Annals of Psychiatry and Clinical Neuroscience

Research Article
Published: 10 May, 2018

Paleontology of Circadian Rhythm Disorders

William W Mc Daniel*

Department of Veterans, Eastern Virginia Medical School, USA

Abstract

The circadian cycle of humans and other mammals is close to one hour longer than the 24 hour period from sunrise to sunrise. It appears that all mammals examined have shown a circadian rhythm with cycle duration over 24 hours. Interestingly, birds show a circadian cycle of less than 24 hours, close to 23 hours. Terrestrial invertebrates, the insects provide the key to understanding this discrepancy. The earliest identifiably mammalian fossils are from the Permian era strata. Insect orders that first appeared in the Permian era include the hemiptera (bugs), orthoptera (crickets and grasshoppers'), and the neuroptera (lacewings), all of whose modern survivors show a circadian cycle longer than 24 hours in at least some stage of the life cycle. The insects whose ancestors first appeared in Mesozoic strata with the birds include hymenoptera (bees, wasps and ants) and lepidoptera (butterflies and moths). Their modern survivors, like the birds, demonstrate a circadian rhythm shorter than 24 hours. There is now evidence for two large meteorite impacts on Pangea near the end of the Permian era, one in Wilkes Land of Antarctica, and the other just west of Australia. The eastward movement of the Australian continent/plate and the southeastward movement of the Antarctic continent/plate indicate that those meteorites were moving eastwards, and struck the planet obliquely. Having done so, they might have imparted momentum to the planet's rotation, and so accelerated it. This may mean that circadian rhythm disorders are the consequence of a change in the duration of the solar day due to a disaster, and that daytime lethargy and depression may have had adaptive value to the mammals who survived that disaster, and the hunters of the Mesozoic.

Introduction

It has now become well-understood that circadian rhythm disorders are the cause of seasonal depression. It is commonplace for psychiatrists at northern latitudes to treat patients who suffer from seasonal depression with bright light. It is easy to stay up late, or to sleep late, but very hard to rise early or to sleep earlier than accustomed. We know that the free-running sleep-wake cycle does not match the planet's rotational period of twenty-four hours, and that the "clock is re-set" each day by a signal from the Supra-Chiasmatic Nuclei (SCN) that coincides with the exposure of the eyes to the light of each new day [1-3]. It seems quite remarkable that the period of the free-running sleep-wake cycle in mammals is between 24.2 and twenty-five hours depending on how it is measured [4,5] and that this is true among all mammalian species that have been examined [5-7]. It is the light of the rising sun that re-sets the clock each day. Failure to re-set the clock results in the human brain (and that of all mammals) falling further behind each day. In humans, the results in depression, and while the mechanism is obscure, the association is robust [5]. There is one animal familiar to most of us that always rises early. Chickens become active before dawn so reliably that they have become a proverb. He who rises early is said to have "gotten up with the chickens". Most of us learned, to that "the early bird gets the worm". Indeed chickens are not the only bird that demonstrates a free-running circadian cycle of less than 24 hours. All the birds that have been studied have a circadian rhythm of about 23 hours [8-11].Why should there be a miss-match between the cycle and the period of the day? And why the difference between mammals and birds? I have suggested [12] that the difference between mammalian circadian rhythm and the solar day may reflect origins in a time when the duration of the solar day was closer to 25 hours, and that the interval may have been altered by a massive meteorite impact. Where I originally thought the meteorite impacts that occurred at the end of the Cretaceous [13,14] might be responsible, models for estimating the mass of an impactor from the size of the crater [15] showed that even the largest crater could not have been made by a mass large enough to alter the momentum of the planet, and the length of the day by one hour. While the earliest primate fossils are all known from Cenozoic strata, and are not associated with any major impact crater, the earliest mammalian ancestors identified were the Permian therapsids [16-18].The great end-Permian extinction has long been known to be associated with massive volcanism (the Siberian Traps), there have now been identified at least two very large impact craters, one on Antarctica [19], and one off Australia [20] dating to that time. The earliest

OPEN ACCESS

Correspondence:
William W McDaniel, Department of Veterans, Eastern Virginia Medical School, Hampton VAMC 116A, 100 Emancipation, Hampton, VA23667, USA, Tel: 757-722-9961; Fax:757-726-6025;
E-mail: William.McDaniel@va.gov

Received Date: *19 Jan 2018*
Accepted Date*: 25 Apr 2018*
Published Date*: 10 May 2018*

Citation:
Mc Daniel WW. Paleontology of Circadian Rhythm Disorders. Ann Psychiatr Clin Neurosci. 2018; 1(1): 1002.

