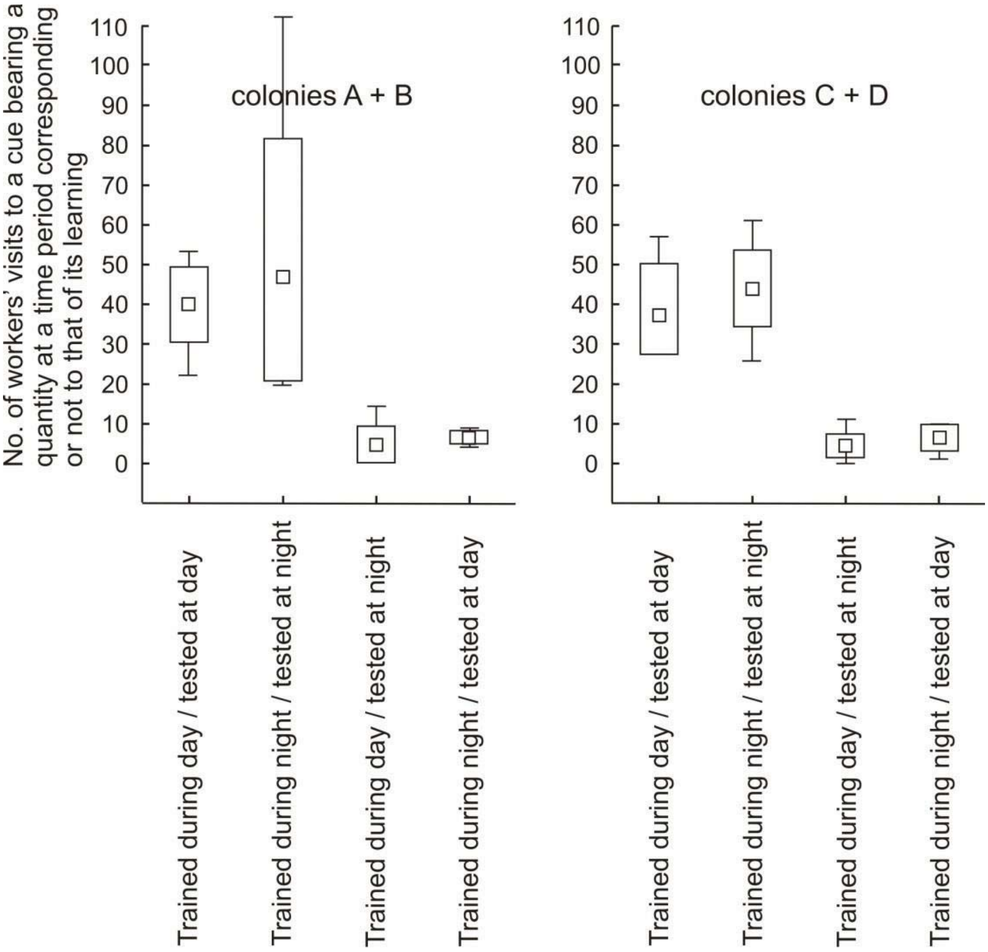

Figure 3. Graphical summary of the ants' association between a quantity of an element and the time period of the day during which this quantity was learned

The ants' responses were assessed by their numbers of visits to each cue (a stand bearing a quantity) at a 'day time' (16 o'clock) and a 'night time' (4 o'clock) corresponding or not to the time during which the ants learned the cue (the quantity). The box-plots show the mean, 95% confidence interval and extremes of the numbers of visits to the learned quantities of elements. The first testing session was not taken into account since the learning of one of the two quantities had not yet begun. The ants reacted each time more to the quantity expected to be present at a time of the day corresponding to its learning.

3.3 Comparison of Experiments I and II

The results of the two experiments were in agreement with each other though the size of the presented quantities and the time period of their presentation were inverted. The association between the learned elements and the time period of their perception by the ants does not depend on the size or the quantity learned.

The ants' percentages of responses at 4 o'clock to the elements presented during training from 20 to 7 o'clock (1 element was then presented on a stand during Experiment I, and 4 elements during Experiment II) were somewhat higher than those recorded at 16 o'clock to the amounts presented from 8 to 19 o'clock during training (3 elements were then presented on a stand during Experiment I, and 2 elements during Experiment II). This difference between the ants' conditioning scores in function of the time of the day, although not particularly marked (the mean of the ants' proportions of responses at the time of the day corresponding to that of their learning was 91.49% (84.06 – 100, with σ = 4.44) when tested during the night and 85.56% (78.05 – 96.43, with σ = 5.33) when tested during the day), was nevertheless statistically significant. Indeed, a Wilcoxon test made between twelve pairs (three pairs per colony because the first counting session could not be taken into account) of scores (percentages of visits in favor of the cues corresponding to the time of the day of their learning) gives P = 0.028 for T = 11. Furthermore, several days after the end of the experiments, thus not in presence of any element, the ants that were moving a few centimeters at the surrounding of their nest entrance were in each colony punctually counted (i.e., during at most a few seconds), each hour from 0 to 6 o'clock and each hour from 12 to 19 o'clock. Thus, a total of 32 counts (8 counts x 4 colonies) were made during the night and of 32 counts (8 counts x 4 colonies) during the afternoon. The mean number of ants observed there during the night was 8.49 (extremes: 3 – 20) and that during the afternoon 1.41 (extremes: 0 – 4). Assuming that one hour between each count was sufficient for avoiding counting the same ants, a Mann-Whitney U test was performed, and this showed that these two series of numbers differed highly significantly (Z, adjusted = 6.764; P < 10E-6). The ants have thus best learned at the time of the day when they walked the more around the cues set at their nest entrance.

4. Discussion

We have here shown that, through conditioning, the workers of *M. sabuleti* could associate a sighted quantity of an element with its time period of occurrence. Let us precise that the graphical elements presented to the ants during each choice test had the same shape, color and size. The only difference between those presented during the two training time periods was their number and their totalized surface. Thus, the ants may have associated quantities with time periods. Note that the inside of the ants' nest was maintained under low lighting thanks to red transparent paper, that foragers navigated all over their foraging area for short time periods as in nature, and that the choice of the concerned periods of the day does not allow us to conclude anything about the existence of a possible association between cue learning and the circadian rhythm of the workers, such a study being not the aim of the present research.

It was also not the purpose of the present work to know whether, when ants associate quantities with the time of day of their learning, their reaction depends (as in an operation) or does not depend (as in a count) on confounding variables such as the shape, color, or size of the items presented.

It is debatable whether the workers' response was due to a preference toward the cue they saw most recently and an aversion to the cue they saw least recently, which is perceived as a novelty (neophobia). Their correct choice of a new element in an arithmetic or geometric sequence (Cammaerts & Cammaerts, 2021a, 2021b) shows that this should not be the case. In addition, experiments about potential neophobia were conducted in the course of our work on ants' association of odors with the time period of the day during which these odors were learned. The results of these experiments allowed concluding that ants obviously and statistically do not display neophobia (Cammaerts & Cammaerts, submitted)

Associating a cue (a visual cue, an odor, or a given quantity of elements) with its time period of occurrence may simply result from conditioning acquisition. Indeed, as stated in the Introduction section, during a conditioning process, several parameters, with among others the running time, play a role, and are memorized together with the conditional stimulus and the reward. In the here performed experiments, the reward was the nest entrance, and on the basis of the high conditioning scores obtained, it can be admitted that, for ants, their nest entrance is a valuable reward.

This ability to associate through conditioning elements with their time periods of occurrence may not be detained by young ants. Indeed, ants 1 to 2 years old must yet acquire the notion of the running time (Cammaerts, 2013b; Cammaerts & Cammaerts, 2015c). The associating skill here revealed in foraging ants certainly exists in other animals, including humans who can associate learned amounts of items with their time period of occurrence. Such an association can be useful along the everyday life. The individuals would know that, during a given time period, they can look for a given amount of items and not for another one. They thus would earn time and save working.

In the laboratory, the workers of *M. sabuleti* were observed to be more active during several time periods between 20 and 7 o'clock than during the 8 to 19 o'clock period. This difference in the ants' daily activity is in accordance with their better learning during the nocturnal period of the day than during the diurnal period. In other words, the ants seemed to better learn while being active. Let us point out that a link between learning and periods of greater daily activity is also observed in humans (Montagner, 2008).

To conclude, we here revealed one more skill detained by ants thanks to their ability of acquiring conditioning, to their perception of the running time and to their capability of distinguishing quantities of elements: the association of sighted quantities with the time of day of their learning. Associating cues to a particular time of day could help ants in their daily tasks.

Conflict of interest

We affirm having no conflict of interest concerning the topic here investigated.

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A Review of Black Skin Research: Gloger Rule/Theory Dead or Alive?

Sylvain Cibangu

Correspondence: Research Forum for the Unserved, USA. E-mail: fscib@uw.edu

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Abstract

Unlike various topics of human life that recurringly naggingly preoccupy scholars, black skin tends to be considered by prestigious biology and science publication outlets as a closed and disposed-of topic. The present paper is not one of experiment, but rather the paper is a long-due comprehensive review of black skin scholarship, using a dominant theory of this scholarship, and suggesting newer insights for future research. Known since Antiquity, black skin -- euphemistically called dark sin -- has become the topic of repeated public debate in recent decades. Part of the reason is that although race is believed to be scientifically nonexistent skin color is not. Meanwhile, among the theories explaining black skin, Gloger rule/theory stands out to be the most popular. While multitudes of reviews have examined Gloger theory, few have confronted the theory with the arguments of Gloger himself. This might be because Gloger writings remain untranslated and unknown to English readership. Although Gloger was an ornithologist by profession, his arguments had immense ramifications far beyond the study of birds. The present paper focused on the key arguments of Gloger to present a critical assessment of black skin materials. To this effect, a comprehensive, historical background of Gloger theory was used along with recent research to bring in sharper relief Gloger teachings about skin color. In light of Gloger critiques, it was determined that Gloger theory is no less than inadequate and so is the description of black skin as a product of natural selection. Taken-for-granted theories and resultant arguments of black skin were reversed and paths for future skin color work were proposed. Gloger arguments highlight variability among species and across latitudes.

Keywords: Gloger rule/theory, black skin, climate effects, latitudinal gradient theory, torrid zone theory, gradient of human skin theory

1. Introduction

The widespread dismissal of and indifference to the topic black skin embarrassingly run counter to the fundamentals of scholarly work. It is like saying, for example, that just because a cure/solution has been found in the course of biology history for cleft lips, cleft palates, epilepsy, tuberculosis, etc. any review/research of those and many similar topics of human life has been already closed and removed from scholarly work. As paleoanthropologists Smith and Wood (2017) reminded all researchers (of biology and skin color, including), “the *overall* [emphasis in original] research agenda of a discipline… must conform to science norms. This means, among other things, that… its knowledge is cumulative and progressive” (p. 672). One cannot improve that which is not researched/analyzed. What is most significant about black skin is that, as is obvious from the present review, just as misconceptions have been crafted and propelled about black skin by illustrious scholars, so too wrong attitudes toward and erroneous concepts about black skin continue to be perpetrated by eminent biology or science scholars and their outlets.

Gloger theory (1833) is an appealing theory, usually applied intentionally or unintentionally across biology and science fields. Fundamentally, Gloger theory takes the view that a cause-effect relationship exists between black(er) skin and warm(er) climate/region. To shed greater light on Gloger theory, a historical background of black skin has been laid out. If biology and in fact any scientific discipline aim to achieve a greater impact in the world, they ought to engage heads-on with the theories surrounding the concepts central to their work and to the world in which they operate, and black skin scholarship is no exception. As anthropologist Jablonski (2017) pertinently reminded skin color researchers, “the absence of scientific justification for races as ‘biological real’ does not mean that they are not socially real” (p. 7). To add to this dilemma, skin color represents one of the most conspicuous traits in the kingdom of living beings, from humans to animals to plants to microorganisms. Theories behind the “differences in biology brought about by racism” (Jablonski, 2020a, p. 6) cannot fail to warrant scrutiny. Oddly enough, black skin resides at the heart of racism and similar phenomena (i.e., slavery, poverty, unemployment, etc.). While racism, to name just this example, figures in human civilization as one of the deepest-seated evils, black skin is one of the least researched and most misunderstood topics of interest.

As an eloquent illustration, a casual glance at Google search, made on May 12, 2021, of OATD [Open Access Theses and Dissertations] one of the most prevalent database engines specialized in the repository of theses and dissertations worldwide since 1972, and spearheaded by UCSB [University of California at Santa Barbara] Library in Santa Barbara, CA, USA, shows 33, 608 hits of thesis and/or dissertation research done on the topic game with only 781 hits for the topic black skin. This is not taking into account the fact that Google would include a thesis or dissertation that mentions nothing but a reference related to black skin or a subject unconcerned with or loosely related to skin such as Black athletes, black music, black literature, black market, etc. Just as game a common topic among others is addressed from all scientific disciplines/perspectives, so too black skin can and should be approached from all scholarly specialties. But black skin is all too well surrounded with taken-for-granted arguments, theories, and narratives. Search was done on dissertation database because dissertations supply a comprehensive account on the state of scholarly work being undertaken, by engaging extensive bibliography and novel approaches. This paper centered the debate on the theories/interpretations given to the nature of black skin (color), although because of the multifarious scope of skin color field, arguments advanced in the paper draw from various relevant life and social sciences. Skin color scholarship was found to compare incomparable units of analysis as well as defend indefensible scenarios/narratives regarding skin evolution. The paper proposed specific pathways forward for future research on skin color.

Despite skin visibility and diversity, however, black skin continues to be held in lower public esteem around the globe, especially among women. In truth, “throughout the world, ideas of white or light-skin supremacy have long been associated with status and privilege for light-skinned individuals and *disdain for dark-skinned ones* [emphasis added]” (Dixon & Telles, 2017, p. 406). The same idea was upheld by Chaplin and Jablonski (2020), Hall (2018, 2019), and Jablonski (2020b, c, 2021a). One reason behind the contempt for dark skin might be the association of dark skin with social and structural inequalities or disadvantages alongside the nearly unstoppable production of skin-bleaching creams done by top-tier multinational global companies. Thus, arguments, interpretations, or theories formulated by skin color analysts to invoke and rationalize the evolution of skin color can very well be used to add fuel to the preference for and commodification of light skin and ensuing social consequences. This paper drilled deep into Gloger theory or justification of black skin color. At the same time, the narratives/theories of skin color are just as old as life itself, and can be traced back to ancient society.

1.1 Skin Color in Ancient Society

One of, if not, the earliest recorded texts of human skin diversity goes back to the Egyptian pharaoh Akhenaten in the 14th century BC. The text, with groundbreaking significance in this world wracked with racism, is known as the *Hymn to Aton*. In 1350 BC, king Akhenaten wrote,

> How various is the world you have created, each thing mysterious, sacred to sight,
>
> O sole God, beside whom is no other. You fashioned earth to your heart’s desire, while you were still alone, Filled it with man and the family of creatures, each kind on the ground, those who go upon feet, he on high soaring on wings,
>
> The far land of Khor and Kush, and the rich Black Land of Egypt.
>
> And you place each on his proper station, where you minister to his needs;
>
> Each has his portion of food, and the years of life are reckoned him.
>
> Tongues are divided by words. Natures made diverse as well,
>
> Even men’s skins are different that you might distinguish the nations. (Foster, 2001, pp. 4-5)

The pharaoh went on, narrating,

> And your Sunlight nurses each field and meadow:
>
> When you shine, they live, they grow sturdy and prosper through you.
>
> You set seasons to let the world flower and flourish—
>
> Winter to rest and refresh it,
>
> The hot blast of summer to ripen;
>
> And you have made heaven far off
>
> In order to shine down therefrom. (Foster, 2001, p. 6)

The ancient text cited above serves as a blueprint of biology and social science fields, insisting on the beauty of nature, sunlight, seasons, and human skins. The text also mentioned the land of Kush; Kush being a Hebrew term standing for black (details below). It is imperative to keep in mind how the king’s text referred to the beauty of seasons and human skins without any social claim of supremacy or exclusivity. Seasons are seen as universally established on earth, without any season being reduced to or monopolized by a given ethnicity or location.

Also worth noting at this juncture of human history is the fact that despite a steady awareness about skin as a distinctive feature of nations, Egypt was called *Khem* or *Khemet*, meaning black land, during the entirety of pharaonic times, which spans three millennia from the first dynasty around 3000 BC to the Greek empire or Ptolemaic period 304-30 BC (Budge, 1901; Bunson, 2002; Foster, 2001; Matić, 2020). This is a glaring indication that if Blacks had nothing to do with a country so rich -- noted for its “fabled wealth,” (Foster, 2001, p. 14), it would not have been called black land to avoid any confusion or misappropriation. Plainly put, Egypt could not be named black land for entire three millennia if the concept black (skin) was pejorative/degraded. Moreover, considering the variety of color and wealth seen in the soil of the hills and valleys of the Nile as well as of the vast landscape of Egypt (Upper and Lower Egypt) and the extensive metallurgic knowledge of Egyptians during pharaonic times, the name of the country could not be confused with or limited to the concept black dirt. In fact, “the black of the fertile soil” (Foster, 2001, p. 235) or “dark colour of the mud” (Budge, 1901, p. 19), so to speak, could only be a fraction of and indeed a diversion from the immense wealth and land found in ancient Egypt. Natural resources of the Nile valley and its hills included: feldspar (orange), malachite (green), beryl (blue or green), jasper (green or yellow), gold (yellow), copper (red), amethyst (lavender or purple), limestone (white, yellow, pink, or black), alabaster (white), granite (black or red), etc. (Bunson, 2002). The appellation of black land for a nation with such a diversity of colors in its soil is far from accurate. Lovari (2016) wrote that the desert in which the main city of Egypt was located was called *deshret*, meaning, red land, a further contradiction with the notion black land. This is not counting the extent of the land bequeathed by ancient Egypt since its beginning. As Bunson (2002) clarified,

> During the eighteenth and nineteenth Dynasties (1550-1307 B.C.E, 1307-1196 B.C.E.), when the empire was at its zenith, Egypt ruled over an estimated 400, 000 square miles of the Middle East, from Khartoum in modern Sudan to Carchemish [Syria] on the Euphrates River and westward to the Siwa Oasis [Libya]… *From the start*, Egypt’s foreign policy was based on a firm control of Palestine, Nubia (modern Sudan), and Syria [emphasis added]. (p. 126)

The expansion of the land was conceivably fairly large from the start. Throughout its entire history, ancient Egypt was shown to be ruled by and spanning a variety of regions and peoples (Matić, 2020). The variety of regions and peoples who ruled/conquered ancient Egypt could not let the appellation black land sit for such a long period of time. Remember that Nubia is a black land so is Ethiopia, both next-door neighbors of Egypt. Hence, designating the land as black only because of the mud dumped periodically by the Nile could have made a serious dent in the extent and integrity of the territory during the three-millennium reign of pharaohs and their dynasties, let alone the color of the mud was/is neither that of the Nile nor of the land. More importantly, a noteworthy characteristic of ancient Egypt is a wide assortment of products for skin care; namely: perfumes, faience (for foot baths), ointments, balsams, unguents, creams, etc. (El-Kilany & Raoof, 2017; El-Shimy, 2003; Foster, 2001; Tatomir, 2016). The preponderance of skin care products in ancient Egypt displays no claim of superiority of one specific skin color upon another. In ancient Egypt, all skin colors called for care and enjoyed respect. Another ancient instance among others that show black skin (color) with no claim of superiority involved is with the Near East, precisely in the books of Job and Lamentations in the Bible (Hebrew Interlinear Bible).

