MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Department of Brain and Cognitive Sciences

Spring Term 2013

9.68 – Affect …

TIMESCALES[1]

"Very deep is the well of the past. Should we not call it bottomless?
"Bottomless indeed, if—and perhaps only if—the past we mean is the past merely of the life of mankind, that riddling essence of which our own normally unsatisfied and quite abnormally wretched existences form a part; whose mystery, of course, includes our own and is the alpha and omega of all our questions, lending burning immediacy to all we say, and significance to all our striving. For the deeper we sound, the further down into the lower world of the past we probe and press, the more do we find that the earliest foundations of humanity, its history and culture, reveal themselves unfathomable. No matter to what hazardous lengths we let out our line they still withdraw again, and further, into the depths. Again and further are the right words, for the unresearchable plays a kind of mocking game with our researching ardours; it offers apparent holds and goals, behind which, when we have gained them, new reaches of the past still open out—as happens to the coastwise voyager, who finds no end to his journey, for behind each headland of clayey dune he conquers, fresh headlands and new distances lure him on." [2]

And even after we have plumbed the depths of the past as far down as the advent of the hominoids and hominids who were the immediate predecessors of *Homo Sapiens*, many billions of years of still more primordial unplumbed pastness still extend into the depths of what Shakespeare once aptly described as the deep and "dark backward and abysm of time."

Was there a beginning of time?
Will there be an end?
Is the universe infinite?
Does spacetime have boundaries?
Is the present event horizon unique or merely one in an infinitely long series of expansions and contractions?
What do you think?

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[1] Originally prepared for use in 9.68 in conjunction with MFA fieldtrip. Adapted from Chorover, S. L., HomeWork: A Primer of Environmental Literacy, WORKBOOK, 1995.

[2] Excerpted from Mann, T. (1934). Prelude: Descent into Hell; p.3 *Joseph and His Brothers*. Part One: The Tales of Jacob. (Trans. by H. T. Lowe-Porter). p. 3. The entire prelude is quite simply amazing. In it, Mann takes some 30 densely packed pages to recount the multifarious ambiguities inherent in our best intended efforts to come cognitively to grips with the vastness of the sweep of historical (and prehistoric) time.

In his engaging 1988 book, *A Brief History of Time: From the Big Bang to Black Holes*.[3] Stephen W. Hawking addresses questions like these and discusses the puzzles, problems and paradoxes of cosmology.

Beginning with Galileo and Newton, he reviews, down to the present, the scientific quest for a "complete theory understandable in broad principle by everyone, not just a few scientists." If we find it, he says, "-it would be the ultimate triumph of human reason—for then we would know the mind of God."[4]

According to what contemporary cosmologists commonly call "the standard view" (that is to say, according to the view prevailing among themselves) all there is, was, and will be in the present event horizon originated some 13,500,000,000 (13.5 billion or 13.5 x 10^9) years before the present. For most of us, this is such a humungous extent of time that we find it quite simply impossible to come cognitively to grips with it.

One reason for this inability (perhaps the main reason) is that we are accustomed to timing the significant events in our lives in years, days and minutes (or less), while reckoning human generations in decades, family genealogies in centuries, and measuring all of recorded history in mere millennia, and all of human biological, psychological and sociocultural evolution in less than a few millions of years. Thus there come to exist, as Mann goes on to say,

> " provisional origins, which practically and in fact form the first beginnings of the particular tradition held by a given community, folk or communion of faith; and memory, though sufficiently instructed that the depths have not actually been plumbed, yet nationally may find reassurance in some primitive point of time and, personally and historically speaking, come to rest there." [5]

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Let us therefore begin by assuming, with the community of contemporary cosmologists, that it actually has been some 13.5 billion years (more or less) since the universe began. [6]

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[3] New York, Bantam Books. 198 pp.

[4] Science and religion – so often and strongly opposed – are here revealed to share the idea that personal beliefs and convictions regarding the nature of the world and its contents (including ourselves and each other) deserve to be taken seriously.

[5] Excerpted from Mann, T. (1934). Prelude: Descent into Hell; p.3 *Joseph and His Brothers*. Part One: The Tales of Jacob. (Trans. by H. T. Lowe-Porter). p. 3.