Table 1: Results for vertebrates.

Earliest Fossils of Class	Class	Order	Modern example	Free-Running Circadian cycle	How Measured
Permian (Therapsids)	Mammalia	Primates	H. sapiens Maccaca sp.	25h 25h	Sleep-Wake[1, 4, 5] Sleep-Wake[6]
		Perissodactyla	Equus	25h	Sleep-Wake[7]
		Rodentia	Hamster	25h	Activity[7]
Jurassic	Aves	Galliformes	Chicken	23h	Activity, calling Acetyltransferase[8, 9, 10]
		Passerine	Sparrow	23h	Activity, calling, temperature [9, 10, 11]
			Warbler	23h	Perch-hopping[11]

Table 2: Results for the invertebrates.

EARLIEST FOSSILS of order	Class	Order	Modern example	Free-Running Circadian Cycle	How Determined
Carboniferous	Insecta	Blattidae	L. maderae	Light-driven	Activity
Permian	Insecta	Hemiptera	Triatoma	25h	Activity[21]
		Orthoptera	Gryllus	25h (nymphs) 24h (adults)	Activity[24]
		Neuroptera	Chrysoptera	25h	Activity, Sensitivity to light[21, 22, 23]
		Coleptera	Anthia	25	Activity [25, 26]
Cretaceous (Mesozoic)	Insecta	Hymenoptera	Apismellifera	23	Worker activity[25]
		Lepidoptera	Antherea	23	Eclosion[25]

fossil birds are Jurassic, and the earliest dinosaur ancestors Triassic-arising after the Permian extinction event. If the contemporaneous invertebrates from those periods (insects are the prevalent terrestrial invertebrates in both eras) have similar circadian rhythms to those vertebrate groups, this might support a hypothesis that the circadian rhythm of each group is an adaptation to living in a time when the solar day was the same-a behavioral fossil.

Method

Literature search was performed using MEDLINE and Google Scholar using the terms Mammalian Circadian Rhythms, Avian or Bird Circadian Rhythms, and Insect Circadian Rhythms, and Earliest Fossil Birds, Mammals, and Insects (by order).

Results

Data for the free-running circadian rhythm (usually these meant conditions were found for several mammals, chickens, and sparrows, and a number of insects whose earliest ancestors are known from the Permian, or from the Mesozoic. The results for vertebrates are detailed in (Table 1), and results for the invertebrates (all insects) are detailed in (Table 2).The circadian cycle of all the mammalian orders was 25 hours under free-running conditions, and that of the birds, 23 hours. For those insects whose circadian rhythm has been measured, those orders that originated during the Permian era have modern representatives whose circadian cycle is also about 25 hours in at least part of the life cycle. For those insects orders that originated in the Cretaceous era have modern representatives whose circadian cycle is 23 hours in at least part of the life cycle.