The story of Job (Batnitzky & Pardes, 2015; Fox, 2018; Guillaume, 2008; Newsom, 2007; Vicchio, 2006, 2020) narrated in the Bible is a character common in the Near East around 6th-5th century BC, describing a righteous, devout man/character of black skin. As the story goes, “my skin is black upon me, and my bones are burned with heat” (Job 30:30 Hebrew Interlinear Bible). The mention of black skin implies a Near East black or dark-skinned righteous and religious individual being the topic of the story. More than likely, the individual (portrayed) in the Job story might be Egyptian, (foreign-born) Jewish, or of some Near East nation (Batnitzky & Pardes, 2015; Fox, 2018; Guillaume, 2008; Newsom, 2007; Vicchio, 2006, 2020) -- having a hard time with heat. Highly significant for our discussion here is that because the character Job represents one of the most undisputed and inspirational characters among Jewish natives, regarded as a spectacular role model of Jewish faith/culture/religion in times of suffering and hardship, Job must have been a Jewish. For Jewish communities, aware of their unique religious position, a non-Jewish especially black-skinned or foreign-skinned individual could not be elevated to the status of an exemplar. Heat was not taken to be analogous to or indicative of a specific population, race, or location. More clearly, as seen in the book of Lamentations, black skin was associated with Jewish communities. Indeed, the book of Lamentations refers to a struggling Jewish community after the destruction of the temple in 587 BC by the Babylonian army (Miller, 2002; Wilkins, 2010). The book of Lamentations notes, “their visage is blacker than a coal; they are not known in the streets: their skin cleaveth to their bones” (Lamentations 4:8 Hebrew Interlinear Bible). A face that is blacker or darker than coal has to be definitely black. In other words, the face of those Jewish members was blacker than a thing as black as coal, and for some reason, these communities were not being noticed in the streets whereas they should have. Further, the book of Lamentations reads, “our skin was black like an oven because of the terrible famine” (Lamentations 5:10 Hebrew Interlinear Bible). The black Jewish community must have undergone some starvation due to the destruction of the temple. Starvation accounts for bony or skinny bodies noted above. It is apparent from the book of Lamentations that the Black community was of a diverse color, with blackish-red, blackish-blue/purple, and pitch-black individuals.

The Hebrew noun or radical שוּכ [kush] used in the book of Lamentations and the book of Job, meaning black/dark (Hebrew Interlinear Bible), is the same as the one mentioned about the land of Kush or Cush noted several times throughout the Bible and in ancient Near East literature (see Burrell, 2020, pp. 60-103; Foster, 2001, pp. 4-5). Thus, black skin was quite common in ancient world, with no negative/deprecatory connotation ascribed to it. The concept Cushite -- not surprisingly translated as Ethiopian -- was also easily applied to Jewish. For example, in the book of Jeremiah (38, 6-10: Hebrew Interlinear Bible), a Cushite, named Ebedmelech, was the top official of defense department/ministry in Israel, and intervened with the king to release the prophet Jeremiah who had just been condemned to death by the king. According to the story, the military guards approached and pleaded with the official, knowing the power entrusted to him. A black-skinned foreigner or any foreigner cannot be given such top power in the land of Israel or any land, with the constitutional ability to reverse the king's decree, and use the army with the approval of the king to do so. Thus, the general must have been a black-skinned Jewish, in charge of the security of the land and the king.

The diversity of the Black Jewish community is given much emphasis in the book of Lamentations when it reads, "her Nazarites were purer than snow, they were whiter than milk, they were more ruddy in body than rubies, their polishing [was] of sapphire" (Lamentations 4:7 Hebrew Interlinear Bible). Evidently, servants of God appeared to be cleaner and more shimmering (the actual translation or meaning of the Hebrew verb *tzchu*, used in text, Hebrew Interlinear Bible) than average people, with their bodies being ruddier than rubies and more polished or shinier than sapphires. Note that rubies display a strong blackish red whereas sapphires have a strong blackish blue or purple, all of which cannot be said of white skin. Of importance here is the phrase black like an oven, mentioned supra (Lamentations 5:10 Hebrew Interlinear Bible), that is also inapplicable to white skin. Some explanation is of the essence. By nature, smoke -- especially when produced constantly as in the case of cooking -- blackens metal or material so deep that it cannot (or can barely) be removed. In fact, a combination of smoke and burnt food items (e.g., oil, paste, soup, meat, bread, flour, etc.) occurring during cooking, causes a stove or oven to turn pitch-black, blackish red, or blackish grey. The insistence on and the superlative of black color in the stories of Job and Lamentations are a patent indication of black-skinned individuals. In addition, as is evident in the book of Lamentations, Black communities had a steady, distinct sense of their Jewish identity/nationality. The book of Lamentations states, "we have given the land [to] the Egyptians, [and to] the Assyrians, to satisfied with bread" (Lamentations 5:6 Hebrew Interlinear Bible). More specifically, the book of Lamentations continues, "our inheritance is turned to strangers, our houses to aliens" (Lamentations 5:2 Hebrew Interlinear Bible). Both the story of Job and that of Lamentations, reflecting the Near East world around the 6th century BC, allude to black skin and heat without any pejorative connotation.

Furthermore, apart from Jewish and Egyptian nations, swarms of historical materials have demonstrated extensive presence of black-skinned communities aboriginal in much of Asia and in Siberia as far as the Caspian regions and Caucasian mountains (Herodotus, ca. 425 BC/1950, ca. 425 BC/1957, ca. 425 BC/1960; Brook, 1999/2018; Kolga, Tõnurist, Vaba, & Viikberg, 2013) without deprecation concerning black skin and heat. Black individuals were shown to be full members of the communities and regions in which they were living, something unusual for slaves or low-class individuals. For example, Herodotus (ca. 425 BC/1957) spoke of Ethiopians of Libya as having "of all men the woolliest hair" (7.70). Ethiopians of Libya could not be called so if they were not Libyan and the same holds true for Ethiopians of Asia, who would not have been identified so if they were not Asian (see below). Also Herodotus noted that among the Asian kingdoms that were bringing gifts to Darius, the king of Babylon, were also Colchians, whom he described as "dark-skinned and woolly-haired" (Herodotus, ca. 425 BC/1960, 2.104) and Ethiopians of Asia (Herodotus, ca. 425 BC/1950, 3. 92-94. 97). The description woolly-haired individuals indicates Black people.

Of paramount interest here is the fact that, according to Liddell and Scott (1843/1996) celebrated Greek lexicon, the Greek word *ούλότριχες* (oulo-trikhes) employed by Herodotus (ca. 425 BC/1960, 2.104) when describing the Colchians, and translated by most commentators as woolly-haired comes from the Greek verb *οὐλοτριχέω* [oulotrikheo], meaning to have curly hair. A further note of interest is that regarding the Greek adjective that derives from the verb to have curly hair, namely, the adjective *οὐλόθριξ, τριχος* [oulothrikhs, oulothrikhos], which denotes someone with curled hair, Liddell and Scott (1843/1996) unmistakably limited this notion to Blacks noting: "with crisp, curly hair, like negroes, opp. [as opposed to] *εὐθύθριξ* [euthuthris]". The adjective *οὐλόθριξ* [oulothrikhs] is composed of two particles: *οὐλό* [oulo] and *θριξ* [thrikhs], which respectively mean curly and hair. Here too, Liddell and Scott (1843/1996) insisted and defined the adjective *οὐλός* [oulos] as: "of the crisp, woolly hair of the negro". As can be seen, the adjective *οὐλό-θριξ* is being opposed to the adjective *εὐθύθριξ* [euthuthrikhs], which stands for straight-haired. Furthermore, Herodotus (ca. 425 BC/1957, 7.70) was able to distinguish the Ethiopians of Egypt with straight hair and those of Libya with the curliest hair of humans. Without question, the Colchians were nothing but Black with curled hair. Curled or coiled hair is a characteristic notably employed by torrid zone theory to underscore the intense heat of Africa, as Smith (1787/1810, pp. 96-97) declared below that just like wool and vegetable leaves, hair curls itself up when put close to a flame.

In addition, slaves much less foreign black-skinned individuals -- if and only if slaves had been imported to the area as some authors tend to argue (Blakely, 1986) -- could not have been allowed to form and have kingdoms in the host land, with the ability to own and ship precious gifts via official delegations to the reigning king (Darius) on behalf of their own kingdoms. Another example, Brook (1999/2018) enumerated several communities of Black individuals living in Siberia, Russia, until the 1880s and later, such as “Black Khazars” (p. 4), “the Magyars [or] the Black Ugry” (p. 5), and “Kuban Bulgars (Black Bulgars)” (p. 125). Not a small number of facts clearly certify a presence of black-skinned people in this part of the world. “For instance, the seventeenth century Arab traveller Ezliya Chlebi encountered black Crimean potters” (Blakely, 1986, p. 11). Slaves are usually kept deprived from basic services/liberties and unmingled with local populations. However, in addition to being able to form a kingdom and send gifts to Darius, Black communities in the Caucasian mountains were so intermingled with local communities that Russian travelers were astounded and contrasted them with Blacks in the US (Blakely, 1986). One characteristic of slaves is that slaves usually have their masters known, and well-identified because slaves’ masters intervene and speak on behalf of slaves, especially when dealing with foreigners or visitors. The geographical conditions of Siberian regions did not allow constant and easy access of foreigners or researchers. The indisputable aboriginal existence of Black Caucasians completely belies all claims of Black slaves or Black aliens in the Caucasian region or other regions beyond the equator.

Thus, “it was not until early in the twentieth century that the Russian public was made aware of the existence of settlements of several hundred Negroes in the Black Sea region” (Blakely, 1986, p. 6). The thesis of slave trade as an explanation of black-skinned communities in ancient world is untenable in many respects. The likeliest reason might be that there was no large-scale labor that would require a titanic, perilous, across-continents, and long-distance trade of hundreds or thousands of foreign-born black individuals in a given land of the Old World, wherein man power was otherwise locally available for merchant, royal, and domestic chores. Another likeliest reason is that private or royal palaces would not and usually do not require long-distance and large-scale shipping trade of foreign or black populations because palaces have no room/space to house and attend to such big personnel made of children, women, and men of all kinds. Normally, it can be argued that kings and emperors might want to ship (via the military) one or two Black or foreign concubines for romantic purposes, or one or two strong Black or foreign men for heavy-duties domestic chores, and not large-scale communities in the slightest. Also, such a costly and challenging shipping business (of humans) would have to be profitable both for traders and buyers (Cibangu, 2015), which is certainly not the case in this specific context of Asia and North Africa.

All in all, in the various communities and nations mentioned above from Egypt to the far east of the world, black skin was not denigrated nor associated with (some place of) heat. Most remarkable is the fact that, although on the one hand the concept others or foreigners could be the object of disparagement often described as barbaric (Gruen, 2011, 2020), and on the other hand the land of Kush, a foreign land, was noted for its wealth and militaristic power (Burrell, 2020), black skin was highly regarded throughout the ancient world. Equally, the concept heat was not stereotyped as exclusive to a given population or community, all of which is also observed earlier with king Akhenaten narrative in the 14th century BC (Foster, 2001). The predominance of aboriginal black-skinned individuals in the Old World from North Africa to the far east of Asia renders less likely both the thesis of slave trade of Blacks and that of deprecation against black skin. What’s more, the persistent designation, during pharaonic times, of Egypt as *Khemet*, meaning Black nation alongside a steady awareness of skin color as distinctive of nations (Foster, 2001) would have constituted a serious threat to the sovereignty, famous wealth, and diverse landscape of ancient Egypt if Blacks had nothing to do with the black land. Most curiously, the words Kush or Cush (now Sudan) and Egypt relate to the same Hebrew radical שׁוּכ [kush] (Brown, 2001), meaning black. Even most worthy of note here is that the Hebrew word Kush, black skin, was readily indisputably applied to persons in Israel, Assyria (now Syria), Egypt, Arabia, Ethiopia, South Sudan, etc. No White nation governed by White kings or rulers would allow their land to be called black land for three millennia.

In Antiquity, black skin was normally associated with Ethiopia, a millennia-long Black nation of unbeaten and stand-alone civilization, with its own writing, language, and political system. As is now clear, black skin was not the subject of deprecation for three millennia BC and for much of the first millennium AC roughly after the turn of the 17th century. In the first half of the 1700s, Swedish naturalist Carl Linnaeus (1707-1778) introduced the first classification of human species based on skin color and latitude, distinguishing: red (i.e., Americans), yellow (i.e., Asians), white (i.e., Europeans), and black (i.e., Africans) species (Burrell, 2020). The classification -- created by Linnaeus in the first volume of the 10th edition of his book *Systema Naturae*, in 1758, first published in 1735 -- carried an explicitly disparaging description of Africans as being lazy and negligent species or varieties (Linnaeus, 1735/1758, pp. 21-22). Skin color was ever since characterized as synonymous with and as a measurement for the standards of decency and civility, with Blacks [*niger*] being at the lowest level, and Whites [*albus*] at the highest one. Proper to Linnaeus system, or Linnean system as it is also commonly called, is the notion gradient or hierarchy of species based on geography or latitude for skin color and for human behavior. Black skin thus became a species, namely the *Africanus*, *niger* [African, black] species, and its characteristics as well as the descriptions or assumptions made on them were (believed to be) congenital. The Linnean skin color-based classification of humans drawn along the lines of the four continents (i.e., America, Europe, Asia, and Africa) will have an unspeakably immense impact in academia and the general public in the 18th-19th century and onward. The inferiority of black-skinned peoples and their skin was thus put forth. On the heels of the Linnean classification of human varieties/species, German philosopher Immanuel Kant (1724-1804), started teaching summer courses on physical geography in 1756 at the University of Königsberg [now Kaliningrad, Russia], the last of which he published in 1775 (Kant, 1775) under the title *On the Different Races of Humans*. In that course, Kant (1775) identified four races:

> *Sie sind 1. die Race der Weissen, 2. die Negerrace, 3. Die Hunnische (Mungalische oder Kalmulische), 4. die Hindaische oder Hindistanische Race* [They are: 1. The race of Whites, 2. The Black race, 3. The Hun race (Mongol and Kalmuck), and the Hindu or Hindustani race]. (p. 4)

Black skin came to be defined as black race and white skin as the icon of whiteness. With Kant popular summer teachings on physical geography delivered for nearly two decades, from 1756 to 1775, the idea of black skin as substandard, black race and whiteness as a model of humanity will be lastingly etched in the minds of people in Europe and beyond. Climate was presented as the reason for the color of black skin (see Kant, 1775, p. 8). Deprecation against black skin climaxed in particular in the first half of the 1800s with the advent of articulate torrid zone theory along with a rapid rise of transatlantic slave trade. The rise of transatlantic slave trade was expedited by new technologies invented during the Industrial Revolution (e.g., steam engine, electricity, telegraph, etc.). As can be imagined, the shift and prediction from biology (i.e., skin color) to social values/standards (i.e., decency or civility) has proven to be the toughest nemesis of skin color research in particular and biology or academia in general. A review paper such as the present paper reappraising Gloger theory and its background is definitely in order.

1.2 From the 18th Century Onward

Deprecation against black skin might be hearkened back to the application of what might be called torrid zone theory, a theory whose ingredients were arguably first laid out in 1646 in Paris by prince Armand de Bourbon (1629-1666) -- prince of Conty, second son of Henry II, also called prince of Condé (Bourbon, 1646). In a reflection about the nature and manifestations of the sun, Bourbon (1646) narrated,

> *Atqui Zona torrida globi terraquei est locus, ubi est plurima & materia vaporabilis, & virtus vaporans, seu conuertens in vaporem. ergo Zona torrida globi terraquei est locus unde maximam vaporum emergit copia… Atqui Zona torrida globi terraquei est locus, ubi est aqua plurima terrae spiritibus & exhalationibus permista, qualis est salsa: & terra plurima quae vel ardore solis torretur vel aquae permiscetur. ergo Zona torrida globi terraquei est locus, ubi est plurima materia vaporabilis* [And yet the torrid zone of the earth is a place, wherein most things are flammable, energy is flaming, or converting into heat. Therefore, the torrid zone of the earth is a place in which more heat rises in abundance… And yet the torrid zone of the earth is a place where most water is mixed with the air and emissions of the earth, which is salty and mostly dirt that is even being roasted by the fire of the sun or even being mixed with water. Therefore, the torrid zone of the earth is a place where most matter is flammable]. (pp. 29-30)

Nothing was mentioned about black skin, other than a startling description of heat and the sun. The reflection is remarkably comparable to that of pharaoh Akhenaten in the 14th century BC (Foster, 2001), with the chief difference being that Bourbon (1646) reflections were more about the explanation/understanding of the sun presence on or relations with the earth, as Bourbon (1646) did not single out any skin, race, or location.

Typically, however, articulate theories of deprecation against black skin and race did not start until German naturalist Johann Friedrich Blumenbach (Rupke, 2021; Rupke & Lauer, 2019; Torres, 2019) -- in his doctoral dissertation in 1775 at the University of Göttingen, Germany, on the innate variety of mankind, published later in 1795 in the 3rd edition of his book -- made a copied-and-pasted blanket application of Bourbon (1646) reflections to Africa (Blumenbach, 1775/1795). Blumenbach was a student of Linnaeus (Burrell, 2020), who initiated the skin color-based classification of humans touched upon earlier. Torrid zone theory (Blumenbach, 1775/1795) is based on the premise that reads as follows:

> *Nullum autem aliud clima, tum vehemencia et diuturnitate ardoris, tum singularibus plane atmosphaerae qualitatibus chemicis huc facientibus, ventis v. c. specificis, pluviis etc., isti fervido et urenti coelo comparandum, quod udis et paludosis* ***Africae*** *tam orientalis quam occidentalis regionibus* ***sub torrida zona*** *incumbit* [No other climate, however, not only with the force and the long duration of heat but also with clearly unparalleled, chemical and so far active conditions of the atmosphere, led by specific rainy winds, etc. is comparable to that of a glowing hot and scorching weather, which *by means of a torrid zone* lies in humid and swampy regions of both eastern and western *Africa* [emphasis in original] (p. 127)

As can be realized, torrid zone theory is derived from the Latin phrase *torrida zona*, taken from Bourbon (1646) work seen above, simply transliterated in English as torrid zone. However, in 1810, more than a decade after the defense of Blumenbach doctoral thesis, torrid zone theory received a clearer exposé with American Presbyterian minister -- and the seventh President of Princeton University, USA, from 1795 to 1812 -- Samuel Stanhope Smith (Kelly& Jamoussi, 2016; Mann, 2009; Noll, 1989; Thornton, 2020) in his 2nd-edition (Smith, 1787/1810) book (details below). Blumenbach described extensively the effects of climate on human body, but he was of the opinion that under the effect of African burning heat black skin came from bile (see Blumenbach, 1775/1795, pp. 127-128). This is probably the reason why in his work Gloger (1833) did not refer to Blumenbach (1775/1795). Nonetheless, in his description of Africa, Blumenbach (1775/1795) put forth torrid zone theory. In a nutshell, torrid zone theory holds that scorching, extreme temperatures are unique to and worst in Africa, and thus, are what caused Africans' skin to be black and Africans' hair to be curled. Concerning black skin, torrid zone theory has left an indelible impression on European and North American audiences.

