

SECOND EDITION

BIOS: MEGAFAUNA

PART II OF THE BIOS TRILOGY



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INTRODUCTION

The owl spermatophore landed on a branch, and pinged the forest with sonar, searching for a female owl to impregnate. It detected what seemed to be a falling leaf. But actually a great fungus had deployed a glider, and the sperm sprayed its ink aerosol defense too late. The fungus attached, and without haste invaded its host with consuming hyphae.

Bios:Megafauna second edition starts where the predecessor game *Bios:Genesis* left off, with the invasion of the land about 450 million years ago. Starting as a phylum of either a plant¹, mollusk, insect, or vertebral skeletal type, from one to four players make a beachhead on one of the four drifting *cratons* in the Ordovician. From a founding *archetype* species, you will sire squawking, flapping, and paddling species, represented by different *shaped* figures. Shapes are important because, for instance, a flying shape can only be preyed upon by another flying shape. Disperse these *creeples* across the weedy, forested, swamp, and sea biomes of your craton, or even to *raft* to new cratons. Each shape is a *species*, and each species has its own *tableau*. *Mutation cards* and *organ cubes* in this tableau enable the creeples of that shape to win in *contests* with other *herbivores* or *carnivores*. At the end of each 5-turn era, you will be awarded *fossil tokens* as Victory Points based on where you rank in terms of living creeples populations. Your struggle for terrestrial dominance may eventually include *mutualism*, *emotions*, *tools*, and *language*, worth VPs at the game's end. Although these achievements elevated a certain mammal species to notoriety, in your game things may occur differently.²

THE BIOS TRILOGY

This edition of *Bios:Megafauna* is an evolutionary descendant of "*American Megafauna*" (see Wikipedia), but as a part of the Bios series of games it is linked to the game *Bios:Genesis*. It plays well independently but if you have both games you can start this game with the macroorganisms you created in a game of *Bios:Genesis* (see **C2**). A successor game, called *Bios:Origins* (which would be a descendant of "*Origins*"), is planned to cover the events of the Pleistocene epoch (Era IV) including the rise of ideas and technology.



Terms being defined are listed in **bold**, or *italicized* if defined elsewhere. Capitalized terms are defined in the glossary. Achterbahn game rules are in blue font.

- a. **Variants.** The tooth and claw game ignores rules in blue font. The Achterbahn game includes all rules. There is a *solo campaign game* for the Bios Trilogy (**C3**), a *Martian solitaire game* (**Part K**), and a *Venusian multiplayer variant* (**Part L**).
- b. **The Golden Rule.** If the text on a card contradicts these rules, the card has preference.
- c. **Colorblind Braille.** As an aid for colorblind players, the red organ icons have a small white dot to distinguish them, and the red emotion (anger) preview icon has angry eyes.

A. SEQUENCE OF PLAY (4 PHASES PER TURN)

A1. PHASE 1: EVENTS (PART D).

These phases are listed on your fossil cards.

- a.  **Reveal the next Event from the ET³ Event Deck.** For the first turn, skip all events (**C1p**). For the tooth & claw game, ignore all Events except for *mutagen* (**D7**), *radiation* (**D8**), and *crowd disease* (**D9**).
- b.  **Stable Biosphere.** Events are either **ET** (extraterrestrial)⁴ or **biosphere** (too hot, goldilocks, or too cold). The **stable biosphere icon** on the ET event card means that no biosphere event card is drawn for this turn.
- c. **Draw Biosphere.** Unless the biosphere is stable, draw 1 biosphere event card from the current biosphere deck (either too hot, goldilocks, or too cold, as indicated by the Atmosphere from last turn). Lay the 2 event cards side-by-side. If the biosphere deck runs out, reshuffle all 12 of its cards for a new deck.
- d. **Impacted Craton.** The *collision/drift-by* (**D3**), *latitudinal drift* (**D1**), and *crater* (**D2**) events only impact a single Craton, called the **impacted craton**. Each Craton

¹ PLANT-ANIMAL HYBRIDS. The players can start as plants? This seems a rather dull existence! But plants do not have to end up as statically rooted to the ground. Indeed, a plant able to detect and move into the sunlight has competitive advantages, as does one that supplements its diet with scavenging or herbivory. In nature, plants team up with certain jellyfish, molluscs, and flatworms to form green "plant-animals" able to move, defend, and find the sun.

² In any non-self running simulation, there must be Lamarckian appeals. Mike Wasson, Fat Messiah Games

³ ET stands for "extraterrestrial". Following the tradition of Bios:Genesis, extraterrestrial (ET) events are those that come from outside the biosphere of Earth. Stuck between a rock and a hard place, the biosphere is struck from above by comets, radiation, and space weather from the solar wind, and from below by volcanos and earthquakes, products of magma weather. Both the sun and earth have a magnetic dynamo, which influence each other by mechanisms not well understood.

⁴ ET EVENTS. In 1997, Henrik Svensmark and Eigil Fris-Christensen published "Variation of Cosmic Ray Flux and Global Cloud Coverage – a Missing Link in Solar–Climate Relationships". They present evidence that when Sol is inactive, the heliosphere shrinks and allows more galactic cosmic rays to penetrate the Earth's magnetic field. The secondary particles from the cosmic rays increase cloud formation. The latest sunspot cycle (Cycle 24) started in March of 2012 and peaked in April of 2014, and has been declining ever since. Thus ending the smallest sunspot cycle since Cycle 14, in February of 1906. A quiet Sol means more cosmic rays, clouds, and wet weather for the decade. Longer term climate changes are generated as Sol enters or leaves the galactic arms, since the galactic cosmic ray flux is higher within the arms.

has a unique icon. For the *collision/drift-by* event this is the Craton indicated by the icon on the ET Event card, but occurs only if this Craton contains a Latitude Dice. For *latitudinal drift* and *crater* events this is the Craton specified by the icon in the upper left corner of the turn's biosphere card. In the case of latitudinal drift, if the impacted craton has no Latitude Dice, the event is canceled.

- e. **Event Resolution Order.** Resolve each event row by row, beginning with the top row and reading left to right; resolving all ET card events before Biosphere card events. Resolve each Event per **D1-D14**.
- f. **End Of Era.** If the ET Event drawn is the 5th and last ET Event, set the era card to the next era, and reshuffle all 15 ET Event cards and place 5 of them facedown half on the era card. Remember to *award fossils (I4b)* at the end of the turn.
- g. **Reset Latitude.** If the Atmosphere changed, be sure to check and, if necessary, change the Latitude Strip to be correct for the current climate, see setup diagram **(C1)**.

A2. PHASE 2: ACTIONS (PART E), IN PLAYER ORDER (A5).

- a. **Action Maximum.** All players receive (tooth & claw game) 2 actions, or (Achterbahn game) a maximum number of actions indicated by the current Oxygen Level (from 1 to 4).
- b. **Green Exception.** In the Achterbahn game, Player Green gets a maximum number of actions as indicated by the current greenhouse level of the Atmosphere.
- c. **Action Sequence.** In *player order (A5)*, each player performs all his actions. The actions are:

- **E1 Mutate.** Select a Mutation from the Display and play it into the Tableau of one of your Species. The combined Costs of all the selections a Species makes cannot exceed the number of its Unborn.
- **E2 Promote.** Promote a Mutation (flip it, choose 1 of its orientations and gain its Plus Organs).
- **E3 Speciate.** This is a promote to a new Creeple Shape. This creates a new Genotype with *Inheritance (E3b)*. Replace one Creeple of the old Shape (mother) with a Creeple of the new Shape.
- **E4 Populate.** Move some of your Unborn Creeples to your Newborn Card. They will be dispersed in the next phase **(A3)**.
- **E5 Neoteny.** Discard up to 1 Basal Organ from each Genotype.
- **E6 Resize.** Resize each Genotype by up to 1 step.
- **E7 Resurrect.** If Lazarus, restore your Archetype.
- **E8 Claim Medea - Requires all your actions.** Take the Medea card.

- d. **After all your selections, refresh the Display per E1e.** It is suggested to perform all mutate actions before making other types of actions.

A3. PHASE 3: MOTHERS & DISPERSAL (PART F), IN PLAYER ORDER (A5).

- a. **Action Sequence.** In *player order (A5)*, each player chooses a *mother* for each Creeple on his Newborn Card **(E4)**, and then *disperses* it **(F2)**, until all his Newborns are dispersed. Then go to the next player.
- b. **Inhabiting A Biome.** Upon entering the Biome the Newborn is to inhabit, it immediately makes a *Trophic Choice (F6)*. If this choice is contested, then immediately perform an *herbivore contest (Part G)* or a *carnivore contest (Part H)* to determine the winner.

A4. PHASE 4: BURIALS & FOSSIL AWARDS (PART I).

- a. **Disperse Endotherms.** In *player order (A5)*, each player disperses all his endangered *endotherms* into uninhabited Trophic Levels and stands them upright per **I1**.
- b. **Bury Endangered.** Convert all Endangered Creeples into Unborn Creeples **(I2)**.
- c. **Fossil Awards or Final Scoring.** If you drew the last ET Event of the Era during phase 1, then *award fossils* per **I4b**. If it's the *final era (A6)*, instead conduct *final scoring* per **A7**.

A5. PLAYER ORDER.

In the upper middle of each ET event card is a row of three colored icons. The leftmost icon indicates the color of the **first player**, and then the second color in the row shows the second player, etc. If the first player is a color who is not in the game, the second color is the first player, etc. The first player is the first to perform his actions in phases **A2, A3, and A4a**. He is also the first to choose *Atrophies* or *deaths* in certain events **(D7g, D8d, D9)**.

A6. GAME LENGTH.

The game lasts 10 event cards, ending at the end of Era II (Mesozoic). The game can also end due to *runaway greenhouse* (D10h) or *language* (J6f). The game continues even if all players have become Lazarus. When the game ends, do *final scoring* (A7) to determine the winner.