[6] The actual time continues to be a matter of dispute, but – in terms of "the standard view" --we are here very much "in the ballpark." One variant of this theory holds that the myriad galaxies and clusters of galaxies that condensed out of the initial hydrogen explosion constitute an ever-expanding astronomical universe whose constituents will continue to fly apart forever. Another has it that the expansion will be followed by a contraction which will either end in a vast collision or then give rise to yet another expansion with galaxies then condensing anew while flying outward in all directions. According to this latter view, this cosmogonic oscillation of expansion and contraction (diastole and systole; inhalation and exhalation) has been eternally repeating itself and will forever continue to do so, in a never-ending series of cycles having a period of some 60 billion years. An alternative view holds that the universe is a steady state system within which there is constantly occurring a continuous creation of hydrogen atoms out of which new galaxies are condensing as the old, continuing to fly apart, pass out of the range of astronomical observation.

But so soon as we proceed in this way, the question that next immediately comes to mind as to how an enormity of such spatiotemporally vast cosmic magnitudes can be conceived in terms of a timescale or reference frame that has a place for humanity within it.

The only commonsensical and scientifically intelligible way to proceed under these circumstances is to find some more readily accessible, familiar, – more "homely" and "down to earth"-- system of measurement to serve as a standard and basis of comparison. Can we find a timescale whose span and units of measurement are familiar ones? (Notice this inescapable use of spatial metaphors in our temporal vocabulary.)

Nigel Calder exploits some neat ones in his *Timescale: An Atlas Of The Fourth Dimension*. [7] He uses the spiral below to give us a sense of the extreme disproportions of scale that boggle our minds when we try to reckon in terms of cosmic or geological time, on the one hand, and our mundane sense of historical or personal time, on the other.

In his book, as in the relatively contemporaneous spatial scaling work of Morrison, et al. (1982)[8] an exponential system of notation involving "powers of ten" provides a systematic and straightforward way of reconciling remote and recent periods.

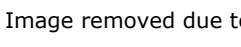
Figure removed due to copyright restrictions.

[7] (1983). New York, Viking Press. 288 pp.

[8] Philip and Phyllis Morrison and the office of Charles and Rae Eames: *Powers of Ten: The Relative Size of Things in the Universe and the Effect of Adding Another Zero*, New York, Scientific American Library, Freeman, 1983.

Calder also gives us what I find to be an even simpler and more down-to-earth, way of making sense of the ultimately incomprehensible enormity of the expanse of time in question: He invites us to liken it to the time and distance involved in walking the length of a familiar landmark. Presuming that most people are at least somewhat familiar with the urban geography of New York City (my home town), Calder invites us to think of the history of the development of the universe as a duration equal to the length of Manhattan Island. Calder then takes us on an imaginary (virtual) walk along the full length of Broadway, from Columbia University's Baker Field on the northern tip of Manhattan, to the end of Battery Park, at the extreme south (see **Figure below**). That's about 20 kilometers. Walking at an average speed of, say, 3km/hr, we might expect to complete the actual journey in around 6.6 hrs.

Following Calder, and assuming for this purpose that the lifetime of the universe is 15 billion years, let's set the moment at which we imagine ourselves setting off to correspond to the instant of the "big bang" and thus begin walking (virtually) southward.



With each 1-meter-long step we traverse some 750,000 years of cosmic history.
Years thus speed by us in their tens of millions every minute; thousands of millions every hour; the universe expanding at putative lightspeed (or maybe even faster).
Yet this enormous duration of time -- as we are moving through it seems to be passing exceedingly slowly. We have to keep walking for more than four hours, before we arrive at mid-town—around Broadway and 42nd Street—Times Square.
We have covered some 10 billion years and are more than two thirds of the distance to our destination.
But what will become our solar system has yet to come into existence!
By the time we have reached 34th Street, some 4.5 billion years ago, the solar system is beginning to form..
The Earth's oldest rocks (and perhaps also the first intimations of life) are beginning to show up .
When we arrive at 23rd Street, we are well into the Precambrian Era. Ice ages are coming and going.
We pass the World Trade Center site a block west.. The pace of evolution and change around us appears to be accelerating.
When we reach the entrance to Battery park, a mere half kilometer from Manhattan Island's southern tip, the supercontinent Pangaea has begun to assemble itself.
Just a few paces further on, it is beginning to break up again.
As we cross most of Battery Park, the dinosaurs are in their heyday. When their mass extinction occurs, some 65 million years ago, we are only a hundred paces from the island's tip!
The earliest humans have not yet arrived.
We are just five steps from the water's edge and our species: Homo sapiens have not (yet) come into existence.
We are latecomers...
The whole of human history during the present so-called common era (i.e., since the time of Christ) corresponds to the outermost three millimeters of the sea wall.
A human generation (30 years) is less than the thickness of a coat of paint on the railing.
And the length of an average human life is not much more or less than the thickness of a human hair.