Central to torrid zone theory is the notion "*Varietas caucasia* [Caucasian variety]" (Blumenbach, 1775/1795, p. 303), first introduced in the classification of humans by Blumenbach in 1795 in his 3rd-edition book as the only race (i.e., Whites) encapsulating beauty as well as human origin and rationality. The concept Caucasian was analyzed also by Freedman (1984) and Holubar (1996), among others. Blumenbach classification of humans was modeled on the Linnean classification (Linnaeus, 1735/1756) and on the Kantian classification (Kant, 1775). The Linnean classification was used primarily for its concept species and/or varieties whereas to a greater degree the Kantian classification provided the concept whiteness. The reason given by Blumenbach (1775/1795) in using the classification Caucasian was taken from an account of the 18th-century French explorer Chardin (1771) who claimed to have been impressed by the beauty of the women he encountered in the Georgian/Caucasian part of Siberia. Chardin (1771) indicated,

> *Le sang de Georgie est le plus beau de l'Orient, et je puis dire du monde… La Nature y a répandu sur la plupart des femmes des graces qu'on ne voit point ailleurs. Je tiens pour impossible, de les regarder sans les aimer. L'on ne peut peindre de plus charmans visages, ni de plus belles tailles, que celles des Georgiennes* [The blood of Georgia is the most beautiful of the East, and I would say of the world… Nature has provided most women with graces not seen elsewhere. I find it impossible to love those women when I watch them. One cannot describe faces more charming and heights more beautiful than those of Georgian women]. (p. 123)

It needs to be underlined here that the above statement does not amount to a valid and representative description of Siberia, a region vastly researched by Pallas (1780a, b, 1784, 1811/1831a, b, c) and Gloger (1833), who both characterized Siberia as a region of marked diversity (details below). It might also need to be said that the romantic description of Chardin (1771) is not entirely different from the one offered by Stanley (1878) about the women he found in Uganda. Stanley (1878) wrote,

> *For pure Waganda are not black by any means. The women and chiefs of Mtesa who may furnish the best specimen of Waganda, are nearly all of a bronze or a dark reddish brown, with peculiar smooth, soft skins, rendered still more tender and velvety to the touch by their habit of shampooing with butter*. Some of the women, I observed, were of a very light red-gold colour, while one or two verged on white. [emphasis added]. (pp. 196-197)

Based on the aforesaid reasoning and description of Blumenbach (1775/1795, p. 303) referring to Chardin (1771) portrayal of the notion Georgian/Caucasian, the classification and qualification of Caucasian perfectly fit in with Waganda women. The point noted above by Stanley worth-making here is the aboriginal presence of white-skinned individuals in Uganda on the equator.

Yet, the word Caucasian is an old term utilized to designate nothing but the Caucasus mountains or Caucasia mountains. For example, Herodotus (ca. 425 BC/1950, 3.97) used the word Caucasian in the 5th century BC. The Caucasus mountains are located between Black Sea and Caspian Sea in Eastern Europe. With torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810), the idea of inferiority of black-skinned people was propounded ever since. Along the same lines, renown Spanish writer Feijóo noted, "*Si Adán fue negro, nosotros no somos hijos suyos; si blanco, no lo son ellos* [If Adam were Black, we [Whites] are not his sons/daughters, if [he was] White, they [Blacks] are not [White]" (1736/1778, p. 69). This means that Whites could not share the same origin or dignity with Blacks. Thus, Feijóo (1736/1778) concluded, "*el color negro de los Etíopes es de tal modo natural, y congénito a aquella raza de hombres, que por ningún accidente puede alterarse, ni en ellos, ni en sus sucesores* [the black color of Ethiopians is so natural and innate to this race of humans that it cannot be changed by any means in themselves or their descendants]" (p. 68). Most clearly, in the 19th century, the idea of inferiority particularly assigned to Black populations gained greater traction with Swiss-born American naturalist Jean Louis Rodolphe Agassiz (1807-1873), who earned a PhD in natural philosophy at the University of Erlangen (Germany) in 1829 and in the following year 1830 a PhD in medicine at the University of Munich (Irmscher, 2013; Weissmann, 2013). Agassiz (1850) affirmed,

> This compact continent of Africa exhibits a population which has been in constant intercourse with the white

> race… and nevertheless there has never been a regulated society of black men developed on that continent, so particularly congenial to that race. (p. 143)

The inferiority or the lack of civilized, regulated society of black-skinned individuals was claimed to be congenital to Africans, and thus appeared to have received an established and entrenched dimension in university circles. Agassiz was described to be "the incorrigible racist" (Irmscher, 2013, p. 4), and for the same reason "a leader of the anti-Darwin crusade" (Weissmann, 2013, p. 1289). Agassiz lectured for more than two decades at Harvard University and Cornell University, which lent prominence to his teachings. Such a condition has dwarfed the research environment of black skin and of related individuals and communities.

Similarly, although Smith (1787/1810) believed in and defended the unity of mankind, he vigorously advocated the superiority of white skin as the beacon of civilization. To a great degree, transatlantic slave trade since the 15th and 16th centuries came to provide additional, solid grounds for deprecation against black skin in Europe and North America (Kendi, 2017; Sussman, 2014), with Blacks not being seen as humans and being denied aboriginal existence beyond Sub-Saharan Africa (details below). A further boost for deprecation against black skin was with the concept dark continent introduced by British-born American journalist and explorer Henry Morton Stanley (1841-1904), noted above, during his travels to Africa (Stanley 1878, 1899). As Stanley (1878) diarized one of his expeditions, upon nearing the African continent, "A wave of my hand, and the anchors were hove up… The sun sinks fast to the western horizon… as we glide away through the dying lights towards the Dark Continent" (p. 69). Perhaps to make things even worse, from the 20th century onward, with the dissemination of skin-bleaching creams, cosmetic global companies have nothing but intensified deprecation against black skin (Dixon & Telles, 2017; Hall, 2018, 2019). For better or worse, Gloger theory can be used to that effect.

1.3 Significance of the Study

The significance of the present review dovetails well with the salience of black skin. Indeed, in an increasingly interacted, instantaneously informed, and racially intermingled world, the topic black skin, how it is viewed and what is done to it, has been rising to the fore. Meanwhile, the history of black skin and/or black-skinned people is abuzz with examples of bad, unscientific theories leading to bad decisions and to a fractured world (Jablonski, 2021a; Kendi, 2017; Samson, 2013; Sussman, 2014). Thus, critically reassessing Gloger theory in light of its historical/social roots has the potential to allow for a better understanding of black skin and smoother integration of black-skinned individuals. Such an understanding will in turn pave the way for a more constructive conversation on and informed deterrent to racial inequality and injustices seen to be relentlessly wreaking havoc on our growingly multiracial world.

1.4 Clarification

One major concept needing to be clarified from the outset is that of theory. Many a good material of life sciences and social sciences has used the phrase Gloger rule (Glaubrecht & Haffer, 2010; Delhey, 2017, 2018, 2019), some authors have referred to the term Gloger school (Homeyer, 1868). This paper preferred the phrase theory, providing more freedom or room to the researcher and the researched than a rule does. Thus, "theory is a set of propositions that explain specific relationships between the phenomena being studied" (Cibangu, 2012, p. 98). As researchers, theory is a core component of our inquiries and our interactions with the world in which we live. Theory represents a series of statements used as a blueprint to investigate and/or interpret a research question. One term variedly employed in place of theory is hypothesis (Beck, 2019; Delhey, 2017, 2019; Elias & Williams, 2015, 2016, 2018; Jablonski, 2017, 2018; Jablonski & Chaplin, 2017; Schemske & Mittelbach, 2017), which also tends to give more leeway to the researcher and the researched. As can be seen, in academic circles, freedom of the researcher and indeed of the researched is key to the impact made on the world -- especially when the researched are human. Sure enough, animals, plants, and nature in general are increasingly believed to be endowed with inalienable rights more than ever before, in the hopes of bringing about healthier, safer, or more sustainable ecosystems. All in all, Gloger theory or hypothesis comprises a set of Gloger statements or propositions taken to interpret a given biological phenomenon or topic. Along with a conclusion, the rest of the paper is structured around four sections: (1) background of Gloger theory, (2) key arguments of Gloger theory, (3) discussion, and (4) pathways of future research on skin color.

2. Background of Gloger Theory

In this section, attention is given to a brief biography of Gloger and to key figures that have shaped or contributed to Gloger theory. Constantin Wilhelm Lambert Gloger was born in Kasischka (then southeast of Germany) on September 17, 1803 and died in Berlin on December 30, 1863. Gloger grew up in Upper Silesia, at the border of Poland and Czech Republic. After his high school (or secondary school) studies in Neiße (Nysa, Poland), he took zoology at the University of Breslau, now Wroclaw (Poland) where he earned his PhD in the same field in July 1830 (Haffer, Hudde, & Hillcoat, 2014; Glaubrecht & Haffer, 2010). He did much of his work particularly on birds of the Eurasian region. After earning his PhD, he taught natural history at the Gymnasium (High School) of Breslau until 1842, at which point he moved to Berlin to undertake as an independent researcher various bird projects nearly unsuccessfully. From 1853 till his death, Gloger was -- for a modicum of stipend -- a collaborator of German ornithologist Jean Cabanis, the editor of the *Journal für Ornithologie* [Journal of Ornithology] and director of the Berlin Museum. Part of his work helping Jean Cabanis, Gloger published quite profusely in the *Journal of Ornithology* (Haffer, Hudde, & Hillcoat, 2014). As Gloger was undertaking his work, three individuals came to be key figures with invaluable impact on his arguments and writings.

The first individual who had influenced Gloger was University of Berlin (now Humboldt University) German zoology professor Martin Heinrich Karl Lichtenstein (1780-1857), founder of the Zoological Museum of Berlin (Haffer, Hudde, & Hillcoat, 2014; Glaubrecht & Haffer, 2010). Indeed, during his studies at the University of Breslau (Poland), Gloger enrolled in courses of winter semester at the University of Berlin in the academic year 1824/1825, over the eight-month period of which he was exposed to the teachings of professor Lichtenstein -- the then director of Berlin Natural History Museum -- mentioning the phenomenon of bird coloration presumably driven by climate (Haffer, Hudde, & Hillcoat, 2014; Glaubrecht & Haffer, 2010). On this note, Haffer, Hudde, and Hillcoat (2014) wrote that

> Lichtenstein himself published hardly anything on these important conformities, but was in full agreement with his student Gloger using the Berlin [Natural History Museum] material to study geographical variation in the coloration of birds and mammals and later publishing his findings in a long paper. (p. 71)

Lichtenstein did not publish or cite a work on the topic of bird coloration, as is apparent from his foreword to Gloger work (Lichtenstein, 1833, pp. iii-iv). In the foreword to Gloger work, Lichtenstein is seen to be more thrilled by Gloger brilliancy and enthusiasm for research than by the topic of geographic colorations.

The second key figure that had shaped Gloger theory after Lichtenstein was German naturalist and explorer of Siberia and Far East, Peter Simon Pallas (1741-1811) who completed varying extensive research on animals of the Eurasian region (Pallas, 1780a, b, 1784, 1811/1831a, b, c). As Haffer, Hudde, and Hillcoat (2014) clarified, before Lichtenstein, "this phenomenon [of bird coloration] had already been pointed out by… Pallas" (p. 71). More clearly, Gloger received the idea of climate-led coloration of birds from Pallas published work entitled *Zoographia Rosso-Asiatica* (Pallas, 1811/1831a). This work is referred to by Gloger (1833, pp. v-vi). In his book, Gloger (1833) cited Pallas research substantially. Concerning bird coloration, Pallas (1811/1831a) noted,

> *Semper enim aves ad ea loca, ubi exclusae sunt, ad prolificandum revertuntur, ideoque climatis effectu perplures generationes continuato, etiam colores mutare possunt, ut exemplo in Alauda nivali demonstravi* [Indeed, birds can change even colors and therefore shall continue to reproduce under the effect of climate through many generations in those places where they were excluded and are returning to proliferate, as I demonstrated with an example of *Alauda nivali* (skylarks)]. (p. 185)

Part of the above statement on coloration is cited on the frontpage of Gloger (1833) book. The idea of coloration was reflected upon by Pallas (1780a, pp. 234-235). Bird coloration was demonstrated to be a function of climate effect in a research run by Pallas on skylarks species in the Eurasian region.

What is most notable with Pallas research is that black coloration is predominant across the artic region as well as across the body parts of birds and animals species (Pallas 1780a, b, 1784, 1811/1831a, b, c). As a result, black coloration is not a latitudinal manifestation, but rather an internal mechanism of birds to adapt to ambient temperature. Meriting special consideration here, however, is that Pallas research about climate-based coloration of animals in the Eurasian region was arguably first published in 1780 (Pallas 1780a, b, details below) the year in which Lichtenstein was born (Haffer, Hudde, & Hillcoat, 2014).

The idea of climate effect on species or life goes back to immemorial times with the effect of the weather on plants. In this respect, Pallas (1780b) was of the belief that climate effects do not necessarily engender a variation by species or by latitude. In his paper on the variation of animals, Pallas (1780b) argued,

> *L'influence du climat, la nourriture, les accidents multipliés… dans les espéces qui pullulent le plus… ne pouvoient jamais, quelqu'ancienne qu'on suppose leur influence, changer le total des forms, les proportions & même la structure intérieure* [Climate influence, food, [and] multiple accidents… among species that reproduce themselves the most… can never, no matter how long is the influence, change the forms, proportions, and even internal structure [of species]]. (p. 78)

Climate effects do not alter species significantly externally and internally. This means that variation does not go by species and latitude.

Pallas (1780b) went on to specify that

> *sur la même longitude on trouve trois nations semblables, jusqu'à la physionomie & la couleur des cheuveux & de la peau, sous des latitudes et des conditions aussi différentes, que l'Indien phytophage, civilisé & habitant d'un*

> *climat brulant, le Tatare & le Mongole nomade & carnacier du milieu de l'Asie… & le Samoyede ichthyophage de la Zone glacée… à coté du peuple Ostiaque, trés-voisin, nourri de même, sous le même climat, mais tout à fait différent par les traits, le teint & les cheveux* [at the same longitude we find three nations identical in terms of physiognomy, color of hair and skin, [and yet] at different latitudes and [under different] conditions as the vegetarian Indians, civilized and inhabiting a scorching climate, the carnivore nomadic Tatars and Mongols in mid-Asia… [and] the Samoyeds living on fish-diet in the freezing zone… near Ostyak people very close-by neighbors, with the same diet and climate, but completely different by traits, skin color, and hair]. (pp. 80-81)

Identical latitude, diet, longitude, and climate are indicated to be characteristics of people with entirely different traits and skin color and hair. The variety of color, skin, and hair shown in peoples living across the Siberian region, as demonstrated by various authors such as Pallas (1780b, pp. 80-81), Herodotus (ca. 425 BC/1950, 3. 92-94. 97), Brook (1999/2018, pp. 4-5, p. 125), and Kolga, Tõnurist, Vaba, and Viikberg (2013, p. 88), comes in striking contradiction with the notion Caucasian race propelled by torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) as the sole autochthone people of the Caucasian mountains.

The contradiction is further compounded by the predominance of lighter-complexioned skins observed in equatorial Africa by Stanley (1878, 1899), a first-hand researcher of that region, not counting the existence of aboriginal un-mixed Black communities in Siberia (Brook, 1999/2018; Herodotus, ca. 425 BC/1950, 3. 92-94. 97) mentioned earlier. The variety of humans in the Siberian region has led Blakely (1986) to consider "this general area… richer in mystery and fable than any other in the world" (p. 5). This broad-based and proven variety is key in Gloger arguments. For example, Pallas (1780b) noted,

> *Qu'on admette même l'influence d'un climat étranger à l'animal, beaucoup plus puissante, qu'elle ne l'est en effet: on ne pourra cependant jamais rendre raison, de ce que tant d'espéces qui se trouvent dans les deux continents, & qui se sont répandus dépuis la zone glaceé jusqu'au tropique n'ont pas varié et ne changent pas continuellement de forme & de naturel… l'homme même, qui s'est naturalisé dans tous les climats & sur toutes les terres du globe, a conservé son espéce pure & n'a éprouvé, tout au plus, que des changements superficiels de sa peau et sa chevelure* [Let's assume even the effect of a climate foreign to an animal, and more powerful than it really is, we still can never make sense of the fact that plenty of species that live in two continents and that have spread from the freezing zone to the tropics, have not varied and have not continually changed their form and their nature… Even man who has become indigenous to all climates and regions of the globe has kept his species pure and has undergone no more than superficial changes of skin and hair]. (p. 80)

The point is that climate effects cut across species and latitudinal boundaries, and thus cannot be categorized as per species or latitude. Pallas argument of climate effects is an indispensable element to Gloger arguments. Indeed, Pallas position about climate effects is a complete reversal of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810).

Moreover, although Pallas (1811/1831a) was an ornithologist, he made a remark of utmost significance for the African continent and the species thereof -- even as torrid zone theory was brewing the widest during that period of time in the late 1700s and early 1800s when he undertook much of his research (Blumenbach, 1775/1795; Smith, 1787/1810). Statements made about the African continent ought to be open to future research, as opposed to being stereotyped regardless of whether they are proven or not. Pallas (1811/1831a) affirmed,

> *Et videtur sane pluribus constare speciebus, quam quae hactenus sunt notae; ex Africa enim semper aliquid novi expectandum, donec interiora hujus vastae continentis innotuerint* [Also the plurality of species in Africa appears by all means to be self-evident, and there are many more than those observed so far, because from Africa indeed there is always something new expected until the interior variables/aspects of this vast continent become fully known]. (p. 180)

Reconsideration of all too often taken-for-granted assumptions about Africa is immeasurably essential to a better, safer theory of black skin and the populations thereof. Torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) did not do a good job regarding biogeographical research on the African continent.

The third and last key figure after Pallas and perhaps the most influential figure ever to have affected Gloger theory was German naturalist and explorer Alexander von Humboldt (1769-1859), who invented some of the first tools for measuring temperatures and latitudes (Norder, 2019; Pausas & Bond, 2018; Rupke, 2021; Wulf, 2016), and whose thoughts are abundantly cited by Gloger (Gloger, 1833, pp. 13-15, pp. 33-34, pp. 61-62, pp. 106-107). Humboldt is known for the theory that organic life tends to increase and multiply as one moves nearer the tropics. This theory is commonly designated latitudinal gradient in species diversity (Beck, 2019; Fieldsend, 2020; Hanly, Mittelbach, & Schemske, 2017; D. Jablonski et al., 2017; Schemske & Mittelbach, 2017) or latitudinal gradient (Bartels et al., 2020; Kerkhoff, Moriarty, & Weiser, 2014). It is crucial to emphasize that Humboldt spoke of organic life or bio-diversity in general, without any limitation to or predilection for a specific location or ethnicity. As Humboldt (1808) indicated,

> *Je näher dagegen den Tropen, desto mehr nimmt Mannigfaltigkeit der Bildungen, Anmuth der Form und des Farbengemisches, ewige Jugend und Kraft des organischen Lebens zu*. [The closer one moves to the tropics, the more there is an increase in the multiplicity of growth, the beauty of design, and the mixture of colors as well as the continual bloom and vitality of organic life]. (pp. 167-168)

As noted above, the colorfulness, fluidity, growth, vitality, and bloom of biodiversity increase with latitude. It needs to be borne in mind that abundance of life is spread across the globe.

> *Ist aber auch Fülle des Lebens überall verbreitet; ist der Organismus auch unablässig bemüht, die durch den Tod entfesselten Elemente zu neuen Gestalten zu verbinden: so ist diese Lebensfülle und ihre Erneuerung doch nach Verschiedenheit der Himmelsstriche verschieden* [But the abundance of life is also spread all over (the earth); and organism endeavors relentlessly to fasten the components released by death, together into new forms. Then this abundance of life and its renewal, however, vary according to the differences of hemispheres]. (Humboldt, 1808, pp. 166-167)

Death or the apparent interruption of productivity is presented as a way in which nature firms up life components. Interruption of life is not the same as absence of life, rather it's an affirmation of life. This is, as Humboldt (1808) explained, "*denn Flüssigkeit ist Bedingniss zum Leben* [because fluidity is a prerequisite for life]" (p. 167). Life cannot be restricted to a concept, form, variable, or process. As claimed earlier, the idea of life found across the globe was also propounded by king Akhenaten in ancient Egypt over three millennia ago (Foster, 2001). Perhaps most central to Gloger background is the idea developed by Humboldt (1831, pp. 407-409) and followed considerably by Gloger that, due to an array of variables, latitudinal distance is not a straightforward, mathematical line.

This idea is given more prominence with the fact often forgotten that the division between northern hemisphere and southern hemisphere starts at the equator. What this means is that northern hemisphere encompasses all the equatorial section north of the equator and the pole to the north just as southern hemisphere comprises the entire equatorial section south of the equator and the pole to the south (La Condamine, 1745). Indeed, French naturalists and geographers, namely La Condamine (1745) and his companions, undertook some of the first geodesic measurements on the equator and left a monument in Ciudad Mitad del Mundo [Middle of the World City] in Quito, Ecuador (see Table 1), showing the northern hemisphere on one side and southern hemisphere on the other. At this monument one can stand with one foot in the northern hemisphere and the other in southern hemisphere.