Discussion

While it was long thought that there was no impact events associated with the much larger mass extinction at the end of the Permian, a 600km crater has been discovered under the ice of Wilkes Land, Antarctica [18]. Similarly, the Bed out High on the ocean floor off NW Australia has features that have led some to conclude that it represents the remnant of a large impact crater [21,22]. It seems certain that both Antarctica and Australia moved east (and Antarctica south) from Pangea [23]. While much less is known about end-Permian impacts than about the Chicxulub crater, this is likely to mean those impacts could have imparted angular momentum to the rotation of the planet. The degree of this is confounded by the fact that even at the end of the Permian, both impact craters were thought to be closer to the pole than to the equator. The present location of the Australian continent far to the east of late-Permian Africa is probably good evidence for an impact or also moving eastward. The somewhat less eastward position of Africa and Eurasia may suggest other impacts that have yet to be discovered or are obscured by sediments or plate tectonics. Is there any other geophysical evidence? Sharma's recent exhaustive dissertation on the interaction of the earth and the moon showed that the braking torque of the lunar tides on planetary rotation, expressed as $dJ_{orb}/dt = 4.47613 \times 10^{16}$N-m [24-27]. Thus given the current mass of the earth and moon, and assuming the braking torque has been constant, one can extrapolate to a proposed time of the giant impact thought to have created the moon, 2.8 billion years ago, and the solar day after the impact about 21 hours. Calculating the time since the solar day was 23 hours yielded a day 268 million years ago-approximately the estimated time of the end of the Permian era. The observation of a longer circadian cycle for late-Permian animals and Mesozoic animals would be consistent with a solar day of 25 hours before an impact, and 23 hours afterwards. If the solar day was 25 hours before an impact or impacts, and 23 hours afterwards, that might push back the day of the Giant impact and the age of the Earth by more than double. It is not clear whether this can be reconciled, and it may be a serious weakness for this theory. There is weakness, too in the assumption we began with, that the duration of the circadian day was once in fact the conditions our forebears lived in. It is entirely possible that a match between the circadian day and the solar day would be completely accidental, and has always been corrected by the onset or ending of daylight. Ontological evidence suggesting this is the absence of clock genes from the oldest of the terrestrial arthropods-the centipedes [28] (originated in Devonian), and the nearly complete dependence on light conditions in governing activity in modern dragonflies and cockroaches [26] (both originated during Carboniferous era).On the other hand, that may represent phylogenetic evidence of an early stage in the evolution of the clock genes that govern the lives of nearly all animals alive today. This is my belief, and if it is so, then an end-Permian impact event is not relevant to the age of the planet or the moon. Does this have any implications for our thinking about circadian rhythm disorders? While we have no real clues to the mechanism by which they produce depressed mood, it is not hard to conceive an adaptive advantage for the mammalian survivors of the end-Permian disaster who did not venture out much by day, and so avoided the swift, active, and well-armed predators (including birds) that dominated the days during the Mesozoic [19,20].

Conclusion

The anomalous dys-synchrony of the solar day and the mammalian (human) circadian cycle is thought to be contributory to seasonal affective disorder and sleep phase advance disorder. It may be explained by meteorite impact, possibly at the end of the Permian era.

Key Points

Mammalian intrinsic circadian cycle is 25hr, about 1hr > duration of solar day. The earliest mammalian ancestors date to the Permian era. Several orders of insects also first known from the Permian have modern descendants with a 25 hour circadian rhythm. Birds and at least two orders of insects that also originated in the Mesozoic have modern descendants that have a circadian rhythm of about 23 hours. It is possible this reflects the true duration of the solar day- 25hr in duration? The circadian cycle may be in a sense, a behavioral fossil. The impacts associated with the end of the Cretaceous era are thought to have been insufficiently energetic to account for a 1h change in the duration of the solar day.