- a. **Long Game.** The **Apocalyptic Chicxulub Game** continues into Era III (Cenozoic). However, the card “Chicxulub Class Comet” is shuffled into the ET event deck for Era III as one of the 5 cards. When this Event is drawn, the game ends suddenly at the end of the Event Phase. Therefore, this game is from 11 to 15 Events long. The long game can be flowed into a solo campaign game (C3) or a *Bios:Origins* game (Part N).

A7. FINAL SCORING.

In the final era, instead of the *Fossil Awards* (I4b) count victory points as follows:

- a. **Fossil Record.** 1 VP for each Fossil (cards or tokens with the fossil icon).
- b. **Population.** 1 VP for each Living Creeple of your color on the map.
- c. **Tableau.** 1 VP for each card in your Tableau with the Fossil icon (includes Tools, Medea, and Genotypes).
- d. **Mutualism.** 1 VP for each *Host Creeple* (J2) on your mutualism cards.
- e. **Emotions.** 1 VP for each Emotion, and 3 VP if you have *Language* (J6f).

The winner is the player with the most VP. If 2 or more players have an equal amount VP, they share the position they end up on.

A8. THE TOOTH & CLAW GAME.

I recommend that you play the **tooth & claw** game first, which ignores all game rules in blue font. This game is best for beginners, and is also preferred by competitive players who prefer pure infighting. The full game includes all the rules, and is known as the **Achterbahn⁵ game** because it adds the chaos of surviving in a roller-coaster climate engine. The tooth & claw game features the following:

- a. **The Creeples are always at size one**, so the *resize* action and the *size dice* are not used. Dispersal Points (DP) for a Species is therefore always one plus the number of blue organs.
- b. **Only the ET Event cards are used**, so the biosphere event cards are not used. On the ET cards, only the *mutagen*, *radiation*, and *crowd disease* events are used. If a mutagen event occurs, make a **mutagen roll** using a number of dice equal to 1 plus the Era number (C1m). Then remove all the dice except the highest face number. The highest number is the *dark heart limit* to the number of Organs, see D7b.
- c. **The climate is not tracked**, so the Reservoirs and Latitude Strips are not used. Each player gets two actions per turn.
- d. **The Cratons do not move**, so the *collision/drift-by*, *latitudinal drift*, and *rift* events on the ET cards are ignored, and *Latitude Dice* are not used.
- e. **No disks are needed**, since there are no mountains, ice, forests, or climate.
- f. **In Herbivore contests**, the *humidity niche* (G5) is always green (since the climate is permanently humid, see D5a).
- g. **Medea supervillain, Venom and Monsters** are not used.
- h. **Player Green** is treated as an ordinary Species.

⁵ ACHTERBAHN is German for “roller coaster”. Some biologists believe that species must struggle against extinction due to competition with other species, or even (the selfish gene model) individuals versus individuals. Others, such as the evolutionary biologist Olivia Judson, believe that the struggle against extinction is mainly a struggle against the “Achterbahn” of nature’s catastrophes. Dr. Judson has identified 5 stages of increasing biological control of free energy sources for survival. These stages are: geochemical energy (i.e. refugia in the Bios:Genesis game), solar energy (Genesis promoted mutations), oxygen (Genesis macroorganisms), flesh (Genesis/Megafauna Carnivory), and fire (Megafauna/Origins promoted mutations). The Achterbahn game envisions the development of a life-planet system as “the interplay between the planet’s cosmic situation, its intrinsic properties, and the paths evolving life can potentially take (in their) transformations of their planetary home.” Olivia Judson, 2017.

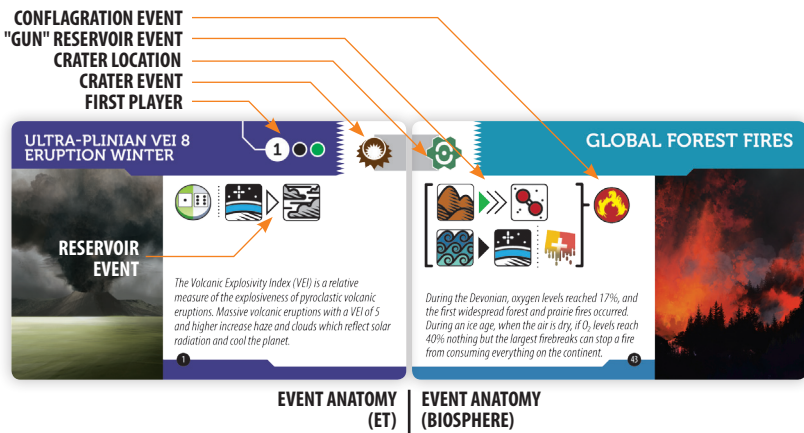
B. GAME COMPONENTS

B1. CARDS

- **92 Mutation cards.** (4 colors: nervous (red), circulatory (yellow), digestive (green), reproductive (blue)).

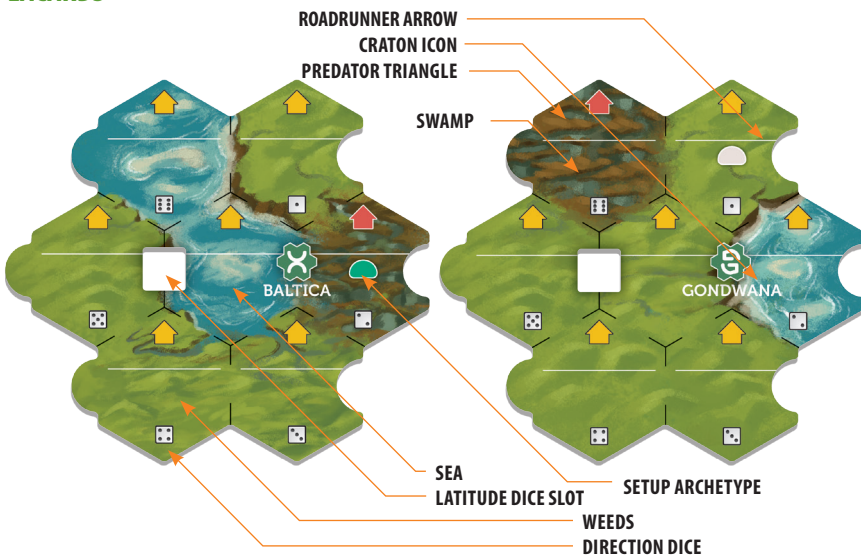


- **51 Event cards (ET, TOO HOT, TOO COLD, GOLDILOCKS)**

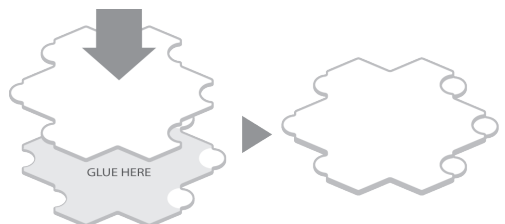


- 4 Archetype cards, 1 of each player color
- 4 Newborn Cards
- 4 tool cards
- 1 era card
- 1 Medea Card
- 3 Player Aid cards

B2. PLACARDS



- **4 Craton punchboards.** 8 Craton Placards. These are assembled to form 4 Cratons, with terrestrial on one side, and ET on the other. Each Craton has a unique icon.
- If you wish, they can be optionally glued into

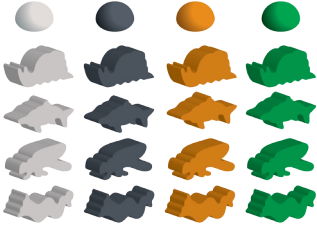


this configuration, with Earth on one side, and Mars or Venus on the other (it doesn't matter which Earth goes with which Mars/Venus Craton). If you do so YOU MUST GLUE THEM SO THAT THEY FORM 3 SHELVES, AS SHOWN IN THE DIAGRAM ABOVE. If you glue them correctly, each side will have 3 white shelves. If you glue them incorrectly, you will have to tear them apart.

- **1 Latitude Strip punchboard.** 3 Latitude Strips. Use for the 6 Greenhouse Levels.
- **1 Reservoir placard.** Use for the 3 Reservoirs.
- **16 Fossil Tokens.** (part of the Reservoir punchboards, 4 per punchboard).
- **16 Monster Tiles.** (part of the Reservoir punchboards, 4 per punchboard).



B3. WOODEN CREEPLES



- 28 Archetype: 7 green, 7 orange, 7 black, 7 white
- 28 Armored: 7 green, 7 orange, 7 black, 7 white
- 28 Swimmer: 7 green, 7 orange, 7 black, 7 white
- 28 Flyer: 7 green, 7 orange, 7 black, 7 white
- 28 Burrower: 7 green, 7 orange, 7 black, 7 white

B4. WOODEN CUBES

- **110 Organ cubes.** (25 each of yellow, red, green, blue; 10 of white)

B5. DISKS

- **12 black disks (climate disks that represent carbon cycle and mountains).**
- **12 white disks (climate disks that represent water cycle and ice).**
- **18 green transparent disks (climate disks that represent oxygen cycle, forests, and upwellings).**

B6. 6-SIDED DICE

- **24 dice:** 5 green, 5 orange, 5 black, 5 white, and 4 brown.