Table 1. Southern Hemisphere (left) and Northern Hemisphere (right) (Google image)

One more specific reason for Humboldt (1808, 1831) insistence on latitudinal variation along with the universality of life, ensuing fluidity, and heat can be found with Blumenbach (1775/1795) torrid zone theory. While La Condamine (1745) and Humboldt (1808, 1831) made seminal measurements and observations of the equator and latitudinal differences, they never defined the concepts heat, radiation, or sunshine as limited to a specific location/weather much less Sub-Saharan Africa. Because the earth is (viewed as) a sphere, the notion equator was thus understood as the dividing line at which geomagnetic force increases the most as one moves from the tropics toward that line (Korte & Mandea, 2019). No skin color was implied or predicted.

As indicated earlier, while torrid zone theory was first put forth by Blumenbach in 1775 in his doctoral dissertation at the University of Göttingen, it was fully fleshed out by Smith (1787/1810). Smith stated, "in various districts of the torrid zone of Africa, many of their domestic animals, and particularly their dogs, and common poultry, as well as the human inhabitants, are uniformly black" (1787/1810, p. 78). To show the fiery effects of the torrid zone in Africa, Smith (1787/1810) recounted,

> Modern travellers, who have explored the interior of that continent [Africa] with the greatest intelligence and care, inform us that, although … there are shady forests and a fertile soil, yet almost the whole region embraced between the tropics is a tract of sand that often literally burns. This state, not of the atmosphere only, but especially of the earth… will have its effects in increasing the close nap of the wool, for the same reason that a hair held near a flame will coil itself up, or the leaves of vegetables be rolled together under the direct rays of an intense sun… The hair as well as the whole constitution, suffers, in that region the effects of an intense fire. (pp. 96-97)

Burning sand as well as the atmosphere of torrid zone are presented to be the cause of Africans' black curled hair and black-burnt skin. To emphasize, Smith (1787/1810) posited that "something may be ascribed also to the *excessive ardor of that region of burning sand*. Africa is the *hottest country on the globe* [emphasis added]" (pp. 95-96). Knowledge of torrid zone theory is foundational to a crisper picture of Gloger theory in particular and of skin color literature in general. As Smith (1787/1810) put it, in the torrid zone of Africa, "all nature bears the marks of a powerful fire" (p. 221). All vegetation in this continent is said to be on fire. Principally, Smith (1787/1810) wrapped up his ideas, saying: "the whole interior [of Africa], as far as it has been explored, is represented to be a desert of burning sand which often rolls in waves before the winds" (p. 222). It is said that the winds on this continent are made of fiery waves, searing everything in their paths. Owing to such blazing climate conditions, a key tenet of torrid zone theory is the belief that human darker skin is located closer the equator and lighter skin is nearer the poles. As Smith (1787/1810) expounded,

> *In tracing the various climates of the globe, advancing from the arctic circle to the equator, we find them marked with considerable regularity by the colour of the inhabitants*. In the European continent, we meet, in the *highest temperate latitudes*, *with a ruddy, and sanguine [pink] complexion*, which is commonly conjoined with different shades of redness in the hair. We soon descend to a *clearer mixture of red in white*. And afterwards succeed the brown, the swarthy, and passing over into Africa, the tawny, *increasing by darker and darker shades as we approach the hottest temperatures of the torrid zone*. In the Asiatic continent we pass at once from the fair to the olive, and thence by various gradations in the darkness of the hue to the black colour which prevails in the southern provinces of the peninsulas of Arabia and India [emphasis added]. (pp. 35-36)

As explained above, torrid zone theory presents a climate and latitude-based gradation of skin color. To be precise, Smith (1787/1810) was perhaps the most stalwart supporter of the idea of "general uniformity in the effect [of climate], as we proceed towards the North, or the South… that the various shades of complexion which distinguish the different latitudes are to be ascribed chiefly to the influence of climate" (p. 62). As is all clear now, torrid zone theory is a fairly attractive theory taken to be something of a mainstay for the characterizations of skin color among species (details below).

Undoubtedly standing against torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810), especially its misconception on or regionalization of heat, Humboldt propounded the idea of heat as a universal feature of life, an idea that Gloger (1833, pp. 61-62) developed at lengths. More specifically, Humboldt (1831) contended,

> *Des animaux que nous considérons aujoud'hui comme des habitants de la zone torride, ont vécu jadis (tant des faits géologiques l'indiquent)… dans le nord de l'ancien continent* [Animals that we consider today as endemic to torrid zone had lived at some point (plenty of geological facts demonstrate so)…in the north of the ancient continent]. (p. 389)

To further debunk torrid zone theory, particularly its idea of heat or summer, Humboldt (1831) went on, writing,

> *Des tigres entièrement semblables à ceux des Grandes Indes… se montrent encore de nos jours de temps en temps, en Sibérie jusqu'au parallèle de Berlin et de Hambourg* [Tigers completely identical to those found in Great Indies … had been spotted even nowadays from time to time in Siberia up to the latitude close to Berlin and Hamburg]. (p. 388)

The idea was also verified in pharaonic times by Egyptian king Akhenaton (Foster, 2001), who, in fact, in the 14th century

BC, presented the blast of summer as central to and indicative of life. In essence, the idea of universal heat along with that of life fluidity and richness is quite at variance with torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). As it becomes evident, the background of Gloger theory spans a vast and diverse arena: zoology, ecology, geography, ornithology, physics, biology, etc. The point that has the most bearing here is that the ideas and figures outlined above are essential to a better and firmer understanding of Gloger theory (details below).

3. Key Arguments of Gloger Theory

It is safe to state from the outset that Gloger theory has been profoundly influenced by Humboldt (1808, 1831) and Pallas (1780a, b, 1784, 1811/1831a, b, c). It bears stating also as is evident below that Gloger made considerable criticism against the major elements of his own teaching or research, in search of a firmer understanding of the topics at hand. Self-reflectivity is a crucial characteristic of Gloger arguments. Worthy of note here is the fact that the most known and popular version of Gloger theory – commonly called Gloger rule, as explained above -- is the one articulated in 1929 by Bernhard Rensch the then curator of Berlin Natural History Museum (Rensch, 1929), in recognition of Gloger work done at Berlin Natural History Museum. As Delhey (2019) summarized,

> The term ‘Gloger's rule' was coined by B. Rensch in 1929 and included different patterns of variation from those described by Gloger. Rensch defined the rule in two ways: a simple version stating that endothermic animals are predicted to be darker in warmer and humid areas due to the increased deposition of melanin pigments; and a complex version that includes the differential effects of humidity and temperature on both main types of melanin pigments – eu- and phaeo-melanin. The blackish eu-melanins are predicted to increase with humidity, and decrease only at extreme low temperatures, while the brown-yellowish phaeomelanins prevail in dry and warm regions and decrease rapidly with lower temperatures. (p. 129)

The point made above was affirmed from different perspectives by Rensch (1929, p. 160) and Rensch (1936, p. 283). For accuracy sake, the Rensch-formulated theory of Gloger can be called Rensh-Gloger theory. While the Rensch-Gloger theory (Rensch, 1929) is exclusively focused on birds research, it associates animals pigmentation or melanization with climate changes via either a simple or a complex correlation. An informative review of Rensch-Gloger theory was done by Delhey (2019). All the same, the lack of clear mechanisms involved in the stated correlation of climate variation and animals color remains the nemesis of Rensch-Gloger theory. Speaking of Rensch-Gloger theory, Delhey (2019) alerted interested authors that “a complex rule that is not associated with a clear mechanism is a good candidate for confusion” (p. 1297). One reason might be that Rensch formulation of Gloger theory might have been an overstatement (or understatement?) of Gloger arguments. This has caused Delhey (2019) to draw the conclusion that “complex definitions combined with ambiguous use and only partial empirical support may be indicative that Gloger’s rule should be declared invalid or, at least, reformulated” (p. 1307). As clarified above, this paper focused on Gloger arguments to reassess or (re)define Gloger theory. A full-fledged background was provided to allow for a broader and clearer picture of Gloger theory.

As noted supra, while Gloger expertise falls under the scope of ornithology, Gloger theory stretches far beyond the confines of avian research. This is evident already from the subtitle of Gloger (1833) book, which reads:

> *Nach zoologischen, zunächst von den europäischen Landvögeln entnommenen Beobachtungen dargestellt, mit den entsprechenden Erfahrungen bei den europäischen Säugthieren verglichen, und durch Thatsachen aus der Gebiete der Physiologie, der Physik, und der physischen Geographie erläutert* [described according to zoological observations taken primarily from the birds of European region, compared with relevant experiments on European mammals, and explained using facts from the fields of physiology, physics, and physical geography]. (see frontpage)

As pointed out above, the subtitle of Gloger book, alongside the title *Das Abändern der Vögel durch Einfluss des Klima's* [changes of birds under the influence of climate], shows that the fields involved in Gloger theory comprise various interconnected branches of biology: ornithology, mammalogy, physiology, physics, physical geography, biogeography, ecology, and zoology, among others. Laying stress on the universal scope of research, Gloger (1833) highlighted

> *das Bemühen… allenthalben durch ausgedehnte Beobachtungen, sowohl über den organisch-verändernden, wie über den haushälterisch-bestimmenden Einfluß der Klimate auf Vögel und Säugthiere, und endlich auf Thiere überhaupt, wie ins Gesamt auf die ganze organische Welt, immer mehr die genaue Übereinstimmung solcher Erscheinungen mit der gesamten physikalischen Beschaffenheit der einzelnen Erdstriche und ganzer Welttheile nachzuweisen* [the endeavor … to prove everywhere, through extensive observations about organically changing as well as moderately determining influence of the climate on birds and mammals and finally on animals in general as well as the whole organic world at large, more and more accurate consistence of such occurrences with the entire physical condition of particular areas and of all parts of the world]. (p. xx)

As shown in the statements above, the universal, all-encompassing rationale arising from Gloger teachings and/or arguments is very much in tune with the multidisciplinary nature of biology fields. More particularly, the universal rationale is consistent with Humboldt (1808, pp. 167-168) latitudinal gradient theory touched on earlier. This is the rationale in which Gloger theory here discussed is (to be) best situated.

Perhaps, Gloger theory is most firmly and clearly rendered in the following statement:

> *Wenn es bekannt und gewiss ist, daß sogar die, schwarz gebornen, Neger zu bleichen fähig sind und besonders dann etwas heller werden, wenn sie noch jung bereits gegen Norden gebracht wurden; so darf man wohl billig wiederum gar nichts Wunderbares darin finden, wenn die frei lebenden Thiere durch abwechselndes Versetzen hier lichter, nach Umständen zum Theile weiß, und nach Süden hin dunkler wurden* [When it is known and certain that even unmixed black-born individuals are able to bleach and specifically become somewhat lighter-skinned once they have been brought still young right to the North, then one should again so easily find nothing extraordinary when wild living animals would became brighter by moving to a different environment, partly white according to circumstances, and darker in the South]. (Gloger, 1833, p. 107)

In somewhat another context, the same idea was loosely alluded to by Gloger (1833, pp. 14-15). While the explanation outlined above might sound grotesque, it best captures Gloger theory. More interestingly, when the subject black-born individuals is replaced by the concept *Homo genus*, Gloger theory makes total sense (details infra). Typically, as indicated earlier, Gloger received this impetus from Pallas (1780a, b, 1784, 1811/1831a, b, c) research. Gloger was to some degree convinced of his position because at that time, the 18th and 19th centuries, a number of authors (Albinus, 1737; Feijóo, 1736/1778; Mitchell & Collison, 1744; Smith, 1787/1810) dismissed the effect of climate -- at least directly -- on the color of skin. It must be said in passing that Pallas (1780b) was even one of the most fervent detractors of climate effects (details infra). The point here however is that under the effect of climate, humans or living species bleach or darken, depending on whether the location is cold or hot. For more clarity, Gloger theory can be visualized using an equation as follows:

$$W \, x \, L = C$$

(W= Weather, cold or hot; L= Length: number of years, C= color of skin, white or black)

Note that the equation/formula was certainly not devised by Gloger; it is employed here just for visualization purposes. What the equation implies is that unmixed darker-skinned born individuals (Blacks) who had moved to northern regions (e.g., Europe or North America) would see their skin turn white after, say, 1 to 2 million years of being subjected to cold weather, the same is true for unmixed lighter-skinned born individuals (Whites) who had moved to tropical regions (e.g., Africa or South America), they will see their skin become entirely black after the same number of years. The number of years is not entirely known or determined in Gloger theory, but it is assumed to be long enough (at a younger age, for instance) in order to produce the desired effects of bleaching or darkening. More precisely, Gloger explanation can be best understood in light of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) mentioned earlier. As Gloger (1833) described the heat in Africa,

> *So vermag es in Afrika die weit größere Hitze recht bald, sie ohne Unterbrechung immerfort zu steigern* [In fact, there is rather much more heat in Africa, which can rise without interruption all the time]. (p. 19, see footnote)

The idea of heat regarding Africa appeared when Gloger (1833) wrote, "*im heissen Afrika* [in hot Africa]" (p. 64) or when Gloger (1833) stated, "*in dem heissen oberen Afrika* [in hot upper Africa]" (p. 127).

In other words, it can be argued that by moving away from such a rather scorching zone, delineated in torrid zone theory earlier, it is only fitting to imagine that the skin of animals, humans, and even plants will not only cool off, but will also bleach whereas the hair or the leaves of plants will straighten up. Surely, Blumenbach (1775/1795) torrid zone theory, so well articulated by Smith (1787/1810) needs to be borne in mind for a better understanding of Gloger theory.

Although Gloger defined longer exposure of skin to the weather as a conduit for the bleaching or darkening of skin, he was one of the harshest skeptics of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). Citing a German who had lived for a long time in Russia, Gloger (1833) asserted,

> *Moskau und Kasan liegt z.B. sehr nahe under demselben Breitengrade; aber Kasan, das etwa 100 deutsche Meilen östilicher liegt, ist viel, sehr viel kälter als Moskau. Kasan liegt nahezu under derselben Entfernung von Äquator, wie Kopenhagen oder Edinburg; aber wie ungemein verschieden das Klima dieser Städte! Petersburg liegt gegen 5 Grade nördlicher als Kasan, und doch is das Klima von Petersburg bei aller Strenge viel milder, als das der letzteren Stadt* [For instance, Moscow and Kazan are located nearly at the same latitude, however, Kazan, which lies around 100 German miles more toward east, is very much colder than Moscow. Kazan is located nearly at the same distance from the equator as Copenhagen or Edinburg, but, how extremely different is

> the climate of these cities! Petersburg is located at a latitude of 5 degrees north of Kazan, and yet the climate of Petersburg is despite all the rigor much milder than that of Kazan]. (p. 53)

The jarring differences in climate conditions shown above, about Russia, go a long way toward calling into question torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). An array of variables are believed to account for these climate differences, such as sea level, wind, soil nature, distance to the sea, etc. (see Gloger, 1833, p. 5). Variations that inexorably crosscut latitudinal and geographical boundaries have been plentifully demonstrated across Siberia and beyond by numerous authors, for example, Humboldt (1831, pp. 399-400), Pallas (1780b, pp. 80-81), and Smith (1787/1810, pp. 213-216), to name a few. Perhaps most particularly integral to this blatant variation is a preponderance of black color across Siberia and across an animal's body parts in this region of the world (Pallas, 1780a, b, 1784, 1811/1831a, b, c). The signal and widely proven variation crosscutting latitude, species, and animals body parts has left its marks on Gloger thinking. This will probably be the knell for Gloger theory, if not an impetus for a deeper look into the questions left open by Gloger.

The variation shown in Siberian region, as amply validated by Pallas (1780b, pp. 80-81), proves the notion Caucasian race/variety to be nothing short of erroneous, unsubstantiated, and irrelevant. No wonder, Gloger (1833) did not use the expression Caucasian race/skin/variety at all, when talking about humans or Whites in his book, and yet he mentioned the Caucasus mountains more than once (p. 100, p. 146). This is despite the fact not only that Gloger (1833) was an expert of and familiar with the Siberian, Caucasian region, but that Blumenbach (1775/1795) classification with the just coined concept Caucasian race was famous at that time. Perhaps a more suggestive piece of evidence highlighting weather- and latitude-crossing variation is that no species/variety (i.e., birds or mammals) found in the Caucasian area (Gloger, 1833) has been named after the term Caucasian variety/species. This is one of the biggest contributions of Gloger arguments. Gloger did not name birds species by latitude or climate areas. This is also indisputable proof of the influence that Gloger received from Humboldt (1808, 1831) and Pallas (1780a, b, 1784, 1811/1831a, b, c.), whose research did not identify species per latitude, weather, or body parts. There is no such a thing as a map discretely drawn along the lines of species, latitude, or climate conditions.

Moreover, in all species, black color crosscuts latitude, weather, and body parts. Humboldt did not use the concept Caucasian although he was a student of Blumenbach at the University of Göttingen (Korte & Mandea, 2019; Wulf, 2016). Perhaps most importantly, despite the fact that Humboldt invented and used measurement instruments for latitudes and altitudes and that he was an avid traveler himself, he did not conceive or use a global map for the skin color of animals, plants, or humans. Pallas and Gloger did not design one, either, despite a real need for it in their research and that of others. Humboldt (1808, pp. 167-168) proposed the gradient of life diversity, but not of skin color by any means; nor did he insinuate such an idea despite his towering research on the properties and measurements of the equator. Thus, diversity of life on the equator means diversity of skin as well. The idea of savannah vs forest for the origin of early hominins contradicts the uniformity of skin toward the equator. The proof of variety is further verified by the evidence of aboriginal white-skinned individuals on the equator (see Stanley, 1878, pp. 426-427, details below). The thing with human species is that no human naked skin can be claimed to be safe in any location, weather, or latitude, without necessary added protections, especially for the infant, elderly, sick, and disabled, not to mention pregnant women and albinos.

For example, because of variability (i.e., latitude, climate, species, etc.), however, the imaginary line from the equator to the poles -- the centerpiece of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) in accounting for black skin coloration or bleaching -- is no longer as straightforward and predictable as claimed. Consequently, Gloger (1833) specified,

> *Denn, obwohl die mittlere järliche Temperatur in der alten and neuen Welt von Äquator bis zum 20ºn. Br. übereinstimmt; so nimmt sie doch in östlichen Nord-america im Vergleiche zu Europa durchschnittsmäfsig vom 20º -- 30º um 2º, vom 30º-- 40º um 4.8º, vom 40º -- 50º um 7º, vom 50º an um 9.4º ab* (Because although on the equator the yearly average temperature, in the Old and New Worlds, consistently reaches up to 20ºC [68ºF] on the east coast of North America in comparison with Europe, it rises from 20ºC – 30Cº [68ºF-- 86ºF] to 2ºC [36ºF], from 30ºC – 40Cº [86ºF-- 104ºF] to 4.8ºC [41ºF], from 40ºC -- 50ºC [104ºF-- 122ºF] to 7ºC [45ºF], from 50ºC [122ºF] to 9.4ºC [49ºF]). (p. 59)

As seen in the example cited earlier, the highest temperatures of North America are nowhere near as high as those of Africa. Using the notion equatorial zone, an important theme of torrid zone theory, Gloger (1833) maintained, "*in der Äquatorialzone ist da selten Sonnenschein; Tag und Nacht sind gleich, das Wetter ist veränderlich* [in the equatorial zone, sunshine is rare, day and night look alike, and the weather varies]" (p. 47). The hottest sunshine and its scorching effects, the hinge of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810), are demonstrated to be lacking in equatorial Africa. The statement is also evidenced by Stanley experience in equatorial Africa when Stanley (1899) wrote, "on the 6th of November [1876] we drew near to the dreaded and black chill forest…and at last, *bidding farewell to sunshine and brightness*, entered it… We knew not whether it was a sunshiny day or a dull, foggy, gloomy day [emphasis added]" (p. 101). With this statement Gloger (1833) distanced himself from torrid zone theory. This position fits in well with one of the most memorable warnings of Pallas (1811/1831a) seen earlier against the broad-brush statements of torrid zone theory made about the African continent. The prevalence of black-skinned aboriginal communities along with the diversity of skin color seen across North Africa and Asia as well as the stories of Job and Lamentations (Blakely, 1986; Brook, 1999/2018; Herodotus, ca. 425 BC/1950, ca. 425 BC/1957, ca. 425 BC/1960; Humboldt, 1808; Job 30:30 Hebrew Interlinear Bible; Pallas 1780a, b, 1784, 1811/1831a, b, c; Lamentations 4:7-8, 5:10 Hebrew Interlinear Bible) is unmistakable testimony to latitude-crossing variety of humans. Humboldt (1808, pp. 73-74) spoke of black-skinned Tuaregs, among the natives of Libya, to which Gloger (1833, p. 60, see footnote (*)) referred. As is now abundantly clear, variety in its manifold aspects comes to be a common thread running throughout Gloger arguments.