References

1. Fuller PM, Gooley JJ, Saper CB. Neurobiology of the sleep-wake cycle: sleep architecture, circadian regulation, and regulatory feedback. Journal of Biological Rhythms. 2006;21(6):482-93.
2. Rosenthal NE, Sack DA, Gillin JC, Lewy AJ, Goodwin FK, Davenport Y, et al. Seasonal affective disorder A description of the syndrome and preliminary findings with light therapy. Arch Gen Psychiatry. 1984;41(1):72-80.
3. Czeisler CA, Kronauer RE, Allan JS, Duffy JF, Jewett ME, Brown EN, et al. Bright light induction of strong (type 0) resetting of the human circadian pacemaker. Science. 1989;244(4910):1328-33.
4. Sack RL, Brandes RW, Kendall AR, Lewy AJ. Entrainment of free-running circadian rhythms by melatonin in blind people. N Engl J Med. 2000;343:1070-7.
5. Czeisler CA, Gooley JJ. Sleep and circadian rhythms in humans. Cold Spring Harbor Symposia on Quantitative Biology. 2007;72(1):579-97.
6. Masuda K, Zhdanova IV. Intrinsic activity rhythms in Macaccamulatta: their entrainment to light and melatonin. J Biol Rhythms. 2010;25(5):361-71.
7. Edgar DM, Martin CE, Dement WC. Activity feedback to the mammalian circadian pacemaker: influence on observed measures of rhythm period length. J Biol Rhythms. 1991;6(3):185-99.
8. Kasal CA, Menaker M, Perez-Polo JR. Circadian clock in culture: N-acetyltransferase activity of chick pineal glands oscillates in vitro. Science. 1979;203(4381):656-8.
9. Gaston S, Menaker M. Pineal function: the biological clock in the sparrow?. Science. 1968;160(3832):1125-7.
10. Aschoff JURGEN. Circadian rhythms in birds. In Proceedings of XIV International Ornithological Conference. 1967;85-105.
11. Gwinner E, Brandstätter R. Complex bird clocks. Philosophical Transactions of the Royal Society of London. Series B. 2001;356(1415):1801-10.
12. McDaniel WW. Epoch-ending meteorite impacts may explain mis-match between solar day and human circadian day. Int J Curr Res.
13. Alvarez LW, Alvarez W, Asaro F, Michel HV. Extraterrestrial cause of the Cretaceous-Tertiary extinction. Science. 1980;208(4448):1095-108.
14. Chatterjee S, Guven N, Yoshinobu A, Donofrio R. Shiva structure: a possible KT boundary impact crater on the western shelf of India. Museum of Texas Tech University. 2006.
15. Durand-Manterola HJ, Cordero-Tercero G. Assessments of the energy, mass and size if the Chicxulub impactor. 2014.
16. Kemp TS. The origin and early radiation of the therapsid mammal-like reptiles: a palaeobiological hypothesis. J Evol Biol. 2006;19(4):1231-47.
17. Von Frese RRB, Potts LF, Wells SB, Leftwich TE, Kim HR, Kim JW, et al. GRACE gravity evidence for an impact basin in Wilkes Land, Antarctica. G^3 Geochemistry, Geophysics, Geosystems. 2009;10(2):1-26.
18. Becker L, Poreda RJ, Vasu AR, Pope KO, Harrison TM, Nicholson C, et al. Bedout: a possible end-Permian impact crater offshore of northwestern Australia. Science. 2004;304(5676):1469-76.
19. Kielan-Jaworowska Z, Cifelli RL, Luo ZX. Mammals from the age of dinosaurs: origins, evolution, and structure. 2005;700.
20. Olson EC. Community evolution and the origin of mammals. Ecology. 1966;47(2):291-302.
21. Settembrini BP. Circadian rhythms of locomotor activity in Triatoma infestans (Hemiptera: Reduviidae). Journal of Medical Entomology. 1984;21(2):204-12.
22. Duelli P. Preovipository migration flights in the green lacewing, Chrysopacarnea (Planipennia, Chrysopidae). Behavioral Ecology and Sociobiology. 1980;7(3):239-46.
23. Kral K, Stelzl M. Daily visual sensitivity pattern in the green lacewing Chrysoperlacarnea (Neuroptera: Chrysopidae). Eur J Entomol. 1998;95(3):327-33.
24. Tomioka K, Chiba Y. Post-embryonic development of circadian rhythm in the cricket, Gryllusbimaculatus: a rhythm reversal. Journal of comparative physiology. 1982;147(3):299-304.
25. Alpatov AM, Zotov VA, Tshernyshev WB, Rietveld WJ. Endogenous circadian rhythm is a crucial tool for survival of the sand-desert tenebrionid beetle TrigonoscelisgigasReitter. Biological Rhythm Research. 1999;30(1):104-9.
26. Helfrich-förster C, Stengl M, Homberg U. Organization of the circadian system in insects. Chronobiol Int. 1998;15(6):567-94.
27. Sharma BK. Basic mechanics of planet-satellite interaction with special reference to the Earth-Moon system. 2008.
28. Chipman AD, Ferrier DE, Brena C, Qu J, Hughes DS, Schröder R, et al. The first myriapod genome sequence reveals conservative arthropod gene content and genome organisation in the centipede Strigamiamaritima. PLoS Biol. 2014;12(11):e1002005.