B7. COMPONENT LIMITS

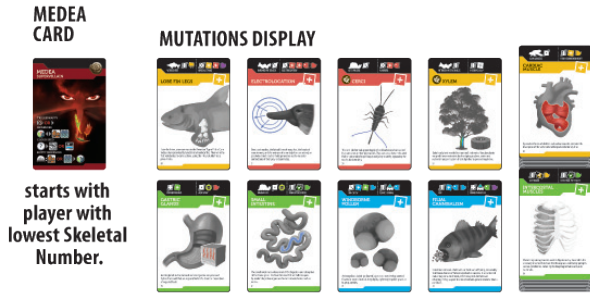
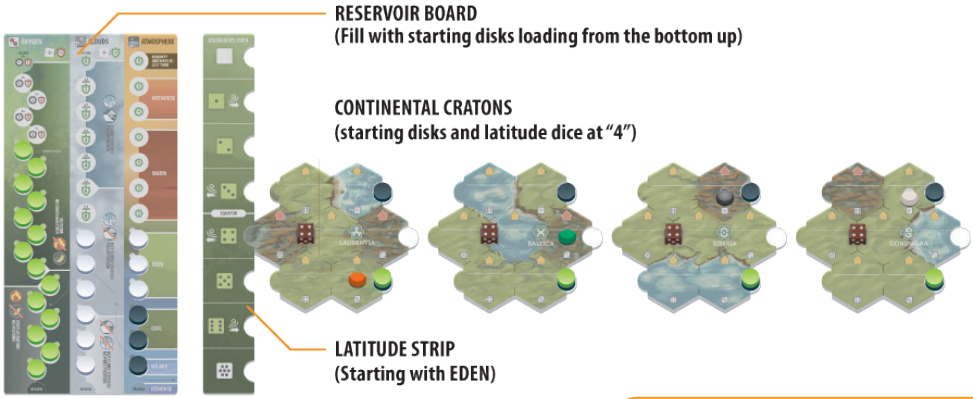
All components except for dice are limited to what is supplied.

- **Cube Genetic Drift.** If the pool has no more cubes of the color you need for a Mutation, promotion, you may take the required cubes from any other Species, including those of opponents. This simulates genetic drift. You must steal Plus Cubes if any are available anywhere, then monster tokens (with size reduction), then (as involuntary neoteny) Basal Cubes.
- **Disks.** The number of disks in the game is fixed, so they should not run out.

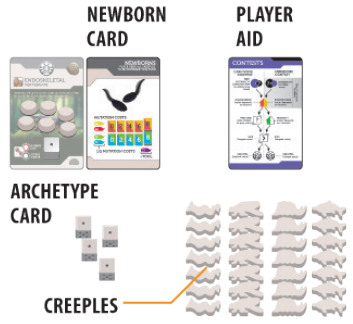
The board is divided into three vertical sections:

- OXYGEN:** Shows levels from 3% to 12%. Each level has a gear icon with a number and a red shield icon with a number. A '+2' icon is at the top. A 'NO DISK' icon is at the top left. A 'HUMAN HYPOXIA' label is between 8% and 9%. A 'MICROB NO CONFLAGRATIO' label is at the bottom.
- CLOUDS:** Shows levels from 0 to 8. Each level has a green shield icon with a number. A '+2' icon is at the top. A 'NO DISK' icon is at the top left. A 'CLOUD-COVERED PRECIPITATION' label is on the right side.
- ATMOSPHERE:** Shows levels from 3 to 5. Each level has a green gear icon with a number. A 'RUNAWAY GREENHOUSE: LAST TURN' label is at the top. A 'HOTHOUSE' label is between levels 4 and 5. A 'WARM' label is between levels 3 and 4.

C. SETUP



PLAYER SETUP



C1. SETUP

- a. **Tooth & Claw or Full?** Players decide if they wish to play the *tooth & claw* (A8) or the *Achterbahn* game. The rules in blue font are for the *Achterbahn* game only! If you choose *Tooth & Claw*, then you do not need disks, reservoirs, or biosphere cards, and need only 3 dice. If you want to play with experimental *apomorphies* (J8), decide this now.
- b. **Sort Cards.** Remove the 4 Archetype cards, 4 Newborn Cards, and the 1 Medea card, which are assigned in the next step. Remove the 4 tool cards and form a public deck. Remove the era card (it will be setup during C1m). Separate the remaining cards into 6 decks: yellow & red (Metabolic Mutations), green and blue (Darwin Mutations), ET Events, too hot events (reddish), goldilock events (green), and too cold events (blue). Unless playing the *Achterbahn* game, the last 3 decks are not used.
- c. **Player Color.** Each player is randomly assigned a color, and receives his color's 35 Creeples, 5 dice, Archetype card, and Newborn Card. Each player places his Archetype card on the table in front of him, with the continental icon (upper left corner) faceup. He places his 7 Archetype creeples (domes) on this card.
- d. **Medea.** The player with the lowest **Skeletal Number** (shown in upper center of the Archetype card) receives the Medea card.
- e. **Starting Size.** Each player places 1 dice of his color, set to 1 pip, in the square marked "size".
- f. **Craton Row.** For each player in the game, find his starting Craton placard. It has an icon of the starting Creeple in the player's color. Other Cratons will not be used. Set these placards in a row, with a space between. The order is random (if you wish to use the historical setup, it is left to right: Laurentia, Baltica, Siberia and Gondwana).
- g. **Achterbahn Cratons.** In the *Achterbahn* game, all 4 Cratons are used, even if some are unoccupied. Place a brown six-sided dice in the square in the center of each Craton with 4 pips faceup, indicating each Craton starts equatorial.
- h. **Offshore Disks.** For each of the 4 Cratons, place one adjacent black disk in the northernmost slot and another in the southernmost. These are on the east coast, see Diagram (C).⁶ These 8 disks are offshore carbon deposits. On top of each of the 4 southernmost black disks, place a green disk (this is called a **bloom** and indicates upwellings where plankton flourishes).
- i. **Continental Disks.** On Laurentia, Baltica, and Gondwana, place a white disk in the center hex. In Siberia, place a black disk there.
- j. **Latitude Strip:** Place the "GOLDILOCKS: EDEN" Latitude Strip faceup to the left of the map so that each Craton is in line with Latitude 4.⁷ Set aside the other 2 Latitude Strips for later.

⁶ THE WEST COAST is assumed to be a continental subduction zone, such that any carbon deposited there is "swept under the rug" as the oceanic plate is subducted by the continental plate. This is the situation in the west coast of Laurentia, now the west coast of North America. This is the oldest known landform on the planet, still recognizable from the beginning of this game to today.

⁷ GOLDILOCKS is taken from a British fairy tale about a hungry golden-haired girl who tries to eat the porridge she finds in a house where the occupants are gone. There are three bowls, and one is too hot, one is too cold, and one is "just right". Astronomy uses

k. Clouds, Oxygen, & Atmosphere. Starting in the bottommost spot, place one disk in each spot indicated by a **disk icon** for the 3 Reservoirs. On the Oxygen, place 14 green disks so that it reads 7% oxygen. On the Clouds, place 6 white disks so that it reads albedo = 0.4.⁸ On the Atmosphere, place 3 black disks then 3 white disks, so that it reads “Warm”.

Note: Load the atmosphere disks from the bottom empty spot on up, and it does not matter in what order the black and white disks are in. If say, a black disk is removed from the Atmosphere, it can be removed from any position, but the remaining disks slide downward to fill in the gap.

- l. Starting Creeple.** Each player places one of his Archetype Creeples (these are domes) as an Herbivore (i.e. below the predator triangle) into the map hex shown with his Archetype color.
- m. ET Event Deck.** Shuffle the ET Event cards and place 5 of the cards facedown to form the first era. Place the **era card** half underneath the ET Events so that the part saying “**ERA I PALEOZOIC**” is shown.
- n. Three Biosphere Decks.** Shuffle the too hot biosphere cards and form a facedown deck. Do the same with the goldilocks and too cold cards so that there are three biosphere decks in all.
- o. Draw Decks & Display.** Shuffle the metabolic Mutations (red and yellow cards) into a draw deck. From this deck deal 4 cards into the top Display row, with promoted side down. Do the same with the Darwinian Mutations (green and blue cards), in a bottom Display row just beneath the top Display row. The draw decks are placed just to the right of each row, see Diagram (C). The Display will now have 2 rows of 5 cards each, counting the card on top of the draw decks.
- p. Boring Ordovician.**⁹ Perform the first turn. The first event card has no effect other than determining the player order, so skip the first event phase and begin with the Action Phase per **A2**.

C2. SETUP (IF CONTINUING FROM BIOS: GENESIS)

If you ended a game of *Bios:Genesis* (that did not end in Armageddon) with a surviving Macroorganism, and continue to a game of *Bios: Megafauna*, you are assigned a color as follows (instead of **C1c**):

- a. Mosses, Mushrooms (plants & fungi):** Terrestrial Player Green (cytoskeletal); Dickinsonia, Seaweed: Marine Player Green.
- b. Snails, Earthworms (mollusks & annelids):** Terrestrial Player Orange (hydroskeletal); Lamp Shells, Flatworms: Marine Player Orange.
- c. Eurypterids, Insects (arthropods):** Terrestrial Player Black (exoskeletal); Trilobites, Arrow Worms: Marine Player Black.
- d. Amphibians (tetrapods):** Terrestrial Player White (endoskeletal); Sea Stars: Marine Player White.
- e. Velvet Worms:** Either Player Orange or Player Black (your choice); Marine if Opabinia.
- f. Terrestrial Macroorganisms** start with as many Basal Organs as Organ cubes on your Genesis Macroorganism. The Organs should match in color as well. For each Biont on your Genesis Macroorganism, including the Trophic Biont, deal one random unpromoted Mutation of the matching color into the Archetype’s tableau and place one Plus Cube on it. Your creature starts as an Archetype Creeple on your starting hex. Your Macroorganism card from Genesis counts as a fossil, so store it in your Fossil Record.
- g. Marine Macroorganisms** start with the marine side of the Archetype card faceup, and with no starting organs. The starting Creeple is a swimmer instead of an Archetype Creeple, and it starts in any sea hex of your choice. The first resize on this Species generates an Archetype *kiwi* (**E6b**).
- h. If two players** are qualified for the same player color, the player with the higher Genesis score chooses first, and the loser takes another color per **C2f** or **C2g** above.
- i. Organs** inherited from your Genesis Macroorganism may be converted into white Basal Organs. Every two organs of a single color may be converted into one white organ, limited to one conversion per color.
- j. Players without Macroorganisms** and players who did not play *Bios: Genesis* assign themselves Archetypes normally after players with surviving Macroorganisms. Macroorganisms. However, they can only select zero-cost cards for the first turn.
- k. Endosymbionts.** If your macroorganism had endosymbiont bionts owned by another player who is part of this Megafauna game, your starting Archetype or

the term “Goldilocks Zone” to signify the right distance from a star such that a planet orbiting there can support oceans and life.