Furthermore, because innumerable variables interfere with climate conditions at same or similar latitudes, Gloger (1833) intently held that "*es… unmöglich bleibt, die Gränzen der klimatischen Varietäten streng geographisch zu bestimmen* [strictly geographically speaking, it remains impossible to determine the demarcation lines of climate varieties]" (p. 30). Weather variations are not the same as geographic variations or species, although they are mutually inclusive. This is a dramatic reversal of the notion varieties or species as expounded by the famous Linnean classification (Linnaeus, 1735/1758), followed by that of Kant (1775), and that of Blumenbach (1775/1795). The resulting challenge for researchers lies in how and where exactly to map out specific regions along with their skin colors, without confusing one with another. To illustrate, Gloger (1833) asserted, "*Niemand aber auf irgend einem Punkte der Erde von einem (absoluten) Osten und Western reden könnte!* [Nowhere on earth, however, can anyone speak of an absolute East and West]" (p. 30, see footnote (**)). This is more problematic with skin color, namely in figuring precisely how and where in a given region a skin color of the west differs from that of the east. More exactly, for example, hundred communities of Nubians (Foster, 2001) and Ethiopians of Libya (Herodotus, ca. 425 BC/1957) are residents of and aboriginal to large swathes of Africa outside of the equatorial, tropical zone. The same is true of hundred communities of Hottentots and Zulus, living at the same latitude, away from the equatorial zone. Yet, "the Hottentots seem to be a race by themselves" (Smith, 1787/1810, p. 94). With these and similar examples in mind, the challenge is how to differentiate a region's skin color from another, such as an equatorial African skin color from a non-equatorial one. Beside skin color itself, the concepts tropical, rainforest, and savannah regions are already highly subjective (Beck, 2019; Waide, 2019). Indigenous populations (i.e., animals, humans, plants) had existed in and beyond their locales irrespective of and before scientific concepts/classifications. This shows how climate effects do not create species and vice-versa.

The variability seen with latitude and species led Gloger (1833) -- citing empirically proven research -- to underline the statement

> *daß die Einwohner wärmerer Klimate wärmer sind; daß Menschen, welche aus einem kälteren Klima in ein wärmeres kommen, wärmer werden; daß ferner nämentlich die Vögel unter allen Thieren am wärmsten sind* [that the inhabitants of a warmer climate [region] are warmer, that individuals who live in a colder climate and move to a warmer [climate] become warmer, and more specifically birds among all animals become the warmest]. (p. 110)

Local geographic variations allow humans, birds, and animals to adjust their body temperature so as to become natural or endemic to the host location. The statement demonstrates an intrinsically built-in interaction between organisms and ambient system, a statement suggestive of Pallas (1780a, b, 1784, 1811/1831a, b, c) findings noted above. This means that "*was man nicht begränzen kann, das soll man doch auch nicht trennen* [what one cannot delimit, one should not separate either]!" (Gloger, 1833, p. 5). The argument points to the complexity of variability in the sense that while there is an irreversible interplay between environment and biology, one should not compare incomparable items nor separate inseparable items (details below in discussion section). In other words, Gloger (1833) explained,

> *Wir wissen, daß klimatische und Altersvarietät untrennbar in einander fließen, so wird, was für die letztere gilt, auch für die erstere gelten* [We know that climate and species varieties influence each other inextricably, thus, what applies to the latter, shall apply also to the former]. (p. 106)

According to Gloger (1833), climate effects unfold in such a way that what affects the environment (i.e., weather) should also affect biology (i.e., species). This is not saying that species and climate varieties are interchangeable, but that they overlap. While both Pallas (1780a, pp. 234-235) and Gloger (1833, p. 107) alleged that climate can produce effects on species, they demonstrated in light of sizable research that climate effects do not create species. The best illustration might be with rain and temperature. It is the case that rain and temperature affect a plant. But it is also the case that rain and temperature do not generate a new species of plant.

Gloger argument on climate effects shown above is copiously supported by Pallas (1780b, pp. 78-80). The most challenging question is how to delimit the phenomena involved in the stated interplay between environment and biology. The question was left open, unsettled purposely by Gloger. To conclude this trail of thought, Gloger (1833) wrote,

> *Hiernach wird es nun in Bezug auf klimatische Varietäten zwar gewiß noch überhaupt recht viel zu untersuchen geben, und es werden der kommenden Zeit gewiß noch eine Menge von interessanten Thatsachen aufzufinden und festzustellen geblieben sein* [Accordingly, there will still be of course quite a lot to investigate regarding exactly climate varieties, and in the coming years there will remain certainly a host of interesting facts to find and determine]. (p. 59)

Because of the infinite variability of the phenomena and factors involved in the interplay between biology and environment, more specifically between black skin and ecosystem, it is of uttermost importance to be alert to newer insights and findings rather than being stuck to unproven ideas however appealing to a researcher's long-held beliefs these ideas can be. Much remains to be found and determined about skin color in general and black skin in particular.

In sum, Gloger (1833) argued that skin color is a function of a longer and earlier exposure of a person to a given climate, with warmer climate blackening and colder climate bleaching the skin respectively. As such, Gloger theory does not warrant support, but Gloger arguments about variability are stronger than his stated theory. Gloger (1833) theory appears to be a perfect replica of torrid zone theory propelled by Blumenbach (1775/1795) and Smith (1787/1810). Notwithstanding, Gloger (1833) highlighted the fact that an infinite number of variables significantly interfere with climate of areas located at the same latitude. To a great extent, this has invalidated the core argument of torrid zone theory, and by implication that of Gloger theory itself. For example, Gloger (1833) noted that species endemic to warmer climate have the propensity to become colder when they move to colder regions, and that species endemic to colder regions become warmer when settled in warmer regions. As a result, Gloger (1833) cautioned that climate variations are not in any way, shape, or form the same as species variations and that environment and biology are inextricably interconnected. Just as Gloger did not use the phrase Caucasian race/skin/variety despite its popularity at the time (Blumenbach, 1775/1795; Kant, 1775; Linnaeus, 1735/1758), he did not identify birds varieties by latitude or climate conditions. As explained earlier, no human naked skin is safe anywhere without additional protection; this is even more true for the infant, elderly, sick, disabled, women, and albinos (details below). The determination of skin color based on region is subjective, to say the least. In much the same way, Gloger (1833) discouraged authors from separating what they cannot delimit. In simpler terms, Gloger (1833) alerted authors that with regard to environment and biology quite a lot of things remain to be uncovered and identified.

Gloger theory and skin color scholarship in particular can be best assessed in terms of their relationship with or allegiance to torrid zone theory (Blumenbach, 1775]/1795; Smith, 1787/1810) on the one hand and to latitudinal gradient theory (Humboldt, 1808, 1831) on the other. This is largely because torrid zone theory and latitudinal gradient theory have come to be the underpinning theories around and from which biology fields tackle black skin and similar topics. Authors of skin color, especially black skin, are not always aware and/or explicit about the underlying theories beneath their works. When drilled deeper, theories are an important tool to show the ways in which a research's specific mechanisms alongside units of analysis or variables have been (mis)used, (mis)understood, and (mis)applied. As seen above, antithetical to Blumenbach (1775/1795) torrid zone theory is Humboldt (1808) latitudinal gradient theory. Unlike the idea of the fieriest sand with the hottest temperature that destroy nature and all organisms, the idea of freshest, coolest, and richest life is the core of latitudinal gradient theory -- as one moves nearer the equator. Ever since latitudinal gradient theory has been expounded in 1808, it has been investigated and proven unrelentingly across numerous disciplines.

> This phenomenon [of latitudinal gradient theory] … is one of the most widely recognized patterns in biogeography. Scientists have argued for over a century about its understanding… Since then over 100 hypotheses have been proposed to explain increased biodiversity in the tropics but we still lack a satisfactory answer. (Beck, 2019, p. 673)

Similar research was undertaken by Hanly, Mittelbach, and Schemske (2017, p. 1) as well as Fieldsend (2020, p. 271). Hypotheses, not mere beliefs, have yet to be formulated about torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). While more than a hundred theories have been suggested to authenticate Humboldt (1808) latitudinal gradient theory, no hypothesis or theory has been proposed to attest to the patterns, if any, of Blumenbach (1775/1795) torrid zone theory in Africa or elsewhere (details below).

Stated differently, despite its understandably powerful attraction, torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) has yet to be thoroughly investigated, from the widely touted extreme, most intense temperatures to glowing sand to heat-curled vegetable leaves and people's hair to fire-scorched black skin, all of which believed to be unique to and rampant in Africa. Meanwhile the idea of burning sand, for example, (said to be) omnipresent throughout the African continent (Blumenbach, 1775/1795) clashes with the reality of not only life itself, but of savannah and forest and their biodiversity. The hottest or extreme temperatures will kill, irradiate, or, at least, reduce the richness of organic life, which is essential and proper to equatorial regions; the hotter is the heat the more species are destroyed. On this point,

> consider that Lake Baikal, located at 55.637N, is the largest by volume and the oldest (>27 million years) lake in

> the world, yet it has just 52 species of fish, 37 of which are endemic. In comparison, Lake Victoria, located at 1.307S, is just 18, 000 years old, yet it has 566 species, of which 450 are endemic. (Schemske & Mittelbach, 2017, p. 600)

As shown by its latitude, Lake Victoria is situated on the equator. The above finding was demonstrated by Stanley in equatorial Africa, in which he observed “innumerable varieties of plants which spring up with such marvellous rapidity” (Stanley, 1899, p. 102, the same idea was validated nearly a century earlier by Humboldt (1808, pp. 167-168) in equatorial regions of Latin America). Africa is not the hottest continent either. As Rafferty (2011) underlined, “although the climate supporting tropical rainforests is perpetually hot, *temperatures never reach the high values* regularly recorded in drier places to the north or south of the equatorial belt [emphasis added]” (p. 16). Interestingly enough, Gloger (1833) was one of the stiffest opponents of torrid zone theory, while at the same a defender of latitudinal gradient theory to the core. Although torrid zone theory lacked (and still does) empirical evidence since its inception with Blumenbach (1775/1795), it has become one of the most ingrained, defended, and believed theories of skin color research. The theory is without difficulty detected in countless modern-day skin color materials.

4. Discussion

Torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) has been the underlying theory according to or against which the discussion of materials related to black skin or skin color scholarship has unfolded in the aftermath of Gloger theory. Torrid zone theory is also the top-tier theory of most skin color research. This discussion can be divided in two periods: the 19th century and the 20th century onward.

4.1 The 19th Century

One of the most critical and synoptic authors of the 19th century, researching black skin -- oftentimes forgotten -- is British naturalist Charles Robert Darwin (1809-1882), the founder of evolutionary theory (Briggs, 2008; Broecker & Moelling, 2019; Loxdale, 2010; Porter & Graham, 2016; Ruse, 2008). The research of evolution theory or natural selection enjoyed the participation of more than one eminent biologist. This is evidenced in a historical sketch presented by Darwin (1859/1873, pp. xiii-xxi) in his 6th revised edition of the *Origin of Species*. One of those biologists was Alfred Russel Wallace (1823-1913) who was marked out to be a co-founder of evolution theory (Briggs, 2008; Caro, 2016; Costa, 2014; Loxdale, 2010). Although Wallace (1871, 1878) works/arguments gained popularity relatively a decade after Gloger death in 1863, they are consistent with and pertinent to Gloger (1833) research (details below). Taken to its basic form, evolutionary theory holds that biological life is a product of natural selection, wherein species struggle to survive in adapting to the challenges posed by the environment and/or the weather (Darwin, 1859/1873; Wallace, 1871, 1878). As seen below, evolutionary theory is indescribably widely espoused by skin color researchers.

Even as Darwin and Wallace were the gurus of evolutionary theory, however, they were some of, if not, the most vehement and vocal opponents of evolution-based or climate-led explanation of black skin. On this note, it is helpful to bear in mind a notable reference made by Darwin (1871/1889) to Pallas (1780b). Equally, Darwin can be considered to be one of the staunchest detractors of torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). Darwin (1871/1889) contended,

> Of all the differences between the races of man, the colour of the skin is the most conspicuous and one of the best marked. It was formerly thought that differences of this kind could be accounted for by long exposure to different climates; but Pallas first shewed that this is not tenable, and he has since been followed by almost all anthropologists… This view has been rejected chiefly because the distribution of the variously coloured races, most of whom have long inhabited their present homes, does not coincide with corresponding differences of climate. (pp. 192-193)

Conceptions of climate-derived skin color were found to be far-fetched in the 19th century. Darwin (1871/1889) continued,

> Whether the saving of the skin from being thus burnt is of sufficient importance to account for a dark tint having been gradually acquired by man through natural selection, I am unable to judge. If it be so, we should have to assume that the natives of tropical America have lived there for a much shorter time than the negroes in Africa, or the Papuans in the southern parts of the Malay Archipelago, just as the lighter-coloured Hindoos have resided in India for a shorter time than the darker aborigines of the central and southern parts of the peninsula… A very damp or a very dry atmosphere has been supposed to be more influential in modifying the colour of the skin than mere heat; but… D'Orbigny in South America, and Livingstone in Africa, arrived at diametrically opposite conclusions with respect to dampness and dryness. (p. 196)

Natural selection proved to be impractical for and inapplicable to black skin or skin color itself. Using empirical research from around the world, Darwin (1871/1889) averred,

> If, however, we look to the races of man as distributed over the world, we must infer that their characteristic differences cannot be accounted for by the direct action of different conditions of life, even after exposure to them for an enormous period of time. The Esquimaux live exclusively on animal food; they are clothed in thick fur, and are exposed to intense cold and to prolonged darkness; yet they do not differ in any extreme degree from the inhabitants of Southern China, who live entirely on vegetable food, and are exposed almost naked to a hot, glaring climate… The Botocudos… as well as the other inhabitants of tropical America, are wholly different from the Negroes who inhabit the opposite shores of the Atlantic, are exposed to a nearly similar climate, and follow nearly the same habits of life. (p. 197)

Even from the standpoint of life conditions, skin coloration is still unpredictable across the world's regions. These findings relay Gloger (1833) warnings about the variability involved in climates and locations of the same latitude. The argument by Jablonski that "if only Darwin lived today if only Darwin had NASA" (2009, 02:37-42) does not override the criticisms raised by Darwin (1871/1889) and by flocks of authors, including Gloger (1833), not in the slightest (details below). In effect, in 1889, in the revised edition of his book first published in 1871, Darwin (1871/1889) was quite emphatic in rejecting climate- and latitude-driven interpretations of skin and race.

The limitation of black skin to natural selection of the equator lacks common-sense context. To better make her point, Jablonski argued,

> Darwin's preference for sexual selection in matters of human variation blinded him to the importance of natural selection in producing the attributes of human skin… Human skin is functionally naked and as such served for hundreds of thousands of years as the sole interface between our bodies and the environment. (Jablonski & Chaplin, 2010a, p. 169, see also footnote 1; 2010b, p. 8962, see footnote *)

The above defense does not validate by any means the idea that black skin is a product of natural selection. It is not true either that with his world-wide empirical research/data, Darwin presented black skin (and not white skin?) as a mere product of sexual, natural selection. Still, sexual selection does not justify in any way how/why/where black skin is an equatorial product. The criticism was made with even greater force by Wallace (1878) in the 19th century: "we have arrived at the conclusion that tropical light and heat can in no sense be considered the cause of colour" (pp. 219-220) of skin. It is important to notice how heat and light in the tropics are being excluded from the formation of black skin.

A complete, resounding invalidation of the argument portraying black skin as a product of natural, equatorial selection is with the watershed research done by the team of Australian geneticist Vanessa M. Hayes (Chan et al., 2019). This research locates the birthplace of *Homo sapiens*, not on the equator in Africa, but rather hundreds of miles away in the area around the formerly vast Lake Makgadikgadi, now a basin situated North-East of Botswana in the current Kalahari Desert, at the latitude of 25° south from the equator, at the border of the savannah region. The corrective attempt of using the word savannah vs forest (Jablonski, 2017) for the skin of early hominins renders heat something less of a factor in the claimed blackening process of skin, thus contradicting the gradient of skin toward the equator. The equator-directed gradient of human skin has been challenged by varying research. Gloger vehemently rejected the idea of heat associated with equator in Africa and with latitude. Also, research led by French paleoanthropologist Jean-Jacques Hublin (Hublin et al., 2017) has shown the birthplace of *Homo sapiens* to be located in Morocco, quite far beyond the equatorial/savannah region. Moreover, regardless of the skin color attributed to *Homo sapiens*, the discovery of human skulls excavated at the turn of the 1990s in Dmanisi, Georgia, east Asia, right in the midst of Caucasian mountains some 90 kms southeast of Tbilisi, the main city in the republic of Georgia, Asia, fully calls into question any attempt to explain black skin with the equator or latitude (Rightmire, Lordkipanidze, & Vekua, 2006). The Dmanisi skulls are overwhelmingly identical to the skulls of the *Homo* species unearthed in the Turkana basin of Kenya, Africa.

The *equatorialization* and *slavization*, by the lack of a right word, of black skin prove to be utterly unseemly. The *equatorialization* or *slavization* of black skin received greater, unexamined credence with torrid zone theory (Smith, 1787/1810), especially with the summer teachings of Kant (1775) and the subsequent implementations of torrid zone theory by Jablonski (2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017). The simple fact that thick foliage, the proper of a forest, is a barrier to light and moisture sharply conflicts with the argument of UVR peak exposure in equatorial Africa, not to mention that by virtue of latitudinal gradient of organic life as one moves closer to the equator, a savannah is made of tall, thick grass and bushes. The rampant idea that black-skinned peoples had not migrated to and/or lived in other continents up until the Europe-sponsored slave trade roughly in the 18th - 19th centuries (Jablonski, 2012b) is untrue. This idea is rooted in torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) as well as in the Linnean classification (Linnaeus, 1735/1758) of human skin color and the Kantian doctrine (1775) of human races. The idea has led to an unconscionable practice of considering slavery as an identifier of black skin. Yet, aboriginal Black communities were scattered and lived across the Old World, as seen with massive ancient materials (Blakely, 1986; Brook, 1999/2018; Brown, 2001; Herodotus, ca. 425 BC/1950, ca. 425 BC/1957, ca. 425 BC/1960; Humboldt, 1808; Job 30:30 Hebrew

Interlinear Bible; Pallas, 1780b; Lamentations 4:7-8, 5:10 Hebrew Interlinear Bible). No ancient materials or empirically proven research show the northern hemisphere to be the province of white-skinned people, either.

The *equatorialization* of black skin is further challenged by the recent thesis of multiple dispersals of *Homo sapiens* out of Africa (Lamb et al., 2018). Multiple dispersals presuppose multiple reasons other than UVR, meaning that when some *Homo sapiens* individuals had to leave the UVR-sweltering equatorial or savannah region, others did not see the point or feel the need to do so. In other words, the natural selection of UVR and hairlessness did not work for all *Homo sapiens* persons, not only on one but *multiple* occasions, in the same area of origin, equatorial, savannah region. And to top it all, the latitudinal uniformity of white human skin increasing toward the northern hemisphere as claimed by torrid zone theory deemphasizes or simply ignores the tremendous existence of Innuit and Siberian dark-skinned persons in arctic regions, the coldest places on earth. Arctic and freezing regions are being subsumed as part of white supremacy, with higher latitudes being presented as the innate province of white skin (Jablonski & Chaplin, 2010a, b, 2017; Jablonski, 2017, 2018, 2021b). Yet, diverse materials looked at above lavishly show the Caucasian or northern mountains to be a region of skin diversity since immemorial times.