Image removed due to copyright restrictions.

The Cosmic Calendar:
Carl Sagan, the late noted astronomer and popularizer of science offers in his 1977 book *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*,[9] another useful reckoning device.

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[9] New York, Random House, 263 pp.

Sagan invites us to imagine the 15 billion-year-long lifetime of the universe as if the whole process was compressed into the duration of a single calendar year.

By this way of reckoning, every billion (10^9) years of actual cosmic history corresponds to about 23.5 days of the "calendar year," while one day of the latter equals 41 million (41×10^6) years of cosmic history; by extension, each hour of "cosmic clock-time," equals 1.71 million (1.71×10^6) years of cosmic history; each minute equals 28.5 thousand years; and each second equals 500 years.

Sagan's Cosmic Calendar
Counting down to New Year's Eve

cosmic calendar/clock time				actual years before present		
January 1	=	365 "days"	=	15,000,000,000	=	15×10^9
December 1	=	1 "month"	=	1,200,000,000	=	1.2×10^9
December 7	=	23.5 "days"	=	1,000,000,000	=	10^9
December 24	=	1 "week"	=	217,000,000	=	217×10^6
December 31	=	1 "day"	=	41,000,000	=	41×10^6
23:00:00	=	1 "hour"	=	1,710,000	=	1.71×10^6
23:25:00	=	35 "minutes"	=	1,000,000	=	10^6
23:59:00	=	1 "minute"	=	30,000	=	30×10^3
23:59:30	=	30 "seconds"	=	15,000	=	15×10^3
23:59:50	=	10 "seconds"	=	5,000	=	5×10^3
23:59:51	=	9 "seconds"	=	4,500	=	4.5×10^3
23:59:52	=	8 "seconds"	=	4,000	=	4×10^3
23:59:53	=	7 "seconds"	=	3,500	=	3.5×10^3
23:59:54	=	6 "seconds"	=	3,000	=	3×10^3
23:59:55	=	5 "seconds"	=	2,500	=	2.5×10^3
23:59:56	=	4 "seconds"	=	2,000	=	2×10^3
23:59:57	=	3 "seconds"	=	1,500	=	1.5×10^3
23:59:58	=	2 "seconds"	=	1,000	=	10^3
23:59:59	=	1 "second"	=	500	=	5×10^2

The following **TIMELINE** -- adapted from Chorover, S. L., HomeWork: A Primer of Environmental Literacy, WORKBOOK, 1995. elaborates on this scheme in an extremely limited way.