⁸ ALBEDO is the ratio of visible light reflected from the surface to the incident radiation. Clouds are very reflective, making the Earth’s albedo quite sensitive to cloudiness. Ice and snow also drive the albedo towards a value of 1 (perfect reflector).

⁹ ORDOVICIAN. The game starts in the early Ordovician (500 Mya), after the coasts have been invaded by fungi and small plants, living off organic material washed ashore. The continental interiors are still barren, there are no vascular plants or trees, and the only animals are those who briefly come ashore to breed or lay eggs in a predator-free world.

swimmer is a mutualist host (**J2**). Give each endosymbiont player one of your starting Creeples to put on their starting Archetype card. Their starting Archetype card is also treated as a mutualism mutation for the purposes of the mutualism rules.

C3. SOLO CAMPAIGN

You can string your solitaire games together in an epic campaign, trying to stay alive from protolife to language-based consciousness (in *Bios: Origins*).

- a. Solo win.** If you win a solitaire game of *Bios: Genesis*, proceed in your setup using the rules **C2** and then use the solitaire rules (**Part K**) for Earth. If you won as a plant, then see **K0e**.
- b. Solo fail.** If you didn't win, start with just a base Archetype as if playing a regular game of Megafauna, but enact the Events of the Boring Ordovician instead of skipping them. This simulates the longer time for Macroorganisms to form due to your mismanagement. Will you be able to get them to thrive under this handicap?

D. EVENTS



During the *event phase* (**A1**), the Events are resolved in the order set by **A1e**.

D1. LATITUDINAL DRIFT (ET EVENT)



If the *impacted craton* (**A1d**) is a **landmass** (i.e. either a Craton or a Continent) with a Latitude Dice, the landmass moves either north or south by one or two Latitudes (single or double arrow icon). However, the Latitude Dice cannot be set any farther north than 1, or farther south than 6.

- a. Latitude Dice.** The face of the Latitude Dice of a Craton or Continent indicates its Latitude, from 1 to 6. Decrease the Latitude Dice if moving north or increase it if moving south.

D2. CRATER (ET EVENT)



If a **crater event** occurs, one of the Biomes in the *impacted craton* (**A1d**) will suffer a **crater**, indicated by Degassing a black disk. This is a Disk of Damocles. To determine the crater location, roll a single die. The biome displaying the number matching the die result is the target.¹⁰

D3. COLLISION OR DRIFT-BY (ET EVENT)¹¹



This Event moves a **landmass** (i.e. either a Craton or a Continent) to either the east or west as indicated, towards a neighboring landmass. This Event can have 3 outcomes: (1) the *impacted craton* (**A1d**) is not a Craton with a Latitude Dice, whereupon the Event does not occur, (2) the *impacted craton* has Biomes or adjoined Biomes that are in the same Latitude as another landmass, whereupon the two **collide** per the bullets below, or (3) the *impacted craton* has no Biomes or adjoined Biomes that are in the same Latitude as any other landmass. In this case, it will **drift-by**, swapping the positions of the moving landmass with one neighbor, so the one that was to the west is now to the east of the other.

- a. Colliding.** If there is a collision, line up the 2 landmasses correctly, then move the moving landmass in the direction indicated until one of its hexes touches a Coast hex in the same Latitude of the “smashed” landmass. Note that it may drift-by 1 or 2 Cratons to make this collision.
- b. Collisional Wrap-Around.** The world is spherical, so that the westernmost moving landmass drifting west may smash the east Coast of the easternmost landmass.
- c. Collisional Orogeny.** Degass a black “Disk of Damocles” to each Biome in the smashed landmass that is adjacent to a biome in the moving landmass. No mountains are formed in the moving landmass.
- d. Collisional Subducted Offshore Disks.** In a collision, the hemispherical shelves of

¹⁰ CRATERS in this game avoid the center of cratons. This is because volcanoes are almost always at the edges of cratons, and not the center. Although impact craters can occur anywhere, the craton coasts are susceptible to impact tsunamis.

¹¹ A CATAclysm that suddenly kills off all terrestrial life would release less than 1000 Gt of carbon into the atmosphere, from all the rotting logs and corpses. That is only 1.5 black disks in the game, and shows that biology takes a back seat to geology and tectonics for major carbon release episodes. Most carbon is stored in the ocean or crust, both represented by offshore black disks in this game. Black disks on continents represent mountains, which through their erosion move atmospheric carbon to the offshore as part of the carbon cycle. Non-volcanic mountains are a carbon sink rather than a carbon emitter.

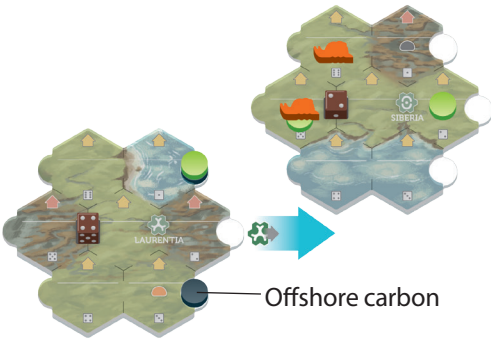
one landmass interlock with the half-moon bays of the other landmass. Any disks that were on these shelves are Liberated and any swimmers are killed to Unborn.

e. Loss Of Latitude Dice. The collision forms a **Continent** (two or more adjoining Cratons). The **Latitude Dice (D1a)** is lost by the smashed landmass and retained by the moving landmass.



LAURENTIA COLLISION / DRIFT-BY EAST

BEFORE:



AFTER :

- Pinched offshore carbon and plankton bloom are liberated in the collision.
- Creeples is endangered and forest liberated
- Siberia loses its latitude dice



- Orogeny. Mountains formed in the collision using black disks coming from the Atmosphere strip.

Example: During the C.A.M.P. Event, the Craton of Laurentia drifts east, towards Siberia (see left side of diagram below). Its center is at Latitude 4, and its northern coast (at Latitude 3) strikes the southern coast of Siberia (right side of diagram). As the smashed craton, Siberia loses its Latitude Dice. Two mountains are degassed in Siberia where they contacted the eastern shoreline of Laurentia. Two Offshore disks were subducted in the collision: a black disk Liberated into the Atmosphere, and a green disk Liberated into the Oxygen. The mountain formation Liberates a forest and Endangers a creeples.

D4. PANGEA RIFT (ET EVENT)



Any Continent that has 3 or more Cratons joined together is called **Pangea**. If a “Pangea Rift” Event occurs, Pangea breaks up so that each of its Cratons separate from each other. However, if its Latitude is less than 1 or greater than 6, its Latitude becomes 1 or 6 respectively. The Cratons end up in a left to right order preserving their relative positions before the break-up.

D5. CLIMAX (ET EVENT)¹²



Each climax icon has one, two, or three dice faces, representing the up to three individual Latitude(s) in which empty weeds become either forests or ice on all Biomes in all Cratons in this Latitude(s). Swamps, seas, and Offshores are not affected by this Event.

a. Forested Humid Latitudes.¹³ The current Latitude Strip has 8 dice icons, one for each Latitude. If the Latitude is a **green dice icon**, first Liberate all continental white disks in weed biomes. Then Degas a green disk on each weed hex (that has no disks). These disks, representing forests, do not disturb any Creeples present.

b. Arid Latitudes. If a Latitude is a **white dice icon**, first Liberate all continental green disks in weed biomes.¹⁴ Then Degas a white disk on each hex that has no disks (weeds, seas, swamps). These disks represent ice caps or deserts.¹⁵

¹² WEEDS represent low climax regimes, while forests are high climax. The term “climax” defines the maturity of a community, as a culmination of an ecological or evolutionary succession. After a major extinction event, such as the P-Tr events, the fossil record consists of astronomical numbers of just one or two “weedy” species. One such “disaster species” are quillworts, which look like small spiky grass with hollow leaves and roots. These weeds radiated from swamps to dominate floodplains and deserts. The oceans became paved with a single species of tiny scallop, *Claraia*, whose fossils form entire pavements in early Triassic rocks from Utah to China. A megafaunal weed is *Lystrosaurus*, an ugly hog-sized therapsid that monopolized herbivory worldwide. Such opportunistic disaster species dominate the first 15 million years of the early Triassic. In contrast, high climax regimes have high biodiversity. I live in a mixed evergreen/hardwood forest, with the former coming from the time of the dinosaurs and the latter from recent deciduous flowering species. Biodiversity is even more extreme in tropical rainforests. This is an artifact of global cooling: the Ice Age came so suddenly, that the entire world of tropical plants got jammed into the equator.


¹³ HUMIDITY. When the atmosphere becomes hotter, it can absorb more water. Conversely, during Ice Ages the chilled atmosphere can hold little water. Moreover, most of the Earth’s water is locked up in ice caps and glaciers, making Ice Ages bone dry.

¹⁴ DEFORESTATION represents replacing forests with grasslands. Grasses are weeds responding to today’s CO₂ famine. Today over 40% of the Earth’s vegetated land area, once covered with forests, have been replaced by this advanced wind-pollinated flower. Grass has evolved only recently, during the last 55 million years (so there were no grazing dinosaurs). Even more recently, 35 Mya, grasses have pioneered the C4 photosynthetic pathway, far more efficient than the C3 pathway used by 97% of plant species. This adaptation is in response to the dry climate and extremely low carbon dioxide levels of today’s Ice Age. Today’s air is so impoverished in CO₂ that C3 plants struggle to breathe, having been adapted to levels 15X higher throughout most of Earth’s history. This struggle can be seen from space; even the modest CO₂ increases of the last 50 years make the planet visibly greener. If CO₂ drops to 150 ppmv, as it almost did during the last deep freeze and may well do during the next one, C3 photosynthesis would shut down and 95% of the world’s biomass would quickly suffocate. But C4 grasses can survive down to 10 ppmv CO₂.