4.2. From Ancient Times to 19th Century: Summary

From ancient times with the writing of the Egyptian king Akhenaten in the 14th century BC (Foster, 2001) to human skulls found in Dmanisi in the republic of Georgia in the Caucasian mountains identical to the skulls seen in Kenya (Rightmire, Lordkipanidze, & Vekua, 2006) to Herodotus (ca. 450BC/1950, ca. 450BC/1957, ca. 450BC/1960) in the 5th century BC to the Hebrew usage of the work Kush, black, across the Old World (Brown, 2001) to Black Jewish communities (Hebrew Interlinear Bible) to Black Caucasian communities (Blakely, 1986) in the late 19th century, black skin was held in high admiration, and was unrelated with the concept equator and the ensuing alleged human skin gradient. Latitudinal gradient of life diversity put forth by Humboldt (1808, 1831) presupposes diversity of skin on the equator. Systematic deprecation against black skin had not started up until Linnaeus (1735/1758) racialization of human species along with Kant (1775) teachings in the 18th century. Deprecation against black skin ballooned nearly uncontrollably with torrid zone theory (Blumenbach, 1775/1995; Smith, 1787/1810). Dispelling popular, unchecked mischaracterizations of black skin, Gloger (1833) completely rebutted the notion heat associated with the equator as well as the notion latitudinal gradient of human skin.

4.3 The 20th Century Onward

The period of the 20th century onward has seen a position particularly conform to torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) as well as to Gloger (1833) theory. One of the best implementations of Gloger theory in modern day times, although Gloger is not explicitly stated in them, is with skin color researcher Jablonski (2009, 2011, 2012a, b, 2013a, 2017, 2018, 2021b). Jablonski presented one of the most coherent and influential contemporary accounts of black skin research (Jablonski, 2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017). In light of Gloger theory and ensuing broad-based historical background perused in sections outlined above, a closer, deeper look at these accounts is needed for a better understanding of black skin and research thereof. The firmest arguments advanced by Jablonski on black skin hinge on three main ideas: (a) UVR [Ultra Violet Radiation; also called UV B-rays or UVB], (b) comparative evidence, and (c) high physical activity of *Homo genus*.

4.3.1 The First Main Idea is UVR

The idea of UVR serves as grounds for the description of black skin. As Jablonski (2017) explained,

> The key events in the human lineage [of *Homo genus*] occurred in equatorial Africa under conditions of intense and relatively invariant sunlight and UVR. Dispersal of hominins into non-equatorial Africa and Eurasia involved movements out of UVR-saturated environments into habitats that were mixed with respect to the seasonal pattern, intensity, and wavelength mixture of UVR. (p. 4)

The statements seen above found an echo in Jablonski and Chaplin (2017, pp. 3-4), specifically Jablonski and Chaplin (2010a, pp. 167-183), Jablonski (2018, p. 30), Jablonski (2021b, pp. 707-709), and more broadly in Jablonski (2012a, pp. 33-58).

These prolifically endorsed statements of Jablonski attach full weight to torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). To demonstrate the intensity of UVR in equatorial/tropical Africa Jablonski referred to NASA map (Jablonski, 2009, 02:59-03:03, 2011, p. 8) as well as to two figures made from an interpretation of NASA data (Jablonski & Chaplin, 2010a, pp. 175-176; 2010b, pp. 8964-8965). Consequently, Jablonski (2017) made clear, saying: “at the equator and within the tropics, average UVB is high… Outside of the tropics, average UVR are much lower” (p. 4). This theory is called “the geographical gradient of human skin color” (Jablonski, 2017, p. 6). The theory is inherited from the Linnean classification (Linnaeus, 1735/1758) of human skin color encountered earlier. It follows from the reasoning of this theory that a longer exposure of skin to UVB zone, to use a word cherished of torrid theory zone, has produced black skin. And Jablonski (2017) concurred, “there has been a cause and effect relationship between UVR and skin pigmentation in human evolution” (p. 6). The causal relationship of black skin with torrid zone is unequivocally assumed, and for this reason, the formula $W x L = C$ employed earlier to visualize Gloger theory at best comes into play. To recap, the formula implies that the amount of the weather (W) multiplied by the length (L) of time produces the color (C) of the skin. When unmixed black individuals move to the poles their skin turns to white after a period of time in low-UVR settings. As discussed above, while the formula may sound ludicrous, it makes perfect sense insofar as the subject unmixed black individuals is replaced by *Homo genus*. Jablonski added, using a key teaching of torrid zone theory mentioned supra, “that darkly pigmented peoples were found close to the equator; lightly pigmented peoples… were found closer to the poles” (2009, 01:44-50). The same idea was supported by Smith (1787/1810, pp. 35-36).

It is worth recollecting here that Jablonski argument is taken squarely from torrid zone theory. As Jablonski (2011) stipulated,

> By the mid-1700s… the American Samuel Stanhope Smith observed that skin pigmentation showed a pronounced gradient according to latitude, from dark near the equator to light toward the poles… “This general uniformity in the effect,” Smith wrote, “indicates an influence in climate, that, under the same circumstances, will always operate in the same manner.” (p. 8)

The same statement was corroborated by Jablonski and Chaplin (2010a, p. 168, p. 170; 2010b, pp. 8962-8963). More specifically, Smith statement quoted above, although not referenced in Jablonski (2011) article, was made in 1787 in the first edition of his book (see Smith, 1787, p. 18), but it was purely and simply dropped in 1810 in the 3rd edition of Smith book (see Smith, 1787/1810, p. 62). This was because much at the discontent of Smith, Smith opinion of climate effect with dark skin being closer to the equator and light skin nearer the poles, had met with scathing objection from armies of authors in England and beyond, based on accounts and research received and done around the globe. Sure enough, in the 3rd edition of his book, Smith (1787/1810) markedly revised his statements and toned down his position. Most distinctly, after having been excoriated by “critical reviewers… round the globe” (Smith, 1787/1810, p. 62, see footnote *), Smith (1787/1810) was, in his 3rd-edition book, rather apologetic, stating: “I have endeavoured… to explain the proximate cause of colour… *although I should have failed to point out the precise mode in which climate acts, or accurately to have traced the chain of its effects* [emphasis added]” (pp. 60-61). Note the qualifier proximate in lieu of definite or absolute cause of color. As acknowledged above, failure to dissect the chain of climate mechanisms and related factors across and within region, latitude, location, group, species, and individuals is what makes torrid zone theory unrepresentative of and inconsistent with the variability proper to the population of the researched and to the world/reality thereof (details below).

While dark or melanized skin is being presented as an evolutionary adaptation of human species to equatorial or savannah intense UVR heat (Jablonski, 2009, 2011, 2012a, b, 2013a, 2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017), the reality of human species rebuts such an evolutionary solution/recipe. In effect, the distribution of UVR does not translate into nature, specifically into the global distribution of mammals, birds, humans, and of living organisms. The simple idea that irradiation/combustion destroys organic life just jars with fluidity/richness of life being at its peak on the equator (Humboldt, 1808). A temperature/weather aflame with UVR and thus hot enough to permanently turn (the color of) skin pitch-black would unavoidably destroy organic life in the process. The fact that in equatorial/tropical Africa, infants, pregnant women, albinos, and the elderly of *Homo sapiens* species have survived UVR intensity with a below-average rate of melanin in their skin demonstrates that the proclaimed UVR-triggered natural selection of black skin did not work/happen. The point being, evolution has to do with the survival of species (Hanel & Carlberg, 2020). This is clearly because the skin of infants, elderly, sick, disabled, pregnant women, and albinos in equatorial Africa is not in any way, shape, or form *naturally* shielded against the extreme intensity of UVR. Most definitely, no population, race, or species even on the equator survives solely with UVR protection, without vitamin D-supplied nutrition, more so for infants, pregnant women, elderly, albinos, and the sick. Therefore, the argument of black skin being an evolutionary adaptation/solution to the intensity of UVR in equatorial/tropical Africa as arguably demonstrated by NASA map (see Jablonski, 2009, 02:59-03:03, 2011, p. 8) is not as sound as claimed, and the concept variability defended by Gloger (1833) comes in greater focus. On this note, protection against UVR as an evolutionary reason of black skin was refuted by recent research. For example, Ammitzboell (2020) maintained,

> It is discussed that the darker skin was developed to protect the person from UV rays that cause skin cancer. But it likely had little effect on the evolution of skin color because evolution favors changes that improve reproductive success and skin cancer usually affects people after they have had children. (p. 189)

Evolutionary adaptation of black skin is contradicted by the fact that reproductive success of human species was not affected by this adaptation. A focus all too reliant on melanin as an ultimate antidote to UVR is not a well-grounded argument, either. Korte and Mandea (2019) waved a flag of caution, stating: “Earth’s magnetic field shields our planet against highly energetic particles from the Sun and outer space, which threaten modern technology” (p. 3801). The somehow imminent adversity of UVR tends to cause panic in studies/interpretations of black skin.

Indeed, a recent review by Caro and Mallarino (2020) and by Cuthill et al. (2017) of research done on skin color of mammals shows the skin color of mammals to be a function of crypsis, and not of scorching UVR on the equator. Most strikingly, Caro and Mallarino (2020) suggested that more than a simple cryptic tool "black and white stripes of Zebras are not a form of waning coloration…instead a growing number of studies indicate that stripes thwart attack by disease-carrying biting flies" (p. 362). It is interesting that Zebras, a species endemic to the equator, are endowed with stripes whiter than Whites living/residing in the northern hemisphere. Similarly, in his review of studies applying Gloger theory among birds, Delhey (2019) rejected UV radiation as a mechanism governing bird coloration, with crypsis being the most common mechanism instead. As to humans, the distribution of global UVR is not representative of the variability existing within human species at the time of *Homo sapiens* and at that of modern humans. To be clear, "hubris easily leads us to forget that *Homo sapiens… is one only one of 400 extant species* allocated to the order of Primates and just one over 6000 species in the class Mammals [emphasis added]" (Martin, 2015, p. 32). A conclusion or reasoning that each and every individual of *Homo genus* species is darkly pigmented has yet to be proven, not to mention the wide range of extant hominin species. Also, it seems implausible to present the northern hemisphere as the province/private property of Whites or lighter-complexioned individuals.

Perhaps the most potent refutation of concentrated UVR as an argument for black skin pigmentation, for the theory of geographical gradient of human skin (Jablonski, 2017), and to a great extent for torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) can be seen in four levels. The first level of refutation comes from Pallas (1780a, b, 1784, 1811/1831a, b, c) research. As demonstrated above, Pallas (1780b), an expert with extensive and unparalleled research into arctic regions, showed diversity of traits, skin color, and hair color to be the marker of arctic regions. To add dimension to the refutation, Stanley (1878, 1899), an explorer with remarkable expeditions in the equatorial Africa the birthplace of *Homo sapiens*, listed a fair amount of aboriginal lighter-complexioned communities on the equator. The second level of evidence sharply refuting UVR argument for black skin pigmentation and for associated theories noted above is with the ubiquity of melanin in nature (Herrera, 2018) and the correlated presence of endemic dark and black fish in Lake Baikal at 53º30N, the oldest, deepest, largest, and coldest lake on earth (Knizhin, Weiss, & Sušnik, 2006; Klump et al., 2020; Schemske & Mittelbach, 2017; Zaitseva, Smirnova-Zalumi, & Zakharova, 2008) as well as the dominance of black bacteria/microorganisms in Black Sea (Michaelis et al., 2002; Sergeeva et al., 2014) located at 44ºN. Note that Black Sea is the blackest sea on earth with microorganisms interestingly blacker than those found in Lake Victoria located at 1°00S on the equator (Schemske & Mittelbach, 2017). Evidence from Lake Baikal and Black Sea was confirmed by Montagna, Prota, and Kenney (1993) research that "all deep-see fish have dark skin. The skin of these fish, which live in darkness, is black or dark-brown as is the fur of most bats, many of which fly at night" (p. 7).

The third level of refutation concerning UVR argument for black skin pigmentation and related theories deals with the fact that despite the omnipresence of pitch-black eyes among species, from reptiles to fishes to insects to birds to mammals and most significantly to humans, eyes of humans living on the equator are not black, According to Kasten and Dürr (2016) as well as Kolga, Tõnurist, Vaba, and Viikberg (2013), black eyes among humans can be found in Siberia the coldest and least UVR-exposed place on earth. While eyes of populations in Siberia can be black, eyes of Blacks living in the UVR-boiling region of Africa are not black or at least no blacker than those found in Siberia among several species including humans. And pitch-black eyes crosscut latitudes in the kingdom of living species. The diversity of color encountered in artic regions (Kasten & Dürr, 2016; Kolga, Tõnurist, Vaba, & Viikberg, 2013; Pallas 1780a, b, 1784, 1811/1831a, b, c) is extremely worthy of note here. The fourth and last level of refutation regarding UVR argument for black skin pigmentation, for the theory of geographical gradient of human skin (Jablonski, 2017, 2018, 2021b), and for torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) resides in the existence of pitch-black skin, regardless of races and individuals, particularly naturally occurring on or around elbows, nipples, anuses, arm pits, genitals, knees, ankles, toes, etc. (Cibangu, 2015). Most interesting and indeed refuting is the fact that the color of these areas can vary from pitch-black to pink, regardless of races, individuals, and latitudes. Following from the scenario depicted above, the best consequence would have been the existence of pink nipples, for example, solely among white-skinned individuals living in northern regions as well as the existence of pitch-black nipples solely among black-skinned individuals living in equatorial regions of Africa. Quite conversely, pink nipples or genitals, to mention just one case, exist across latitudes, races, and individuals. Perhaps most antithetical to the thesis of UVR-flooded regions as an evolutionary reason for human skin color is the fact that Tasmanians (Black aboriginals of Australia) had lived in freezing, wintery, and UVR-deficient conditions much longer than Whites had lived in the cold region (see Diamond, 2006, p. 116). The variability of species and of their locations is undeniably proven by the above recent findings.

Closely associated with the geographical gradient of human skin theory is the geographical gradient of human body size/physique. This theory is best summarized by American biologist William R. Leonard (Leonard, 2015) when he reasoned,

> Among human populations around the world, body size and proportions are strongly influenced by differences in environmental temperatures. Human populations living in cold, artic climates are relatively heavy with large trunks and shortened limb lengths. Conversely, tropical populations are lighter and typically have more linear physiques. These patterns of variation are consistent with the classic "ecological rules" of Bergmann and Allen. (p. 251)

However, a vast majority of Scandinavians along with the populations listed by Gloger residing in the same latitude from Kamchatka (Russia) to Kazan (Russia) to Petersburg (Russia) to Moscow to Dresden (Germany) to Amsterdam to Copenhagen to London to Edinburg (Gloger, 1833, pp. 53-54) display nothing nearing physiques of shortened limbs and large trunks. Research undertaken on various groups of Nordic individuals shows a variety of body size and height (Holmgren et al. 2018; Sorokowski et al., 2020; Zammit et al. 2007), which is a stark contradiction against the claimed gradient of human physique. Human physique is not entirely dependent on latitude. Gloger (1833) finding on the variability seen in Nordic areas was also borne out by Pallas (1780b, pp. 80-81) finding in the Siberian region as well as Humboldt (1831) research. If Gloger arguments were taken seriously, too many cookie-cutter characterizations of black skin could have been avoided, and the complexity of the myriad mechanisms involved in the organic life of black skin would have risen to the fore. Indeed, it has been recently suggested

> that the *genetic basis of skin color is less simple than previously thought* and that geographic variation in skin pigmentation was influenced by the concerted action of different types of natural selection, rather than just by *selective sweeps in a few key genes* [emphasis added]. (Rocha, 2020, p. 77)

The statement encountered above is a disproval of an argument made to justify black skin using UVR. The argument was a reaction against Jablonski (2011) who wrote,

> When people started moving away from very sunny places with high levels of UVB to less sunny places with lower levels of UVB, those individuals who had lighter skin were able to stay healthier and leave more offspring. Evolution was at work again… We see evidence, in fact, that "selective sweeps" – greatly accelerated periods of evolution by natural selection – led to genes for lighter skin becoming fixed in the population over the course of just a few thousand years. (p. 9)

Selective sweeps did not increase the understanding of black skin and the genes behind it. The truth is, "while continent-scale selective sweeps have been relatively well-characterized, the more subtle interplay between natural selection and the uniquely human impact of culture and demography in shaping pigmentation diversity within smaller regions remains poorly understood" (Quillen et al., 2019, p. 14). Well beyond smaller regions, diversity more exactly variability lies at the heart of every aspect of organic life and physical world, the spinal cord of Gloger theory. It was also suggested that UVR protection is only one among the many functions of skin such as epidermal hydration, proteins and lipids reconstitution, elasticity, etc. (Badreshia-Bansai, Patel, & Taylor, 2016). The complexity of skin is reflected even in its functions. Variability of organic life and the mechanisms involved was a dominant theme of Darwin research on the origin of species since early on, and Wallace (1871, 1878) followed suit. Darwin [1859] 1873 confirmed, "natural selection has been the most important, but not the exclusive, means of modification" (p. 4). The statement applies to the manner of understanding and researching black skin formation.

4.3.2 The Second Main Idea is Comparative Evidence

Comparative evidence can be seen as the basis for Jablonski (2017, 2018) strongest arguments on black skin. The point is that "because skin is mostly not preserved in the fossil record, arguments about the evolutionary causation… have relied on critical examination and integration of pertinent comparative anatomical, physiological, palaeoecological and climatological evidence" (Jablonski & Chaplin, 2017, p. 2). While the reasoning sounds magnificent, its flaw lies in comparing and mixing together incomparable and inseparable units of analysis. To elaborate, there are broadly speaking four disciplines involved in the comparison suggested supra, namely: (1) anatomy; a sample of bones/skull taken from individual A, (2) physiology; a sample of a black skin cut taken from individual B, (3) paleoecology; a sample of a leaf taken from plant A, and (4) climatology; a sample of a temperature taken from spot A. As can be anticipated, the listed samples are units of analysis/research and worlds completely separate and different from one another. The issue was well raised by Smith (2016) and Smith and Wood (2017), namely, how counterproductive and almost impossible is the endeavor to consider a unity of study as representative of the concerned group and of variation (regarding the group and its individuals), not to mention surrounding mechanisms. The idea here refers to Gloger key argument about the complexity of variability mentioned earlier (Gloger, 1833). The variability of one sample and its specific world cannot override or be overridden by that of another. For example, and in line with Gloger (1833) thesis homing in on variability, (a skull of) individual A and (a leaf of) plant A are inextricably unique although they might be related, and cannot be lumped together as one species per location, weather, or latitude. More precisely, considering by way of illustration individual A as a whole in and by himself, his skull cannot be separated from the whole (i.e., world around it and the rest of the individual's body). The same is true of black skin. Black skin (i.e., its ingredients and nature) cannot be separated from the whole.

A reflection fairly supportive of comparative study/evidence adopted by Jablonski is the one that reads as follows,

> Comparative study of the human melanocortin 1 receptor (*MC1R*) locus demonstrated that the timing of evolution of permanent, dark, eumelanin-rich, skin pigmentation coincided with the evolution of functional hairlessness and increased density of eccrine sweat glands early in the history of the genus *Homo*, approximately 1.2 million years ago or earlier… Adaptive evolution for sun-resistant alleles of the MC1R locus appear to have occurred, therefore, when early members of the genus *Homo* became mostly hairless and highly physically active inhabitants of open savannah environments in Africa. (Jablonski, 2017, p. 2)

A similar argument was made in detail by Jablonski and Chaplin (2010a, pp. 167-183) and Jablonski (2018, p. 30). By all odds, the dating of MC1R has helped deduce the (time of) dark skin of *Homo genus*, which in turn has been described as a protective tool against sun-drenched environments of equatorial Africa. While comparative study can be a powerful tool for a researcher to make an argument, such as dating the protein MC1R in hominins, it is not a valid/scientific indicator of representativeness for the researched and their world. Indeed, the dating of MC1R at around the time of *Homo genus* presence in equatorial Africa not only falls short of representing the variability of human species at that specific time/period and the world thereof, but comes in sharp contradiction with the ubiquity of melanin or dark/brown pigment in nature (Galván & Solano, 2016; Herrera, 2018). The concept hairlessness of *Homo genus* is not without flaws, either. Wallace (1871), a renowned co-discoverer of evolution theory with Darwin, quite empathically stated, "*man's naked skin could not have been produced by natural selection* [emphasis in original]" (p. 347). In more ways than one, naked skin poses no small health hazards in a savannah or forest setting; a setting famed for irresistibly rapidly reproductive organic life such as bugs, germs, pollens, etc. (details below).