Months, Weeks and Days of the Cosmic Year

- January 1: 15 byr. ago: Big Bang...
- May 1: 10 byr. ago: Origin of the Milky Way galaxy...
- July 25: 6.7 byr. ago: The expanding universe reaches 1/4 of its present size...
- September 11: 4.6 byr. ago: Origin of our Solar System...
- September 14: 4.4 byr. ago: Precambrian/Hadean era: formation of the Earth.
- September 20: 4.2 byr. ago: The expanding universe reaches about 1/2 of its present size...
- September 25: 4.0 byr. ago: Origin of life on Earth...
- September 30: 3.8 byr.ago: Precambrian/Archaean era; formation of oldest known rocks on Earth; photosynthesis in bacteria...
- October 30: 3.7 byr. ago: Oldest known fossils (bacteria & stromatolites)
- November 1: 2.5 byr. ago: Precambrian/Early Proterozoic Era: origin of sex (in microorganisms)...
- November 6: 2.3 byr. ago: Supercontinent Pangaea build-up...
- November 13: 2.0 byr. ago: Oldest fossil photosynthetic plants...
- November 20: 1.7 byr. ago: Eukaryotes (first nucleated cells) flourish...
- November 23: 1.6 byr. ago: Precambrian/Middle Proterozoic Era: blue-green algae (cyanobacteria) flourish...
- November 30: 1.3 byr. ago: Fungi; proto-animals; seaweed...
- December 2: 1.2 byr. ago: Development of significant oxygen atmosphere on Earth.
- December 10: 900 myr. ago: Precambrian/Late Proterozoic Era.
- December 13: 770 myr. ago: Ice age.
- December 17: 620 myr. ago: First worms.
- December 18: 57 myr.ago: Precambrian/Proterozoic Eras end; Phanerozoic ("visible life") Era begins with Paleozoic("old-life") Era; Early Cambrian Period; invertebrates flourish; "Gondwanaland" supercontinent.
- December 19: 540 myr. ago: Middle-Late Cambrian Periods; first oceanic plankton; trilobites flourish.
- December 20: 520 myr. ago: Ordovician Period; first fishes; first vertebrates.
- December 21: 435 myr. ago: Silurian Period.
- December 22: 410 myr. ago: Early Devonian Period; first insects; first land animals.
- December 23: 365 myr. ago: Late Devonian Period: first amphibians; first winged insects.
- December 24: 330 myr. ago: Carboniferous Period: first trees; first reptiles.
- December 25: 290 myr. ago: Permian Period: first dinosaurs.
- December 26: 245 myr. ago: Permian Terminal Catastrophe; end of Paleozoic, beginning of Mesozoic ("middle-life") Era; Triassic Period.
- December 27: 205 myr. ago: Early Jurassic Period: "Pangaea" supercontinent; first mammals. dinosaurs flourish
- December 28: 160 myr. ago: Late Jurassic Period: first birds.
- December 29: 120 myr. ago: End of Jurassic Period; beginning of Cretaceous Period; first flowering plants.
- December 30: 80 myr. ago: Cretaceous Terminal Catastrophe; end of Cretaceous Period; dinosaurs extinct; end of Mesozoic Era; beginning of Cenozoic ("new life") Era and Tertiary Period: first cetaceans; first primates.
- December 31: 41 myr. ago: New Year's Eve

THE LAST DAY:

hrs:mins:secs ("cosmic clock time")

- 13 : 00 : 00 40 myr. ago: Paleocene/Eocene Periods: Early evolution of frontal lobes in brains of primates; first hominoids; whales...
- 15 : 00 : 00 15.4 myr. ago: Origin of *Proconsul* and *Ramapithecus*;probable ancestors of apes and humans
- 20 : 30 : 00 6.0 myr. ago: Dogs...
- 21 : 10 : 00 5.0 myr. ago: Himalayan uplift; apes and apemen split...
- 22 : 10 : 00 3.25 myr. ago: End of Pliocene Period; beginning of Quaternary (Early/Late Pleistocene; Holocene)
- 22 : 30 : 00 2.4 myr. ago: First humans (*Homo Habilis*); earliest stone tools; early Paleolithic Period
- 22 : 40 : 00 1.8 myr. ago: Big cats; bison; sheep; wild hogs...

The Eleventh Hour (pp. 75-141)[10]

We are already into the last hour of the cosmic year and, almost at once are reckoning its last moments. We have stopped counting down in terms of the cosmic calendar, and begun reckoning in sidereal years. We are about to begin figuring also in terms of human generations (1 generation = 30 years)

- 23 : 00 : 00 1.7 myr. ago: Second humans (*Homo Erectus*) extensive use of stone tools...
- 23 : 04 : 00 1.6 myr. ago: *Homo Habilis* extinct...
- 23 : 37 : 00 650,000 yr. (21,667 generations) ago): Third humans: Homo Sapiens)
- 23 : 46 : 00 400,000 yr. (13,333 generations) ago: Domestication of fire

Ten Minutes ago

- 23 : 50 : 00 300,000 yr. (10,000 generations) ago: An estimated one million hunter-gatherers are living in scattered groups throughout tropical and subtropical Africa. The human population is growing exponentially at a rate of about 0.0002% per year.
- 23 : 56 : 00 114,000 yr. (3,800 generations) ago: Beginning of most recent glacial period...