¹⁵ PLANT GROWTH CLIMAX is set both by climate and by consumers (including fire and megafauna). Consumer-driven vegetation has left much of the globe out of equilibrium with the climate. W.J. Bond, 2005.

Example: Siberia experiences a 1-6 climax during a Warm greenhouse. Siberia is far north, with a weed and a swamp biome at Latitude 0, one mountain, forest, and weed biome at Latitude 1, and two sea biomes at Latitude 2. Latitude one is green dice, so the one weeds in Latitude 1 becomes forested.

D6. DELUGE (ET EVENT)

- a.**  **Rising Sea Levels.** If a **deluge** occurs during too hot or goldilocks, Liberate all disks (black or green) on seas (but not Offshores).
- b. Falling Sea Levels.** If a deluge occurs during too cold, all seas (but not Offshores) become land, either forested or ice (because the oceans are being sequestered into icecaps). On each sea biome, first Liberate any disks present, and then Degas a white disk in arid (white dice) latitudes, and a green disk in humid (green dice) latitudes (**D5a**). Each degassed white disk is a Disk of Damocles.¹⁶ A sea biome is treated as land for as long as it retains its green disk.


D7. MUTAGEN (ET OR BIOSPHERE EVENT)




This Event causes the 8 Display cards not on top of the draw decks to be discarded from the game, and replaced with new ones from the draw decks. It also causes each Species to suffer Mutation Atrophy (see glossary) if it has too many Organs. If this causes the loss of a Basal Organ, it goes **extinct (I3)** with its Creeples killed outright (i.e. not becoming Endangered).¹⁷

- a. Tooth & Claw Game.** Make a **mutagen roll (A8b)** to determine the dark heart limit for all players.

Example: During Era I, the mutagen roll is 1 and 2. Therefore, the dark heart is 2. Player Black has two Species: his Archetype with two basal cubes and 3 cubes on Mutations, plus a daughter species with 5 basal cubes. The Archetype loses all its Mutations, and the daughter goes extinct. If the mutagen roll had been snake eyes, Player Black would have gone Lazarus.

- b.**  **Dark Heart Limit.** For Players Black, White, and Orange, the **dark heart icon** on the Oxygen sets the maximum number of Organs each Species can have if a mutagen event occurs.

Example: A mutagen event strikes when the oxygen level is 4% with a dark heart of 2. Don't forget to first churn the Display. Player Orange has an Archetype with 3 Basal Organs and a flyer with 2 Basal Cubes and 3 Plus Cubes. The Archetype goes extinct, and the flyer loses both Plus Cubes.

- c.**  **Green Heart Limit.** For Player Green, the **green heart icon** on the Clouds sets the maximum number of Organs each of his Species can have if a mutagen event occurs.¹⁸

- d. White Organ Shield.** For every white organ a Species has, its heart limit (dark or green) is increased by two.

- e. Monsters.** If a monster token Atrophies during mutagens, the species size is reduced instead. A monster cannot be removed until the Species is at size 1. See **J4**.

- f. Haustorium.** During a **mutagen event**, a Species with a haustorium Skeletal Number of 0 must use the **dark heart limit (D7b)** and a Species with a haustorium Skeletal Number of 5 must use the **green heart limit (D7c)**. See **J5**.

- g. Order.** Atrophy Organs in **player order (A5)**.

16 WINTER IN A GREENHOUSE WORLD. The beginning of this game in the early Paleozoic had high greenhouse, as shown by the formation of minerals such as Aragonite which are sensitive to CO₂ concentrations. Yet the Paleozoic was also increasingly punctuated by brief glacial episodes. The next era, the Mesozoic, also saw high atmospheric CO₂ concentrations starting around 600 ppmv in the early Triassic, rising to perhaps 2400 ppmv by the Cretaceous, and falling to today's icy values of 400 ppmv. Atmospheric humidity, which accounts for 75% of the greenhouse effect, also rose correspondingly. The insects, mammals, dinosaurs, and flowers got their kickstart and thrived in a warm humid incubator set to "ideal" in an entirely ice-free world with jungles from pole to pole. And yet there were mysterious "cold snaps", cold enough that bewildered dinosaurs encountered snow and ice, substances unknown in their evolutionary history. The puzzling combination of glaciers in a greenhouse world is easiest to reconcile by considering that greenhouse is only one factor in climate, with the primary factors being solar and other extraterrestrial influences. We live in a cosmic environment.

17 MASS EXTINCTION is a loss of species that is over 2X the base extinction rate, as calculated from the long-term life expectancy of a species. It is often asserted that we live in a human-caused mass extinction, but there is no evidence for this. North America is a well studied case, having about 1000 mammal species since the Pleistocene. Since studies of the fossil record indicate that mammal species survive for about a million years, this equates to a base extinction rate of 1 mammal per 1000 years. A speciation rate of at least 1 per 1000 years is necessary to maintain mammal biodiversity. The known number of North American extinctions since the Pleistocene is 45 mammals in 10,000 years, and this qualifies as a mass extinction. Among the losses were megafauna such as horses, giant sloths, mammoths, and sabertooth cats. However, in the 500 years since Columbus landed, there has been but one extinction, a Mexican rabbit that may have been a subspecies. This is in line with the expected base extinction rate. (I ignore subspecies in this tally because they are undefinable. I also ignore species from predator-free islands, such as the Stellar's Sea Cow, since they have no genetic future in the world with predators.) If you look at birds, plants, insects, etc., calculating the base extinction rate is harder because these organisms don't fossilize well. However, from what is known the results do not change much. Nor do they change much on other continents. There was a mass extinction in the Pleistocene, in which humans may have been a factor, but that extinction ended centuries ago. On the other hand, North America has at least 31 introduced mammal species, so biodiversity is up 3%, and this may be causing a speciation explosion. There is at least as much evidence for an "Anthropocene Explosion" as there is for a "Anthropocene Extinction". Man is the only species that gives sanctuary to more species than it drives extinct. Domestic and semi-domestic species from aurochs to camels to ginkgos would be long extinct if not for the intervention of humans.

18 ANGIOSPERMS are a totally new plant type evolved during the Cretaceous, rapidly colonizing landscapes across the world with flower- and fruit-bearing shrubs, trees, and herbaceous browse. The secret of their success is coevolution with animals, especially insects, to disperse their genetic material.

Example: The albedo level is 0.2 (green heart = 3) when a mutagen strikes. Don't forget to first churn the display. Player Green has a size 3 Species with 3 basal cubes and one monster token, which counts as 3 Plus Organs. The Species loses 2 organs by shrinking twice to size one and loses a third organ by discarding the monster token along with its mutation card. Another Species has 4 basal cubes, including one white cube, and this Species is unharmed.

D8. METABOLISM/DARWINIAN RADIATION (ET EVENT)



This Event simulates two types of ionizing radiation. **Metabolism Radiation** (red/yellow) forces each Species to Atrophy one Plus Organ, either red or yellow (owner's choice). **Darwinian Radiation** (green/blue) forces each Species to Atrophy one Plus Organ, either green or blue (owner's choice).¹⁹

- Mutation Loss.** Except for Cheshire Cats, remove a Mutation that loses its last Plus Organ.
- Monsters.** If a monster token Atrophies during radiation, the species size is reduced instead, see "Atrophy". A monster cannot be removed until the Species is at size 1. See **J4**.
- Immunity.** Radiation has no effect on a Species with no Plus Organs of the color specified. Note that cards that gain no Plus Organs when promoted can never be lost.
- Order.** Atrophy Plus Organs in **player order (A5)**.

Example: The hypercapnia event occurs, with a metabolism radiation event. Your Archetype has two blue Basal Organs, which are unaffected by radiation. It also has one yellow Plus Organ, and this being the only choice, must be the one removed, along with its Mutation.

D9. CROWD DISEASE (ET EVENT)



The Species with the most Creeples on the map, including Endangered, loses half its Creeples, rounding down. The owner chooses which ones are killed outright (i.e. removed to the Unborns, and not becoming Endangered). If two (or more) Species are tied, all suffer the disease, choosing in **player order (A5)**.

Example: When a crowd disease strikes, your Archetype Creeples are tied for the most populous, with 5 Creeples on the map. You lose 2 of them, and you choose 2 that are being preyed upon by your opponent's birds, so that those 2 carnivores become Endangered. Player Orange has two Species with 5 Creeples, his Archetype and his predatory birds. Both Species lose 2 Creeples, and for the bird losses Player Orange chooses the 2 Endangered ones.

D10. RESERVOIR²⁰ (BIOSPHERE EVENT)



Each of these Events shifts one disk from the **Reservoir** or map indicated on the left, to the one indicated on the right. The Reservoirs are the Oxygen, Clouds, and Atmosphere, and the map includes all the Biome hexes and Offshore shelves. The color of the disk shifted is indicated by the color of the triangular arrow.

- Triggerhappy Superpower.** If an Event includes the **gun icon**, the **Medea supervillain (E8)** can decide that all the disks of that color are moved, not just one. They all come from the indicated reservoir and go to the indicated reservoir. This superpower must be applied globally, e.g. if the Event liberates a Continental green disk, the gun would liberate all Continental green disks.
- Ricochet Rule.** If the Medea triggers a gun, he must immediately surrender the Medea card to another player of his choice. The ricochet rule is only used if Player Green is in the game.
- Microbe, Conflagration Events.**²¹ An Event that has the icons shown to the left does NOT occur if oxygen levels specify "no microbes" or "no conflagration" respectively.