Variability has been raised and/or demonstrated on multiple fronts by Gloger (1833) as well as his research mentors Pallas (1780a, b, 1784, 1811/1831a, b, c) and Humboldt (1808, 1831). To date, variability -- also called endogeneity or sample representativeness to highlight all factors endogenous or proper to a given phenomenon or population and the world or context thereof -- is key in defining a research impact. Research impact is measured by a research's "*sample representativeness*, meaning that when the process of selecting the sample has been performed properly, the sample will often have characteristics similar to those of the population [emphasis in original]" (Sotos et al., 2007, p. 101). Recent research materials identify variability as a researcher's ability to produce results fully representative of and/or consistent with the variability pertaining to the population of concerned participants and to the reality or world in which the participants are situated or live. As Lichtenstein (1833) unambiguously acknowledged in the foreword to Gloger (1833) work,

> *Man wird dem Verfasser dieser Schrift [Gloger] immer das Verdienst beimessen dürfen, den… von unsrer Zeit dringend gefordeten Untersuchungen… nach einer neuen Richtung die Bahn gebrochen zu haben* [one would always give to the author of this paper [Gloger] credit for having broken fresh ground with the pressingly required research of our times… in the path toward a new direction]. (p. iv)

Listened to closely, Gloger was a powerful mover of skin color research, particularly regarding the relations between environment and species. In this respect, there are myriads of inconsistencies plaguing present day skin color scholarship about black skin.

4.3.3 The Last and Third Main Idea is High Physical Activity

High physical activity of *Homo genus* underlies Jablonski (2017, 2018, 2021b) forceful arguments on black skin. The argument is premised on

> increased density of eccrine sweat glands early in the history of the genus *Homo*, approximately 1.2 million years ago or earlier… when early members of the genus *Homo* became mostly hairless and highly physically active inhabitants of open savannah environments in Africa. (Jablonski, 2017, p. 3)

The same idea was justified by Jablonski and Chaplin (2017, p. 3), Jablonski (2018, p. 30), and Jablonski (2021b, p. 707). While the argument is fascinating, high physical activity is downright unworkable and unwarranted when it comes to the forces/factors at play in a savannah and forest natural setting. For example, one cannot easily run or walk on sand or on pointed, uneven rocks. To explain, sand, mud, dead leaves, hanging and entangled shrubs, broken branches, and fallen trees, to name a few features of a savannah or forest, are incompatible with, disruptive of, and hazardous to a normal and more so to a high physical activity of running and walking. Moreover, as one is in the midst of all the activity of running fast, bugs or moist as well as dust from sand, clay, wood, hay, and grass pollen only make the likelihood of injury and damage to eyes greater, and there is also a reasonable chance of choking and sneezing as the mouth and nostrils tend to remain wide open for better oxygenation. In all probability, untreated/unprepared terrain poses a nonnegligible hazard to both shod and unshod runners or walkers.

Even more hazardous, naked skin is not at its best in a savannah or forest on the equator, considering on the one hand the richness of microorganisms, pathogens, bugs, etc. in that part of the world (Humboldt, 1808, 1831) and on the other hand the moisture constantly found/replenished in skin (Jablonski, 2013a, p. 2). The moisturizing aspect of skin was asserted by Yadav et al. (2019, p. 2) and Badreshia-Bansai, Patel, and Taylor (2016, p. 67). As largely shown above, no naked skin -- human, animal, or plant -- remains secure in the open air, across latitudes, species, and individuals. Wallace (1871) observed that indigenous peoples found in tropical, equatorial forests were seen wearing fur and/or large leaves to protect their bodies/skins. This would not have happened if their skins were adequately shielded by natural selection. One classic example on this note is with human swollen lips, a characteristic singularly distinguishing humans from (the lips of) their ancestors primates according to Blumenbach (1775/1795). Yet, human lips are one of the most UVR-unprotected organs of humans, noted for its varying color across races and individuals (from brown to pink to black to red to yellow), and also an organ known for being the most exceptionally vulnerable to ambient air across latitudes and climates, both indoors and outdoors. If the melaninization of skin in hominins and modern humans had happened as claimed by skin color scholars (Jablonski, 2009, 2011, 2012a, b, 2013a, 2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017), lips would have been the most melanized organ of humans because lips tend to be particularly susceptible to ambient air, regardless of temperatures and latitudes. Therefore, the claimed melaninization of skin is not an effective natural protection of skin. As Darwin (1859/1873) reminded skin color researchers earlier, natural selection although important is in no way the sole means of species modification. One other distinguishing characteristic of humans full of interest about naked skin of *Homo genus*, as Wallace remarked, is,

> In man the hairy covering of the body has almost totally disappeared, and, what is very remarkable, it has disappeared more completely from the back than from any other part of the body. Bearded and beardless races have the back smooth… the back, and especially the spinal cord region, is absolutely free, thus completely reversing the characteristic of all other *mammalia*. (Wallace, 1871, p. 345)

With the back being most vulnerable to rain, wind, and cold, particularly in the spinal cord area, the idea of naked skin and eccrine glands as a means of natural selection makes no sense. Other mammals have their spinal areas well protected with fur or scale.

As an illustration, concerning the forest in Africa in which *Homo genus* are claimed to have started or been born, Stanley (1899) testified,

> And all this time the trees kept shedding their dew upon us like rain in great round drops. Every leaf seemed weeping. Down the boles and branches, creepers and vegetable cords, the moisture trickled and fell on us. Overhead the wide-spreading branches, in many interlaced strata, each branch heavy with broad thick leaves, absolutely shut out the daylight. (p. 101)

Such a context filled with hanging twisted vegetable cords and creepers is completely inadequate and indeed dangerous for any form of high physical activity, much less walking and running. To make things even more dangerous, regarding the soil similar to that of a savannah, Stanley (1899) asserted,

> We, accustomed to rapid marching, had to stand in our places minutes at a time, waiting patiently for an advance of a few yards, after which would come another halt, and another short advance to be again halted… The path soon became a stiff clayey paste, and at every step we splashed water over the legs of those in front, and on either side of us. To our right and left, to the height of about twenty feet, towered the undergrowth, the lower world of vegetation. The soil on which this thrives is a dark-brown vegetable humus, the débris of ages of rotting leaves and fallen branches, a very foreing-bed of vegetable life, which, constantly fed with moisture, illustrates in an astonishing degree the prolific power of the warm moist shades of the tropics… Every few minutes we found ourselves descending into ditches. (pp. 101-102)

The texture and density of the undergrowth arising from the soil, marshy, muddy, clayey, slippery and awash with broken branches defeat the purpose of walking and running. As Hunt (2015) indicated, “bipedalism is not only slow and unstable compared with quadrupedalism – unlike most adaptations (say, adaptions to chewing harder foods), it is clumsy and inefficient in its earliest evolutionary stages” (p. 108). Human feet do not carry as much grip as the feet of birds, mountain goats, and cats do, to name a few. Therefore, human feet are ill-equipped on branches, rocks, holes, bumps, slippery soils, dead leaves, etc. In a forest or savannah, wet and dry leaves constantly cover the soil, leaving it slippery. Humans don’t jump while running; jumping is essential in catching prey in a savannah or forest. Bipedalism is the least common way of motion in the kingdom of livings. Primates who are bipedal are excellent climbers whereas humans are not. Because bipedalism is unusual, clumsy, and imbalanced compared to quadrupedalism, crawling, or flying, there is a far greater likelihood of injury of ankles, toes, knees, and hips, which can happen regardless of shod or unshod feet, of heathy or unhealthy persons. In those days (i.e., *Homo sapiens*’), people didn’t have surgery or ice pads.

According to Jablonski and Chaplin (2010a, b, 2017 and Jablonski (2017, 2018, 2021b), high physical activity to explain black skin evolution is closely correlated with eccrine production because of hairlessness or human naked skin seen with *Homo sapiens*. However, regardless of age, race, latitude, mobility, health, and location (i.e., outdoors or indoors), human skin invariably suffers from cracks, blisters, bruises, cuts, blotches, etc., all of which constitute perfect targets for germs and bugs, not to mention that band-aids and baby powder were unavailable during *Homo sapiens*' days. Perhaps the biggest shortcoming with the argument of high physical activity is with the hunting duty of *Homo genus* being described as part of and reason for high physical activity (Jablonski, 2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017). This argument can be rebuffed using two facts.

The first rebuffing fact is that high physical activity or hunting came quite late in the history of *Homo genus*. The reason is that "no actual fossil evidence of tools designed for hunting exists earlier than approximately 400, 000 years ago" (Sussman & Hart, 2015, p. 75). This shows that the melanization of human skin due to high physical activity is a moot point. "In fact, when we look at the fossil evidence, hunting may have come quite late in our human family. Interpretations of hominin behavior, therefore, should be conservative and cautious" (Sussman & Hart, 2015, p. 74). The behavior of high physical activity for early *Homo genus* is unjustifiable considering the wild/unarranged terrain of a savannah or forest. Perhaps more clarifying is the idea that hunting is not as much a characteristic of humans as agriculture (i.e., plowing, shepherding, gardening, etc.), metallurgy (e.g., mining, foundry, alloyage, etc.), and art (e.g., sculpture, painting, jewelry, etc.). Monkeys or primates, the ancestors of humans, do not hunt, and although as noted earlier monkeys are skillful climbers, humans are not.

The second rebuffing fact is that, even if hunting were to be taken as part of *Homo genus* activity, the argument is still unconvincing since hunting is not the same as running fast, supposedly to catch prey. Curiously enough, the synonyms of the English verb to hunt are: to look, to search, and to seek (*Cambridge Advanced Learner's Dictionary*, 2013), and not to sweat, to run, to race, to dash, etc. It is like saying that fishing consists of swimming fast in order to catch fish. No wonder the concept hunting often *goes hand in hand* with the concept *gathering* because one cannot gather while running and one cannot run while gathering, hence the phrase hunters/gathers. Taking everything into consideration, one realizes that running is well out of the picture partly because gathering, especially of food, has to be carefully slow/selective. Consider even wild cats (e.g., lions, jaguars, leopards, tigers, etc.) and wild dogs (e.g., coyotes, foxes, jackals, wolves, etc.), known to be among the fastest runners in the kingdom of animals: they do not spend days and/or hours running fast, panting/perspiring, in order to hunt prey. On the contrary, wild cats and wild dogs (Castelló, 2018, 2020; Driscoll, Macdonald, & O'Brien, 2009; Hunter, 2015; Spencer, Crowther, & Dickman, 2014) hide and move slowly, cunningly, and surreptitiously to entrap and capture prey; thus running if it ever happens during hunting, is done in the blink of an eye. These hunting animals often times give the impression of being deeply asleep, motionless, inoffensive, and inattentive only to jump and catch prey in a fraction of a second.

For instance, describing Hadza people, famous hunters/gathers of Tanzania, Marlow (2010) underlined,

> Hadza men *rarely run*. They may run briefly to get a second shot at a large herd. Occasionally, when they see a small animal like a hyrax, they may run to cut it off before it can reach its home in a rock [emphasis added]. (p. 118)

Remember that this is one of the species-richest – so to speak -- areas on the globe, therefore running or high physical activity is uncalled for in order to find food/prey. Just as one does not need to sweat or swim fast in order to find fish in the ocean, so too one does not need to sweat in order to hunt prey in a forest or savannah. One paramount thing to acknowledge is that evolution concerns/affects a whole species (Ammitzboell, 2020; Hanel & Carlberg, 2020). But still, women, children, disabled, and elderly do not usually hunt, while being every day exposed to and grilled by intense UVR close to the equator. This means that their skin could and should not have turned black. Therefore, hunting and high physical activity as evolutionary solutions/adaptations are unsuitable, at least inadequate for the variety of human species dealing with this specific environment, variety being a central argument of Gloger.

Another no less gripping argument arising from high physical activity is that of vitamin D and folate regulation among hominins and modern humans. The classic explanation given here is that "the primary role of dark constitutive skin pigmentation in hominin and modern human evolution is that of a natural sunscreen to conserve folate" (Jablonski, 2017, p. 3). The explanation has received support at various levels, as shown by Jablonski (2012a, p. 11), Jablonski and Chaplin (2017, p. 3), Kelly and Jamoussi (2016, p. 6), and Taylor and Kyei (2016, p. 9). This explanation cannot help but bolster torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810) in general and the formula visualizing Gloger (1833) theory in particular (see supra). Jablonski (2017) alleged that "when we consider the evolution of skin pigmentation, it is clear that long-term occupation of non-tropical latitudes would not have been possible without loss of some constitutive eumelanin pigmentation in order to prevent the serious sequela of hypovitaminosis D" (p. 5). As can be realized, the higher is the amount of pigment/melanin in a skin the more deficient in vitamin D is that skin, which in this case is black skin.

Meanwhile, the vitamin D and folate argument to account for black skin has been disproven extensively in recent studies. Thus, Jones, Lucock, Veysey, and Beckett (2018) noted,

> The vitamin D-folate hypothesis and related theories propose that skin pigmentation evolved to regulate the biological effect of differing UVR levels in different regions of the globe… However, the migration of human populations across large distances over the last several hundred years has created an evident mismatch between the adapted skin types of individuals and their UVR environment. (p. 7)

Similar research was conducted by Elias and Williams (2018, p. 2). A mismatch has equally been shown regarding the distribution of vitamin D across the globe. This research has been undertaken by Elias for more than a decade (Elias & Williams, 2013, 2015, 2016, 2018; Elias, Williams, & Bikle, 2016). Natural selection of skin pigmentation has been immensely disputed. “Current theories for the development of epidermal pigmentation in hominins are problematic… Latitude-dependent pigment dilution to facilitate cutaneous vitamin D3 (VD3) synthesis is also problematic” (Elias &Williams, 2015, p. 273). Latitudinal skin pigmentation is rife with inaccuracies.

The argument of Vitamin D for skin pigmentation was further rebutted using extensive empirical research. In minute details, Elias, Williams, and Bikle (2016) asserted,

> Given its importance… natural selection surely would have evolved more efficient regulatory mechanisms than latitude-determined gradations in skin pigmentation… In fact, pigmentation did not lighten in a predictable fashion as humans emigrated out of Africa … Very fair pigmentation evolved solely in populations residing far to the north in Europe… long after they had migrated out of Africa. Likewise, virtually all other Eurasian populations display intermediate shades of pigmentation, independent of latitude… Consider also that melanin is a relatively inefficient UV-B filter in comparison to another endogenous mechanism that is much more efficient; that is, *transurocanic acid* (t-UCA), which intercepts well over 50% of incident UV-B, even in darkly pigmented skin. (p. 756)

Elias, Williams, and Bikle (2016) elicited,

> Moreover… even dark-skinned individuals, living at latitudes comparable to New England, can generate sufficient vitamin D during normal summer seasons… Finally, and perhaps most importantly, melanin exists in many non-sun-exposed organs of mammals, as well as in many pro- and eukaryotic organisms … where it must mediate other functions, known or unknown. Even in mammalian skin, pigmentation modulates numerous other functions, ranging from insolation to camouflage. (p. 756)

Elias research can be described as the most comprehensive and solid repudiation of the claimed skin pigmentation of hominins. The key idea being that regarding skin natural selection cannot be reduced to melanization.

The fact that both folate and vitamin D are related to a wide variety of cancers and chronic diseases debunks the evolutionary thesis of black skin as a byproduct of vitamin D and folate adaptation. Perhaps the biggest rebuttal against the vitamin D and folate argument is with what is called the vitamin D paradox. As Vieth (2020) elaborated,

> The vitamin D paradox relates to the lower risk of osteoporosis in people of sub-Saharan African ancestry (Blacks) compared with people of European ancestry (Whites). The paradox implies that for bone health, Blacks require less vitamin D and calcium than Whites do. (p. 617)

To a great extent, the paradox cited above has led to relentless reexamination of Vitamin D argument regarding black skin. Consequently, Hanel and Carlberg (2020) contended, “thus, archeogenomic data as well as comparisons of today’s populations did not provide any indication for an evolutionary pressure for light skin created by the need for vitamin D” (p. 871). Neither vitamin D nor folic acid amount to sufficient/cogent evolutionary grounds for black skin.

Moreover, the argument that maritime diet accounted for dark skin of arctic individuals was discredited. As Hanel and Carlberg (2020) wrote,

> Accordingly, the dark skin of some of today’s Arctic Native people, such as Inuits, has been traditionally explained for their marine diet rich in vitamin D3… However, nitrogen and carbon isotope analysis of northern and western Scandinavian hunter-gatherers revealed that they had an extreme marine diet as well and yet developed light skin. (p. 871)

This idea was also demonstrated by Cibangu (2015, p. 57). Evolutionary explanation of black skin loses ground in countless respects, all of which validates the concept variability that Gloger (1833) brought to the fore.

Another powerfully appealing argument related to vitamin D put forth to explain the natural selection of black skin regards sunscreen protection (Jablonski, 2012a, b, 2013a, 2017, 2018, 2021b; Jablonski and Chaplin 2017). Nevertheless, black skin is not as sun-proof as alleged. As Ansari, Le, and Harvey (2017) cautioned,

> The American Academy of Dermatology (AAD) recommends that all individuals apply sunscreen prior to outdoor exposure regardless of age, gender, or race… Sunscreens should be applied 15 minutes prior to going outdoors, and reapplied approximately every two hours, or after swimming or sweating… Guidelines also recommend usage of protective clothing such as long-sleeved shirts, pants, and wide-brimmed hat. (p. 58)

This recommendation across races and skin types is corroborated by Solano (2020) finding that "sun exposure without skin protection can be harmful anytime and anywhere" (p. 5). The finding comes as a blatant repudiation of the pretended sunscreen property of black skin in hominins and modern humans living on the equator. The finding has reversed the long-standing misconception that solely light skin was sensitive to UVR. As Del Bino, Duval, and Bernerd (2018) underscored, "while fair skins were in the past considered as the only sun sensitive phototypes due to higher skin cancer prevalence, nowadays, concerns regarding pigmentary problems of people with darker skin are emerging" (p. 26). Sunscreen protection/property is no longer a valid evolutionary characterization of black skin. For example, infectious and/or cancerous conditions can occur and are more difficult to diagnose in black-skinned people in large part because, as Abdulhak and Moiin (2020a, b) demonstrated, black-skinned patients are rare in most hospitals and medical practices. The lack of diagnosis or knowledge about the conditions of black-skinned individuals leads to a mischaracterization of black skin. Adding a dynamic to this dilemma, most clinical skin conditions tend to be consistent among skin types (Hines & Moiin, 2020; Lawrence & Moiin, 2020a, b). This has created grave misunderstandings about black skin. One of the most common misunderstandings or misrepresentations of black skin resulting from the hypothesis of vitamin D is the idea that "the relationship between skin color and skin cancer is well established: the less melanin in one's skin the greater the risk for developing skin cancer" (LaBerge et al., 2020, p. 69). While such an idea is empirically established, the blunt reality is that black skin or melanin is not even among the palliatives or cures against the symptoms of regular diseases such as nausea, headache, fever, etc., not to mention cancer itself.