One minute ago

- 23 : 59 : 00 26,500 yr. (883 generations) ago: Extensive cave painting in Europe. Peopling of the Western Hemisphere...
- 23 : 59 : 22 18,000 yr. (600 generations) ago: Most recent ice maximum; cultivation of crops; herding of animals...
- 23 : 59 : 33 13,000 yr. (433 generations) ago: Pottery...
- 23 : 59 : 36 11,000 yr. (367 generations) ago: Neolithic civilizations; dogs, sheep, and goats tamed; accountancy; bureaucracy, wheat grown; first towns...
- 23 : 59 : 38 10,000 yr. (333 generations) ago: The rate of human population increase has grown to about 0.06%...
- 23 : 59 : 45 7,000 yr. (233 generations) ago: First cities in Mesopotamia and Sumer; Egyptian calendar...
- 23 : 59 : 47 6,000 yr. (200 generations) ago: End of Paleolithic Period along the Mediterranean coastline. Sumerians settle the site of Babylon. Invention of the alphabet and the wheel; Akkadian Empire; copper and silver metallurgy...
- 23 : 59 : 48 5,750 yr. (192 generations) ago: First year of Jewish calendar is 5,760 yr. ago, or 3,760 yr. before beginning of present (Common) era (hereafter B.C.E.)
- 23 : 59 : 49 5,300 yr. (177 generations) ago: Height of Sumerian civilization; temple compounds at Ur (Chaldea) and Uruk (Erech); Neolithic period begins in Europe; earliest known use

[10] Page numbers refer to chapters of the source text.

of numerals in Egypt; first date in Mayan chronology is 3,372 yr. B.C.E.; use of potter's wheel in Mesopotamia; First and Second Dynasties in Egypt; agriculture and animal husbandry widespread in Egypt and Mesopotamia...

Ten Seconds ago

• 23 : 59 : 50 5,000 yr. (167 generations) ago: Semitic tribes occupy northern parts of Sumer and Akkad; Phoenicians settle at Tyre and Sidon on Mediterranean coast of Syria; first known systematic astronomical observations in Egypt Babylo-nia, Mexico, India and China; Neolithic settlements in Crete; Old Kingdom in Egypt (period of 3rd to 6th Dynasties = 2,815-2,294 yr. B.C.E.; Abraham leaves Ur in Chaldea around 2,100 yr. B.C.E.

• 23 : 59 : 52 4,000 yr. (133 generations) ago: Hammurabic legal codes in Babylonia; Middle Kingdom in Egypt; Egyptian *Book of the Dead*; *Edwin Smith Medical Papyrus* describes Egyptian medical and surgical procedures...

• 23 : 59 : 53 3,500 yr. (117 generations) ago: bronze metallurgy; Mycenean culture; Trojan War...

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Six Seconds to Midnight (pp. 142-235)

• 23 : 59 : 54 3,000 yr. (100 generations) ago: iron metallurgy; First Assyrian empire; Kingdom of Israel; founding of Carthage by Phoenicians; *Iliad* and *Odyssey*—epics ascribed to Homer; Hesiod's *Theogony* and *Works and Days*; Sappho of Lesbos...

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Five Seconds ago

• 23 : 59 : 55 2,500 yr. (83 generations) ago: Asokan civilization in India; Ch'in Dynasty in China; Thales of Miletus; Heraclitus; Anaxagoras; Pythagoras; Empedocles; Zeno; Protagoras; Euripides; Aeschylus; Sophocles; Periclean Athens; birth of Buddha; Herodotus; Alcmaeon of Croton; Hippocratic medicine; Socratic natural philosophy; Aristophanes; Platonic dialogues; Euclidean geometry; Archimedean physics

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Four seconds ago -- Entering the Common Era (pp. 236-320)

• 23 : 59 : 56 2,000 yr. (67 generations) ago: Beginning of the present (Common or Christian) era; Ptolemaic astronomy; Roman Empire; birth of Christ; Ovid; Galen...