Example: The first wetlands eutrophication event has the "requires microbe" icon, so it occurs only if oxygen levels are 14% or lower (since the anaerobic bacteria only function in low oxygen).²²

¹⁹ HIGH OR LOW METABOLISM PHYSIOLOGY seemed to determine the winners and losers in mass extinctions. In the biggest, the twin P-Tr extinctions, the losers were low-metabolic genera, especially marine filter feeders. Possibly high concentrations of CO₂ overwhelmed their ability to supply oxygen to their tissues, while the higher metabolism animals survived with a closed and well buffered system with active circulation and gills. On land, the neopterous insects (those with hinged foldable wings) survived, possibly because their complete metamorphosis allowed larva, pupae, and higher metabolism adults. The paleopterous insects (not able to fold their wings, like dragonflies) took heavy losses, in the only mass extinction in arthropod history.




²⁰ RESERVOIRS. "Photosynthesis partitions carbon on the Earth into two great reservoirs: the organic carbon reservoir of almost everything living as well as of coal, oil, and other organic remains, and a larger reservoir of inorganic carbon that has not passed through living things, including the limestone in a reef and carbon dioxide in the atmosphere. At the close of the Permian a massive amount of organic carbon was released into the atmosphere and oceans. Where it came from is the critical issue. Among the possibilities is that it reflects the carbon in all the plants and animals that died, or the burning of massive coal deposits in Siberia, or the release of methane gas trapped in sediments on the outer shelf of the continents." Douglas Erwin, "Extinction", 2006.

²¹ WITHOUT FIRE, vast areas of humid C4 grasslands and savannas, especially in South America and Africa, would become closed forests. W.J. Bond, 2004. This assumes CO₂ levels are high enough to favor C3 trees over C4 grasses, see footnote 14.

²² DECOMPOSERS break down dead or decaying organisms. Most breathe oxygen and exhale carbon dioxide, such as fungi and aerobic bacteria. In low oxygen conditions, anaerobic decomposition is performed by acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). The latter are found in the guts of deer, giraffes, cattle, and termites to digest cellu-


- d.  **Precipitation Events.** An Event with the icon shown to the left occurs unless the cloud level indicates “no precipitation” (because there are no clouds).

Example: During a megamonsoon, the 3 Events bracketed by precipitation occur. However, the Earth’s albedo is 0.2 (“no precipitation”), which cancels these Events.

- e.  **Cloud-Covered.** An Event marked with the **cloud-covered icon** only occurs if the cloud level is cloud-covered, as indicated on the Clouds.²³
- f.  **Continents.** If the destination reservoir is on a Continent, the disk is Degassed (see glossary) onto a Biome hex chosen by Medea per **(D12)**. The disks are either green (forests), black (mountains), or white (ice), to a maximum of one disk per Biome.
- g.  **Offshore.** If the destination reservoir is Offshore, the disk is Degassed into one of the semicircular **shelves** on the east coast of a Craton. The disks are either black (stored carbon or methane)²⁴ or green (plankton bloom). There is a maximum of one black disk per offshore position, and a maximum of one green disk that can sit on top of the black disk (representing upwelling of carbon to the ocean surface). Note: A green disk can only be Degassed onto an Offshore black disk. If the black disk is Liberated, any green disk on it must also be Liberated.


- h. **Change Greenhouse.** If disks were Liberated to or Degassed from the Atmosphere, check to see if the Latitude Strip must be changed. If so, replace it with the new valid Latitude Strip (see glossary). If at the end of events there is a disk in the uppermost slot of the Atmosphere, the game ends at the end of the turn **(Phase A4)** due to **runaway greenhouse (A6)**.²⁵²⁶

D11. WINDY EVENT

 This Event blows the Wind in all Latitudes and in both directions this turn. This enables **rafting** in all Latitudes, see **F5c**.

D12. BIOSPHERE SUPERPOWER

If a disk is Degassed to a Continent or Offshore, Medea specifies to which Biome it is added, constrained by **D12a**. Conversely, if a disk is Liberated from a Continent or Offshore, the Medea specifies which Biome it comes from.

- a.  **Rain-Shadow Constraint.** This icon indicates the white disks Degassed to a Continent during a Reservoir Event always go into a **rain-shadow** biome: either (1) the center hex of any Craton or (2) into a Biome adjacent and downwind of any mountain (black disk). For each mountain, look at the **wind indicator** on the Latitude Strip for the mountain’s Latitude to see the direction of the Wind. If there are several possibilities, Medea decides. If there are no possibilities because all rain-shadows have a Disk of Damocles of a higher hierarchy, the event is canceled.
- b. **Plankton Die-off.** Liberation of a black Offshore disk also Liberates any green Offshore disk present. Removal of a green Offshore disk (bloom) makes any swimmers there Endangered.
- c. **Brown Plankton.** If a green disk is to be Degassed to an Offshore, but there is no Offshore Shelf with a black disk to place it on, the Event is canceled.
- d. **Damocles Hierarchy.** A white or black disk Degassed to the map is a Disk of Damocles (see glossary), so you can’t add a new white disk to a biome that has a white or black disk there already.

lose. The cycling of the white disk to the atmosphere represents the belching of the potent greenhouse gas methane.

23 CLOUDS are climate neutral in this game. They reflect sunlight, which cools the planet. But on the other hand, they are a powerful greenhouse, which warms the planet. A cloudy planet like Venus has an albedo of 0.8 (80% of sunlight reflected), compared to a partially cloudy Earth with an albedo of 0.3. You can easily feel the cloud greenhouse by walking outside before dawn. If it’s cloudy the air will be not much cooler than during the day, but if it’s a clear night under starry skies, you can almost feel the heat escaping into the vastness of space.

24 METHANE OUTGASSING is simulated in the game by cycling offshore carbon to the atmosphere. It is the prime suspect for the greatest extinction events, such as the late Permian extinctions. The reason is that the fossil record across the P/Tr boundary shows two spikes of isotopically very “light” carbon (enriched in C-12, indicating a biological source) released in a very brief amount of time (<160,000 years). The effects were global, involving at least 2500 Gigatonnes (Gt) of methane. Only marine methanogens, which produce very “light” methane in the continental shelves, could have suddenly released so much stored carbon this light. In less than a century, the released methane would have oxidized to CO₂, either in the oceans (by bacteria) or in the atmosphere (by OH radicals). Methane is a strong greenhouse gas, so the greenhouse would have skyrocketed, with a gradual reduction as it is converted to the much weaker greenhouse gas CO₂. Because the oceans became hypoxic with the oxidation of so much carbon, immobile filter-feeding corals, crinoids, bryozoans, and brachiopods took catastrophic losses. These creatures, which absorb O₂ through the skin without gills or a significant circulation system, were unbuffered against the new ocean chemistry. The few survivors were mobile creatures with relatively high metabolism (vertebrates, clams, snails, and crabs). These creatures had a closed and buffered system able to deliver sufficient oxygen to their tissues in spite of massive CO₂ or CH₄. Similar extinction patterns occurred on land as well, among insects and vertebrates.

25 IN EARTH’S GREENHOUSE EFFECT, “we find that water vapor is the dominant contributor (~50% of the effect), followed by clouds (~25%) and then CO₂ with ~20%. All other absorbers play only minor roles. In a doubled CO₂ scenario, this allocation is essentially unchanged, even though the magnitude of the total greenhouse effect is significantly larger than the initial radiative forcing, underscoring the importance of feedbacks from water vapor and clouds to climate sensitivity.” Gavin Schmidt, NASA Goddard, 2010.

26 On a summer’s day in my hometown of Tucson, the interior of a parked car can soar above 50°C. There are two possible explanations: (a) greenhouse backscatter (some of the heat trying to escape through the glass is backscattered, heating the interior), or (b) convection blockage (heated air that is blocked from rising gets much hotter than air free to rise and draw in cooler air). Which explanation accounts for most of the temperature rise in an actual parked car or greenhouse? This question is debated, and could be resolved by a high school level science experiment. Yet to my knowledge the experiment has not been performed

Example: A CO₂ desert event occurs during an Ice Age, placing a white disk in a rain-shadow. All the center hexes already have white or black disks. There are several mountains, but only two in windy latitudes. Medea chooses to place the white disk over a sea where an opponent's swimmer is living downwind from a mountain. The swimmers become Endangered, presumably because the sea has become supersaline.

D13. CLOUD SEED SUPERPOWER

If a white disk is Liberated for any reason, Medea decides if it goes into the Clouds or Atmosphere. This choice is indicated by the half clouds/half atmosphere icon on certain Events.



Example: The icon on the left shows a reservoir event liberating a white disk from the continents to either the Atmosphere or the Clouds. Medea, using his cloud seed superpower, decides which reservoir it goes into. Since this is a gun, if Medea pulls the trigger all the white disks on all the continents are Liberated.

D14. EMPTY RESERVOIR SUPERPOWER

If an Event requires a disk to be taken from a Reservoir, but there is no disk of that color left, Medea may remove the required disk from anywhere. This superpower cannot be used during a gun event.

E. ACTIONS

During the **action phase (A2)**, each player performs a number of **actions (E1 - E8)** as determined by **A2a**.

E1. MUTATE - SELECT AND PLAY A MUTATION

Use this action to **select** a card in the Display and immediately add it to the Tableau of one of your Species. There is no hand.

a. Mutation Costs.²⁷ Each Mutation has a **cost** as shown by the Table shown on the Newborn Card (see right). The total costs of cards selected for a given Species during this phase cannot exceed the number of Unborn Creeples it has when it starts its purchases.²⁸

NEWBORNS	
PLACE HERE ALL CREEPLES TO BE DISPLAYED THIS TURN	
MUTATION COSTS	
	0 2 4 6 8
	0 2 4 6 8
1/2 MUTATION COSTS	
+TOOL	

Example: You have 4 actions this turn. You have 2 Species, one with 2 Unborn, and one with 6 Unborn. For your first Species, you select a Mutation that costs 2. For your second Species, you make 3 selections, for Mutations costing 0, 0, and 6. In both cases, you have spent the maximum allowed for each Species. Note that you have not permanently spent any Unborn, and on your next turn you once again can spend 2 for your first Species and 6 for your second species.

b. Emotional Bonus. The Cost required to select any card is halved if since the beginning of this phase that Species has had one or more **emotions (J6)** of the card's color. If it had more than one, see **J6e**.