Vitamin D was also correlated with an increase in caesarean section at delivery, across races (Keats et al., 2021). Such evidence gives an indication that Vitamin D is not reducible to black skin formation. One clarification needing mention here is that some diseases can be more pronounced in certain categories such as age, gender, height, etc. than in others. One case in point is that of ovarian cancer and breast cancer observed to be more frequent among White women than Black women and/or other ethnicities (Chapman-Davis et al., 2020). Thus, the claimed low concentration of skin cancer among Blacks is not something completely unnatural nor something caused by the blackness or darkness found in an individual's or a population's skin.

5. Pathways of Future Research on Skin Color

A number of lessons can be drawn from Gloger (1833) theory and its historical background. Just like organs, for example, eyes, ears, teeth, etc. respectively require a stand-alone department or scientific field to be studied, so does skin. It would thus be misleading, counterproductive to forego the complexity of skin and the color thereof. While the racially based dichotomy blackness vs whiteness was found to plague skin color research (Jablonski, 2021a), entire notions as well as misused and inappropriate narratives continue to beleaguer the understanding of black skin and the research of it. Such practices tend to poison the working atmosphere of black skin research. As paleoanthropologists Smith and Wood (2017) warned, "we generate comprehensive narratives knowing that we do not have all of the relevant data… There is much we would like to know about human evolutionary history, but wanting to know something does not make it knowable" (p. 677). As a matter of fact, notions such as equator, UVR, heat, global map, hairlessness, etc. have been used without relevant data, taken out of their context, and twisted to support (the supremacy of) white skin, and further obscure black skin complexity. Perhaps one of the most detrimental pitfalls besetting black skin scholarship sits in its methodology. Influential tables (Jablonski, 2009; Jablonski & Chaplin, 2010a, b) used to explain the gradient of human skin or of global latitudinal skin variation are nowhere close to required standards for the construction of tables or graphs nor to standard research method (Babbie, 2021). A large part of the shortcoming is that university interpretations of black skin arose in prejudice with the Linnean classification (1735/1758), Kant teachings (1775) on different human races, and torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). Current skin color research has not done much to turn the tide. A larger part of the shortcoming is a lack of data covering the time and site of *Homo sapiens* (and even modern humans) in Africa. Perhaps the largest part of the shortcoming is that existing skin color research relies nearly exclusively on comparative evidence. However, comparative evidence is not a standard research method of quantitative research and qualitative research (Babbie, 2021). What makes comparative evidence, at least as it is applied in skin color research, less than convincing is the lack of needed relevant data.

Methodology is a term generally conceived as covering subjects/courses of quantitative research and qualitative research, which yield results as representative as possible of and/or consistent with selected participants and their worlds on the one hand, depending on a researcher's preference, or as deep-drilling as possible into the lives of selected participants and their worlds, on the other hand (Babbie, 2021). Thus, methodology enables a researcher to further the understanding of a phenomenon's or reality's variability. The idea of species was a way for Gloger (1833) to address variability. Gloger insisted on the interplay between biology (e.g., black skin) and environment (e.g., climate) to warn authors against cookie-cutter approaches that wipe out specifics/variability across latitudes and weather conditions. The lack of "a global map that is *comprehensively* and *individually* representative of human skin variation [emphasis in original]" (Cibangu, 2015, p. 53) is living testimony to the fact that methodology merits attention in skin color discourse. Another testimony to the significance of methodology in skin color scholarship is with the erroneous and inappropriate narratives/scenarios of high physical activity or vitamin D regulation to explain the black skin of *Homo genus*. Another even starker testimony is with existing limited data regarding geographic populations of skin color variation (Jones, Lucock, Chaplin, Jablonski, Veysey, Scarlett, & Beckett, 2020, p. 2) and current scant knowledge on skin microbiome (Jablonski, 2013b). Since the last several decades quantitative research and qualitative research have increasingly been listed across universities and departments around the world as required subjects for the conferment of degrees.

Skin color research is called to be a type of research aiming to reflect the representativeness of and/or in-depth immersion into the lives of concerned participants and their worlds. Just as Gloger was unreservedly self-reflexive about his own research, it is time for skin color researchers to go past researchers' biases, labs, agendas, terminologies, etc. to live up to the standards of representativeness about and/or the unraveling of the life of the researched and of related world. Only then can skin color research produce research, narratives, or scenarios representative of, consistent with, and/or deep-drilling into the lives of black-skinned species/livings and their worlds. This is also one more reason for skin color research – as Smith (1787/1810) a leading figure of torrid zone theory acknowledged -- to tease out piece by piece the mechanisms involved in climate effects, a condition proposed by Gloger (1833) to tackle variability. However, as indicated earlier, Jablonski (2011) referenced Smith (1787) for an argument on equator-based skin color that Smith (1787/1810) already retracted in recognizing the necessity of variability. Comparative study/evidence can be useful in posing a research question, but as claimed above it is not a standard method of representativeness/quantitative research or deep-drilling discourse/qualitative research about the researched and their worlds. Existing narratives alluding to the so called out-of-Africa migration of *Homo genus* (Jablonski, 2009, 2011, 2012a, b, 2013a, 2017, 2018, 2021b; Jablonski & Chaplin, 2010a, b, 2017) obscure rather than illuminating the hardships/struggles/realities proper to the worlds of early and modern humans.

A good start for a rethink of methodology embraced in skin color studies is perhaps with terminology as Jablonski (2013b) recognized,

> Skin science is hobbled by old practices and vocabularies, starting with the very concept of "ethnic skin". For example, the same skin phototypes can be produced by completely different sets of pigmentation genes… but phototypes continue to be used because they are durable traditions.… The importance of future discoveries in human skin diversity will be grasped fully and acted upon only if we have a sophisticated vocabulary to match our science. (p. v)

As stated above, variability of pigmentation might be concealed under a veil of commonly used broad-brush concepts. Nevertheless, the lack of variability-appropriate terms admitted to be plaguing skin color discourse as suggested by Jablonski (2013b) above (and also Jablonski, 2021a, p. 444) is refuted by the well-known tendency of biology and climate sciences to use neologisms for newer, specific phenomena or topics. As a quick illustration, it is apparent even to lay people that every new hurricane or disease to give just one example among others has a name/terminology ascribed to it. One unfavorable prevailing condition of black skin research is that black skin is generally subsumed under broad-scoped headings such as "skin of color… ethnic skin, pigmented skin, and darker skin" (Kelly, Taylor, Lim, & Serrano, 2016, p. xxi). While these concepts and associated organizations can be powerful tools in developing an awareness of nonwhite-skinned populations, they tend to dilute the particulars/characteristics of black skin. Much of the reason is that "the lexicon of human diversity is replete with descriptors that evoke pejorative associations" (Jablonski, 2021a, p. 444), not to mention the narratives misused and concepts twisted in prestigious publications about black skin and skin color. With prejudice lingering behind, the quandary of skin color research is huge. The quandary of skin color research has been best summarized by Wood (2010) saying, "But when all is said and done a taxonomy [e.g., *Homo sapiens*] is just a hypothesis; it is not written on stone tablets" (p. 22), and by Jablonski (2012a) adding, "we can only speculate" (p. 38). Interpretations of black skin are nothing less than culturally motivated and constructed speculations. As Jablonski (2021b) warned, "we cannot assume that the appearance, genetic composition, sun exposure habits, or UVR skin reactions of humans today are the same as those of our ancestors in prehistory" (p. 709). For example, hands, eyes, and hair, among others, pose the toughest challenges to traditional skin color as they completely defy the thesis of latitudinal gradient for human skin color. Perhaps the toughest challenge for skin color research resides in the use of arguments and narratives that are substantially at odds with the reality of the phenomena being researched or talked about (i.e., savannah, forest, running, feet, naked skin, etc.). These and many challenges are also aggravated by the inadequacy of extant nomenclatures for the description of skin color (Dadzie, Sturm, Fajuyigbe, Petit, & Jablonski, 2022), more especially black skin.

Prejudice represents an inconceivably huge challenge derailing black skin research. While temperatures in the equatorial zone, for example, are beyond a shadow of a doubt demonstrated to be lower than those on the east coast of North America as Gloger (1833, p. 59) noted, with no sunshine, again as Gloger (1833, p. 47) and Stanley (1899, p. 101), among others, observed, prejudices of intense heat and sunshine regarding equatorial Africa persist among high ranked skin color scholars (Jablonski, 2009, 2011, 2012a, b, 2013a, 2017, 2018, 2021a, b). Resulting from these and many prejudices is an unquestioned blanket application of concepts proper to manmade parks and woods seen in Western Europe and North America to explain *Homo sapiens* behaviors in savannah or equatorial Africa. It follows that there is no apparent reason for "sustained muscular effort involved in long-distance walking and running in hot conditions" (Jablonski, 2018, p. 30) in areas of wild, unprocessed, rocky, thorny, and slippery terrains, entangled with hanging bushes, grass, and fallen, broken branches, with no trails, paths, or hiking equipment (i.e., boots, gloves, knives, repellents, pairs of glasses, compasses, handguns, first-aid kits, etc.). It is thus unthinkable that areas noted for the highest richness of species would require long-distance walking and running in order for *Homo sapiens* and in fact for any individuals to find food. It is like saying as presented supra that in order to catch fish in the ocean one would need exhaustive/long-distance swimming, not to mention the consequences/hardships arising from naked skin, bare feet, bare hands, bare eyes, etc. As elicited earlier, the prejudices bedeviling skin color research derive in large part from the Linnean and Kantian classifications (Kant, 1775; Linnaeus, 1735/1756) coupled with torrid zone theory (Blumenbach, 1775/1795; Smith, 1787/1810). There is no such a thing as an animal or prey in the kingdom of living species that is known for being caught by running (fast) after it. The pathways of future research remain as a timely reminder of the limitations to overcome/acknowledge to move forward with this paper research/review.

6. Conclusion

While it is generally believed that humans are equal, erroneous attitudes toward, unreasonable concepts for, groundless theories of, and prejudiced narratives about black skin continue to be held by mainstream publication circles. Black skin is being dismissed as unfit and outdated for standard review/research while the concepts equator and UVR, among others, have been removed from their proper contexts and disciplines only to be wrongly reduced and applied to black skin. To make this worse, newer research has shown that the birthplace of *Homo sapiens* is neither on the equator nor in the savannah region of Africa.

The biggest contribution of Gloger, although commonly unrecognized, is a vehement disavowal of equatorial heat and accompanying human gradient of skin color. Part of the problem might be that Gloger (1833) himself started (the problem) by posing a research question or premise, popular during his time, broaching climate-carried color of skin. However, Gloger was never able to find, undertake empirical research to support such a premise, and he was seconded by his mentors (Pallas 1780a, b, 1784, 1811/1831a, b, c; Humboldt 1808, 1831). From the Linnean system (Linnaeus, 1735/1758) to Kant (1775) summer lectures for over two decades and to Agassiz (1850) classes for more than two decades, the notion black skin has been presented with not only misconceptions, but misleading attitudes as well as misapplied and wrong concepts. The notion black skin was further obscured by that of Caucasian race (Blumenbach, 1775/1795) and by the captivating development of torrid zone theory (Smith, 1787/1810). Adding to the hysteria, the Industrial Revolution provided sterling, new technologies never thought of before such as telegraph, steam engine, electricity, etc. which unimaginably bolstered the on-going transatlantic trade of slaves and its already widespread and university-endorsed prejudices on black skin. Unlike in ancient society, however, relatively from the turn of the 18th and 19th centuries onward, unchallenged and often unconfessed narratives of black skin evolution and explanation continue to be propelled and believed across eminent publication outlets and public policy agencies. In the matter of narratives/arguments deploying high physical activity of hominins in UVR-sizzling savannah or equatorial forest of Africa to characterize black skin, it warrants being borne in mind, for example, that human feet offer absolutely no grip in forest or savannah conditions (i.e., ditches, rocks, thorns, fallen trees, etc.), let alone human naked skin, ears, eyes, and noses are naturally ill-shielded against pollens, biting bugs, winds, and similar savannah or forest features. The recently increasingly accepted idea of multiple dispersals of *Homo sapiens* individuals out of Africa imply multiple reasons beyond natural selection.

Quite simply, the hottest temperatures would irreversibly destroy life so as to turn skin into a pitch-black-colored organ. Yet, equatorial/savannah region is recognized for the highest fluidity/richness of organic life (Humboldt, 1808; Schemske & Mittelbach, 2017; Stanley, 1899). Climate effects have been acknowledged since Antiquity, with no deprecation against or limitation to a given geography-bounded skin color or nation. Antiquity writings display a highly neutral respect and presence of black skin across latitudes and places. The respect was also heightened by an extensive existence of aboriginal Black communities in North Africa and across Asia (Blakely, 1986; Brook, 1999/2018; Herodotus, ca. 425 BC/1950, ca. 425 BC/1957, ca. 425 BC/1960; Humboldt, 1808; Job 30:30 Hebrew Interlinear Bible; Pallas, 1780b; Lamentations 4:7-8, 5:10 Hebrew Interlinear Bible), well beyond equatorial Africa to which torrid zone theory (Blumenbach, 1775/1795;

Smith, 1787/1810) and slavery-based transatlantic trade (Kendi, 2017) have tended to restrict black skin. The respect of black skin has survived quite persistently till the late 19th century, when a full-blown torrid zone theory emerged. Even in the 19th century onward, torrid zone theory and similar theories such as geographical gradient of human skin theory (Jablonski, 2017, 2018, 2021b) were met with virulent, unyielding rejection. The rejection was further exacerbated in the late 18th and 19th centuries, when the pioneers of the measurements and observations of the equator and latitudinal differences never reduced the concepts heat and radiation on the equator to a given location or skin such as equatorial Africa or black skin (Humboldt, 1808, 1831; La Condamine, 1745). While Gloger (1833) clearly postulated Gloger theory invoking the idea of climate-bleaching effects, he subsequently fell short of supplying/finding empirical evidence. Pallas did the same when he (Pallas, 1780a) somehow posed the idea of region-based and species-limited climate effects only to completely revoke it with extensive empirical research (1780b). This might perhaps be one reason why both Gloger and Pallas did not finish up their works before they died as promised.

Indeed, the arguments and conclusions critically advanced by Gloger himself have laid to rest Gloger theory as well as torrid zone theory and gradient of human skin theory, bringing into greater focus (Humboldt, 1808, 1831) latitudinal gradient theory as well as Pallas (1780a, b, 1784, 1811/1831a, b, c) position of variability about climate effects. The fact that the seminal writings of Pallas (1780a, b, 1784, 1811/1831a, b, c), Gloger (1833), and to some extent Humboldt (1808, 1831), Stanley (1878, 1899), Wallace (1871, 1878), and Antiquity authors (Bunson, 2002; Foster, 2001) are unknown or uncited among skin color readership has led to significant misleading interpretations of black skin and its ecological setting. Hairlessness alongside high physical activity of *Homo sapiens* were downright invalid as factors of natural selection for black skin, so were tropical light and heat, the favorite concepts of torrid zone theory. Neither Pallas nor Gloger nor Humboldt ever used the concept Caucasian in describing animal as well as human species and subspecies. Neither of them devised a global map of skin color (i.e., for birds, animals, or humans), either, despite their unrelenting penchant for travel, unparalleled geographical knowledge, and the spectacular tools at hand. Neither of them defined the equator and UVR as the yardstick of black skin., but rather as the yardstick of organic life diversity/richness. This is particularly significant because both Pallas and Gloger figure among some of, if not, the most authoritative biologists/naturalists of Siberian region. The concept Caucasian is anything but false so is the narrative regarding high physical activity of *Homo genus* in order to justify black skin. Narratives employed for the natural selection of hairlessness and bipedalism are void of common sense. Neither Antiquity authors (Brown, 2001; Foster, 2001; Matić, 2020), nor Herodotus (ca. 425 BC/1950, ca. 425 BC/1957, ca. 425 BC/1960), nor Darwin (1859/1873, 1871/1889), nor Wallace (1871, 1878), nor Pallas (1780a, b, 1784, 1811/1831a, b, c), nor Humboldt (1808, 1831), nor Gloger (1833) ever found in their trips and/or research the uniformity or gradient of human skin according to the equator or latitude, an idea largely defended by torrid zone theory (Smith, 1787/1810), let alone Smith (1787/1810) himself, later and perhaps for the rest of his life, decidedly retracted his stance on black skin.

This implies that the most tested and increasingly widely accepted pattern, interpretation, or theory that can be used to fully explain/understand black skin in particular and skin color in general is latitudinal gradient theory. As seen with latitudinal gradient theory, (organic) life is too complex a phenomenon to be reduced to a single evolutionary mechanism/hypothesis/theory: black skin too can no longer be lodged in a single, isolated, and all-size-fit mindset/narrative. Rather skin (color) ought to be unraveled in an inclusive multifaceted mix of mechanisms or hypotheses. The variability endogenous to black-skinned population(s) and to the world/reality thereof further amplifies skin complexity. The requirement for skin color researchers and indeed for any researcher to produce research representative of and consistent with the researched and with related world cannot be dispensed with if (skin) researchers want to avoid endogeneity shortcomings. A reformulation of Gloger theory, if any, will have to rephrase if not replace Gloger arguments exposed above. In place of a closed-in and locked-up theory, Gloger himself left a theory that is open to newer findings and reflections. Gloger-postulated theory, Gloger stated arguments, and Rensch-Gloger theory can help researchers remove the misunderstandings about black skin.

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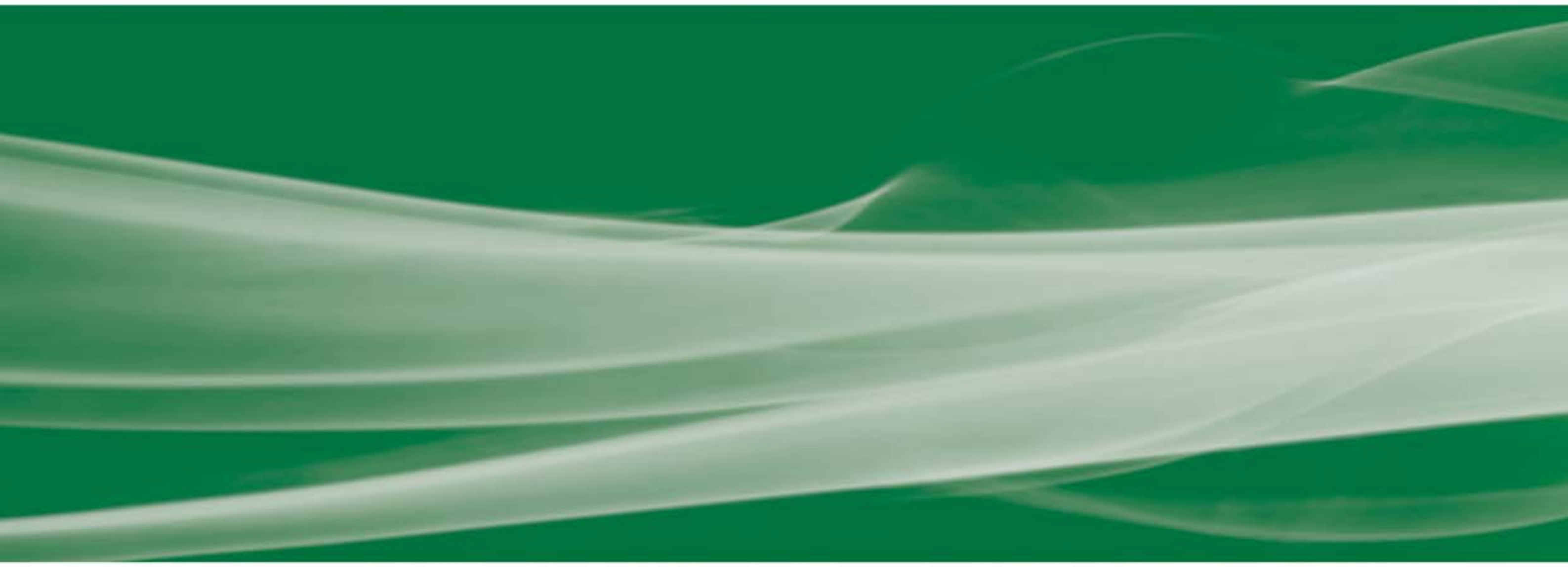

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