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Three Seconds ago

• 23 : 59 : 57 1,500 yr. (50 generations) ago: Indian arithmeticians invent zero and decimals; Rome falls; rise of Islam; Arab culture flourishes; Moslem conquests...

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Two Seconds ago

• 23 : 59 : 58 1,000 yr. (33 generations) ago: Mayan civilization; Sung Dynasty in hina; Byzantine empire; Mongol invasion; anti-Muslim Christian crusades; European Middle Ages

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One second ago --

• 23 : 59 : 59 **The Fifteenth Century (1401-1500)** (pp. 321-380)

600 yr. (Approximately 20 generations) ago: (Beginning of the last second of the cosmic year)

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The Sixteenth Century (1501-1600) (pp. 381-481)

- Approximately 17-14 generations ago: Beginning of "modern times"; Renaissance in Europe; voyages of discovery and conquest from Europe and from Ming Dynasty China; emergence of the modern scientific method; Galileo; Descartes; Newton; Leibniz...

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The Seventeenth Century (1601-1700) (pp. 482-619)

- Approximately 13-11 generations ago: Widespread development of modern science and technology; Emergence of modern medicine...

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The Eighteenth Century (1701-1800) (pp. 620-743)

- Approximately 10-7 generations ago: American and French Revolutions; Extensive colonization of Western Hemisphere

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The Nineteenth Century (1801-1900) (pp. 744-954)

- Approximately 6-4 generations ago: Development and exploitation of electricity, U.S. Civil War; the Industrial Revolution...

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1901-1940 (pp. 955-1092)

- Approximately 4-3 generations ago: First World War; Russian Revolution; World-wide economic collapse; Rise of fascism and nazism in Italy, Spain and Germany; Outbreak of Second World War...

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1941-1960 (pp. 1093-1187)

- Approximately 3-2 generations ago: Nazi holocaust; unleashing of atomic power; electronics; television; emergence of global culture; founding of United Nations; initiation and intensification of US / USSR "cold war;" advent of the "green revolution;" Korean War; escalating nuclear arms and space races

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1961-1970 (pp. 1188-1355)

- Approximately 2-1 generation ago: "Silent Spring" triggers growing concern about pesticides in the human food chain; astronauts and cosmonauts in space; emergence of "counter culture;" U.S. War in Vietnam; rise of civil rights and anti-war movements in U.S....

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1971-1975 (pp. 1356-1478)

- One generation ago: First "Earth Day;" emergence of the environmental movement

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1976-1980 (pp. 1479-1618)

- Toxic nightmare at Love Canal; advent of personal computers; Nuclear power plant disaster at Three-Mile Island

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1981-1985 (pp. 1619-1756)

- World's worst modern agricultural chemical catastrophe occurs at Bhopal, India; outbreak of the AIDS epidemic...

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1986 (pp. 1757-1824)

- Nuclear power plant disaster at Chernobyl...

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1987 (pp. 1825-1905))

- World Commission on Environment and Development issues its report: *Our Common Future*; Emergence of human genome project; increased discussion of "risks;" Montreal protocol on atmospheric release of CFCs arrived at amid growing concern about stratospheric ozone depletion...

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1988 (pp. 1906-1982)

- Record for warmest year is tied

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1989 (pp. 1983-2159)

- Massive oil spill in Alaska's Prince William sound; growing concerns about global climate change and stratospheric ozone depletion

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1990 (pp. 2160-2325)

- Persian Gulf War; Burning Kuwaiti oil fields; beginning of the "green decade"...

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1991 (pp. 2326-2327) HAPPY NEW YEAR

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1992 (pp. 2328-2329)

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1993 (pp. 2330-2331)

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1994 (pp. 2332-2333)

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1995 (pp. 2334-2335)

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1996 (pp. 2336-2337)

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1997 (pp. 2338-2339)

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1998 (pp. 2340-2341)

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1999 (pp. 2342-2343)

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2000 (pp. 2344-2345)

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As indicated above, the "present-day" end of the **homework TIMELINE** WAS COMPLETED IN 1995 substantively ends with entries for 1990As indicated above, it remains to be extended to the present.

9.68 Affect: Neurobiological, Psychological and Sociocultural Counterparts of "Feelings"
Spring 2013