Example: Your only Species has 4 Living Creeples and thus 3 Unborn Creeples. It has the blue emotion (sexual jealousy). You want to select the second and third cards from the left on the Darwinian (bottom) row, which have a Cost of 2 and 4 respectively. Both Mutations are blue, so your Costs are halved. You have 3 Unborns, enough to select both cards.

c. Plus Organ. After playing a Mutation into your Tableau, put the Organ (sometimes 2 Organs) of the color specified on the Mutation card. Place the cube over the cube icon marked with a "+". This cube is called the **Plus Organ**.

d. Player Green restriction. Player Green is not allowed to select any Mutation from the upper row (i.e. the metabolism row with yellow and red cards) unless

²⁷ DARWIN'S DILEMMA. Chapter 6 of "On The Origins of Species" (1859) is entitled "Difficulties with the Theory". In it, Darwin wrote: "Firstly, why, if species have descended from other species by insensibly fine gradations, do we not everywhere see innumerable transitional forms? Why is not all nature in confusion instead of the species being, as we see them, well defined?" The fossil record shows that speciations normally go through initial rapid change, and then as they reach large populations, they enter a period of phenotypic stasis, in which their gross morphology changes little. The game simulates this stasis by counting unborns. This is sometimes called **punctuated evolution**, and without this effect, there would be no species, only a blur of varying individuals, some of which can interbreed. Large central populations are stabilized by their large volume and the process of gene flow. New and even beneficial mutations are diluted by stabilizing selection, in which genetic diversity decreases and the population mean stabilizes on a particular trait value. Large populations also increase koinophilia, the tendency of breeding animals to preferentially seek mates with a minimum of unusual or mutant features.

²⁸ WEED ANIMALS are species that initially radiate in astronomical numbers, but then go into stasis or even extinction as the environment matures in climax. The spark is often a disaster, which can range from a plowed field to a meteor strike. Two recent (post-Columbian) weed animals are passenger pigeons (once the most common bird in America), and Rocky Mountain locusts (one swarm estimated at 12 trillion grasshoppers, a Guinness record). Such decimations are usually blamed on hunting, but hunting has rarely, if ever, driven American mainland species to extinction. How could hunters drive passenger pigeons extinct while leaving intact at least 909 of the 914 other nearctic bird species? According to Charles Mann, in his book "1491" (2005), the disaster that spawned huge numbers of weeds (including the American bison) was the decimation by disease of aboriginal humans (sometimes misnamed "native Americans", even though they were an invasive species). As keystone species, they managed the forests through widespread anthropogenic fires and fire-stick farming, and crafted much of the landscape he calls "the artificial wilderness". In Christmas bird counts in my hometown of Tucson Arizona, we documented the rise of the Inca Dove, a recent immigrant from Mexico related to the passenger pigeon. In southwestern cities where grass seed is used to create irrigated lawns, the annual counts were many thousands in the 1990's, down to just 8 this year. Other dove species remain untouched, so the reason for this shocking decline is unknown


the Mutation has the Horror-plant icon next to the card title.²⁹






- e. **Refresh.** After all your selections, refresh the Display so that it once again has 5 cards per row. Do this by moving each card in the Display to the leftmost empty position in its row. Then draw new cards to fill any remaining empty positions so there are again 5 cards in each row. Draw cards from the respective metabolism or Darwinian draw deck to fill the rows from the leftmost empty slot.



E2. PROMOTE A MUTATION

Use this action to flip one of the Species' unpromoted mutations to its promoted side.

- a. **Preview.** On the top of each unpromoted Mutation is a **preview** of what the promoted side looks like. It consists of two sets of icons, one for each **orientation** (next bullet). See anatomy above.
- b. **Orientation.** The promoted side has two **orientations**. Choose one orientation to be upright in your Tableau. You must not be beyond the maximum size specified for the orientation chosen. Important: If you choose an orientation with a new Creeple Shape, this is a **speciation**, see E3.
- c. **Plus and Basal Organs.** The promoted orientation adds the **Plus Organs** (E1c) specified, placed on the Mutation card where indicated by the "+" sign. The original Plus Organ (or Organs) from the unpromoted side are transferred to anywhere on the Genotype card, and becomes a **Basal Organ**.
- d.  **Plus Organ Monsters.** If the Plus Organ icon has the **monster icon**, a monster token of the correct color is placed here instead of a cube. This token is considered to be many Organs, from 1 to 6, depending upon the current species size. This Organ number is used for all purposes.

Example: You have a 2 ton cow (size 5). The single green Plus Organ on its "cud-chewing" mutation is considered to be 5 green cubes, allowing this Monster to dominate the forests and weeds. If hit by radiation, and this is its only Plus Organ, the cow will need to shrink to size 4 to effectively get rid of one green organ (see "Monster" in the glossary).
- e.  **Maximum Size.** If the mother is larger than the **maximum size** (J1) of her daughter, the daughter becomes a **kiwi** (E6b) using the archetype shape. If this is not possible because the archetype is already in use, then the promotion is not allowed.
- f.  **Mutualism Icon.** When you promote to an Orientation with the **mutualism** ability, and only then, you must choose a **host**. A host is another Species which shares a Biome with your promoting Species (as predator or prey). Take one Creeple from either the Unborn or Newborn Creeples (your choice) of the host species and put it on your mutualism mutation card. This Creeple is called a **Host Creeple**. See J2.
- g.  **Venom.** A venomous herbivore cannot be eaten by a Carnivore unless the Carnivore is either venomous itself, or larger (F4b). See J3.
- h.  **Personality Formation.** Each promotion allows you to rearrange the promoted cards of the Species, including the formation of both halves of an emotion as part of its **personality** per J6. Organize the Species Tableau so that the uppermost Mutation is part of its personality row.
- i.  **Speciation Promotion.** If you promote to an orientation depicting a Creeple shape, this promotion is treated as a **speciation** (E3) instead. This speciation is disallowed if you already have any Living Creeples of this Shape.


²⁹ METABOLISM is the aerobic activities of the circulatory (yellow cards) and nervous (red cards) systems. Plants have mitochondria and thus breathe oxygen and make ATP, like animals. Nevertheless, without muscles or nerves their metabolism is limited. Some plants, such as skunk cabbage, use their relatively high metabolism to melt through snow and thus gain a competitive advantage in the spring. These adaptations, the first steps toward plant endothermy, may someday turn the arctic green. This has not happened yet perhaps because the ice and snow of today's Ice Age is so recent.

E3. SPECIATE A MUTATION INTO A NEW SPECIES³⁰

If you promote a Mutation to spawn a new Species, the Species with the Mutation is called the **mother** and the new Species is the **daughter**. Promote this Mutation, moving all its cube(s) (if any) onto the Genotype of the mother as **basal cubes (E2c)**. Then remove the Mutation from the mother's Tableau and use it to create the new Species following these steps:

- a. **Creating the Genotype.** Use the removed Mutation to start a new Tableau for the new daughter species. This card becomes the **Genotype** of the daughter (i.e. the first card in her Tableau).
- b. **Daughter's Inherited Basal Organs & Size.** Duplicate all the Basal Organs (but not the Plus Organs) of the mother. Note this means the Plus Organ on the promoted card becomes a Basal Organ on both mother and daughter, see Example. Place these new cubes on the daughter's Genotype as Basal Organs. **Also duplicate the Size Dice, at the same size as the mother.** See "Heritable" in the glossary.

Example: Your Archetype has no Basal Organs and 1 red Plus Organ on its electrolocation mutation. It promotes this mutation into an infrared pit sensor, thus speciating into a burrower. The red cube becomes a Basal Cube on the mother, which is inherited by her burrowing daughter.

- c.  **Recession.** If the promotion shows the **recession icon** for a color, then the new Species must discard one of its new Basal cubes of that color (if it has any). This is an involuntary **neoteny (E5)** and thus does not drive the new Species extinct.
- d. **Newborn Daughter.** Take 1 Unborn Creeple of the new Species and use it to replace one of the mother's creeples. This drives the mother **extinct (I3)** if it was her last Living Creeple.

E4. POPULATE A NEW CREEPLE

Use this action to take 1 Unborn Creeple plus up to one Creeple per reproductive organ (blue cubes currently on the Species) and place on your Newborn Card. They will be moved to the map in the **mother phase (Part F)**.

Example: For your three actions, you choose *speciate* (placing 1 armored Living Creeple), *Populate* (creating 2 Archetype Newborns), and *Populate* (creating 2 more armored Newborns).

E5. NEOTENY - DISCARD BASAL ORGAN FROM EACH SPECIES³¹

Use this action to discard up to 1 Basal Organ from each of your Species. Removing Basal Organs is useful to avoid extinction from mutagens.

Example: Your swimmer has two blue Basal Organs on its Genotype. With two neoteny actions, you remove both of them, making it safe from extinction.

E6. RESIZE EACH OF YOUR SPECIES (ACHTERBAHN GAME)

Use this action to change the Size Dice of each of your Species by up to one step (up or down).

- a. **Mutation Maximum Size.** If the Size Dice of a Species goes beyond the maximum listed on any promoted Mutation (**J1**), the card is Atrophied (see glossary).
- b. **The Kiwi Rule.**³² If, after a resize or speciate, the size of your Genotype is larger than the maximum size printed on its card, it is replaced by a new Archetype species called a **kiwi** (so-named because it has lost its ability to fly, swim, etc.). Either way, the Genotype goes into your Fossil Record. However, this replacement is only possible if your Archetype is extinct, otherwise the Genotype simply goes extinct. To create the kiwi, remove the Genotype card and replace it with your Archetype card, preserving all the Organs and Mutations of the former Genotype. Convert all the Genotype's Living and Newborn Creeples into Archetype Creeples.

Example: Your last species is a furry alary muscle flyer, with a maximum size of one. You deliberately resize it to 2, which replaces the alary muscle genotype card with your Archetype card. The fur is retained. There are 3 flyers on the map, and all are replaced with domes.

³⁰ CAMBRIAN EXPLOSION is a speciation event that occurred on turn 0 of this game. It included the proliferation of a dozen new animal morphologies judged novel enough to be ranked as new phyla. Never again would there be such a burst of morphological innovations, even after severe holocausts. For instance, the Permian-Triassic (P-Tr) mass extinctions ended over 90% of the world's marine species, returning to a world at least as barren as before the Explosion. One would expect that the depopulated ecospace would trigger many innovations. Yet, the slowly recovering populations created nothing distinct enough to be judged as a new class or phylum. It is as if the developmental processes constructed during the Cambrian would constrain subsequent reorganization over time. Douglas Erwin, 2006.

³¹ NEOTENY, the retention by adults of traits previously seen only in the young, is seen in animals such as the Axolotl, a Mexican salamander. Normally salamanders, like all amphibians, go through a gilled larval phase and metamorphose into air-breathing adults. But although the Axolotl is descended from terrestrial tiger salamanders, it is totally aquatic. It retains its gills throughout its life cycle and breeds in its larval form. Thus biological neoteny has shed the adult characteristics, in a "backward" step in evolution.

³² THE KIWI RULE is so named because one of the designers (Doull) comes from New Zealand, which has no native mammals except two species of bat and where birds (and some insects) fill most of the ecological niches traditionally inhabited by mammals, in many instances becoming flightless as they did so. Given the size adjustment, it would have been better to call this a moa or elephant bird rule. Or a dodo rule, since the idea is that the new creature has evolved on a predator-free island and thus has no anti-predator specializations.

E7. RESURRECT YOUR ARCHETYPE

This action is only for Lazarus players (see glossary). Use it to reestablish your Archetype card with its Size Dice set at size = 1, just as if in setup. Place any Cheshire Cat emotions to the right of the Archetype.

- a. **Start Location.** Place an Archetype Creeple anywhere on the map that is *habitable* (F3c).

E8. MEDEA - CLAIM THE SUPERVILLAIN CARD (ACHTERBAHN GAME)³³

This requires spending your entire action phase. You take the Medea card (C1b) from whoever is holding it. The Medea card is not in the Tableau of any of your Species, and is not lost if you become a Lazarus. With this card, you have *superpowers* per D10a, D12, and D14, and it is worth a VP if held at the end of the game. You are also in charge of keeping the game moving by announcing the phases, using the SOP on the back of this card.



F. MOTHERS & DISPERSALS

In the *mother & dispersal phase* (A3), in *player order* (A5), each player chooses a mother and disperses all of his Newborn Creeples before going to the next player.

F1. CHOOSING A MOTHER

For each Newborn, choose a **mother** on the map of the same Shape.

- a. **Daisy-Chain Rule.** Each Newborn placed on the map can act as a mother for the next Newborn.
- b. **Orphan Rule.** You can choose a mother even if she is an Endangered Creeple.

Example: On your Newborn Card, you have 2 archetypes and 1 burrower. You choose an archetype on the map to be the first mother, disperse a newborn archetype to the west coast, then from this newborn raft another newborn to a new Continent. The final burrowing newborn disperses from a burrowing mother to become a carnivore on one of the archetypes.

F2. DISPERSAL DP = +

Starting from its mother, disperse the Newborn Creeple up to its Dispersal Points, ending up in a Biome as an Herbivore or Carnivore (F6). If you fail to disperse to a *habitable place* (F3c), return the Newborn to Unborns.

- a. **Dispersal Points.** Each Creeple individually has a number of **dispersal points** (DP) equal to the number of blue organs plus size of the Species.³⁴ To disperse a Newborn, move it from hex to hex, costing dispersal points (DP) for each hex entered. See F3a for DP costs to enter each Biome, and F3c and F4 for restrictions on inhabiting a Biome. See F5 for the special *rafting* maneuver.

Example: On turn one, your Archetype has 1 DP, because of its starting size of 1 (C1e).

Example (Speciation & Dispersal) : For your first action, you speciate your archetype, giving birth to a swimming daughter. You choose an archetype dome in a forest to be replaced with a swimmer shape. The swimmer starts endangered, because swimmers can't live in forests. An enemy predator in the forest also becomes endangered, because its prey is endangered. To save the new species, you also perform a populate action. Because your new swimmer has a blue organ, you place 2 swimmer newborns. During dispersal, these two disperse starting from the endangered mom. One disperses as a predator to a nearby swamp, and the second daisy-chains from the swamp to a bloom in the offshore.

MOVEMENT RULES					
DP* ARE SPENT WHEN A CREEPLE ENTERS A BIOME					
*DP = SIZE +					
BIOME					
SEA	2	2	2	1	1
BLOOM	2	2	2	1	1
WEEDS	1	1	1	2	1
SWAMP	1	1	1	1	1
FOREST	1	1	1	2	1
MOUNTAIN	2	2	2	2	1
ICE	2	2	2	2	1
RAFTING**	3	3	3	1	1

** IN WIND DIRECTION

³³ THE MEDEA SUPERVILLAIN refers to anaerobic microbes under heavy selection pressure for hundreds of thousands of years to eliminate all macroorganisms and return the planet to the single-cell only paradise it was for its first 4 billion years. The superpower "methanogen" refers to the microbes bred to store their methane waste products under an icy cap. The evil plot is to opportunistically await a good earthquake, meteor, or drop in sea level that releases such a huge plume of supergreenhouse gases that the oxygen-breathers go extinct, leaving the methanogens to spread their genes and inherit the Earth. Medea mediated methane releases are suspected of causing the biggest extinction event recorded, the twin P-Tr extinctions. The Medea concept was introduced in card 60 in Bios:Genesis, and I hope including a supervillain in the game will be in keeping with movie trends nowadays.

³⁴ LOCOMOTION COSTS decrease with increasing size. When running at the trot-gallop transition speed, a 30 gram mouse uses 6X the amount of watts/kg than a 300 kg horse does. This is because small animals take more strides per second, and because smaller animals generate larger forces in their running muscles relative to their body mass. Walking, flying and swimming migratory animals tend to be larger than their non-migratory relatives. Locomotion costs on land have an important physics advantage over flyers and swimmers. When traveling by momentum exchange with a fluid, with for instance the beating of fins and wings, conservation of momentum and energy dictate that perhaps half of the energy expended is wasted moving the fluid backward. Whereas the feet of a land runner move the planet only insignificantly backward, transferring almost 100% of the energy into forward motion. Strange as it may seem, a runner is always faster than an equivalently muscled flyer (in level flight), and an auto is faster than a plane or boat with the same powerplant.


F3. ENTERING & INHABITING BIOMES

The **Biome hexes** have 3 basic colors: green, brown, or blue. The Biome hex color is superseded if it contains a **Biome disk**, either green, black, or white. See Table **F2**.

- a. **Biome Entry Cost.** The number indicates the number of *dispersal points (F2a)* it costs to enter each hex.
- b. **Bloom Disks.** An Offshore with a green disk is treated as a separate Biome. It may be inhabited exactly like a sea biome, so that both Herbivores and Carnivores can inhabit it if they can swim. It may only be entered (for 1 DP) by a swimmer, and only from the hex it is adjacent to, or from an adjacent Offshore to the north or south. Other than this, an Offshore is ignored for dispersal or rafting.³⁵
- c. **Uninhabitable Biomes.** If the table shows an "X", then a Creeple can enter it but not inhabit it.
- d. **Roadrunner Niche.** The upward red or yellow arrows describe the *Roadrunner Niche (G4, H3)*.

F4. PREY SUITABILITY

A Carnivore becomes Endangered if at any time it has no Herbivores to eat that are *suitable (H1)*. A Creeple may not move to inhabit a Biome as a Carnivore unless there is at least one Herbivore Creeple there that is suitable for it to eat:

- a. **Shape Requirement.** The Carnivore must have the same Shape as its prey, except that Archetypes can be eaten by any Shape. For instance, flying can only be eaten by flying.
- b.  **Size Requirement If The Prey Is Venomous.** The Carnivore must either be venomous itself, or be larger than its prey if the prey has one or more venom Mutations.
- c. **No Cannibalism.** You cannot move a Creeple into a Biome as a Herbivore where the same Species is already present as a Carnivore, and vice versa. (Note that you can have one Species of your color as a Carnivore on another Species, also of your color.)

F5. RAFTING³⁶

A Creeple may move from one Coast Biome to another Coast Biome in the same Latitude (including *wrap-around*, see **D3b**). Rafting is possible between Continents, stopping at the first encountered Coast, or even between 2 Coasts of the same Continent. The Creeple must follow the Wind (i.e. directly west or east, no turning) and must move from one Coast to another. Rafting costs 1 DP for flyers or swimmers, and 3 DP for others (this is in addition to the cost to enter the hex).

- a. **Tooth & Claw Game:** The wind direction is always blowing from the east to the west (i.e. right to left).
- b. **Achterbahn game:** Wind only blows in Latitudes 1, 3, 4, and 6, and only in the direction shown on the Latitude Strip.
- c. **Windy Event.** If this biosphere event occurs, then for that turn only the Wind blows in all Latitudes and in both directions.³⁷
- d. **Blooms.** Rafting to a bloom biome costs the same DP as rafting to the hex holding the bloom disk.
- e. **You cannot raft over a sea biome within a Craton.**

F6. TROPHIC DECISION

The Creeple chooses to inhabit its destination Biome as either an Herbivore or a Carnivore (regardless of whether its mother was a carnivore or herbivore).

- a. **Enter as Carnivore.** To inhabit a Biome as a Carnivore, the Biome must have a prey *suitable* for the Creeple to eat (**F4**). If there is already a carnivore present, then there is an immediate *carnivore contest (Part H)*.
- b. **Enter as Herbivore.**³⁸ To inhabit a Biome as an Herbivore where there is already

³⁵ SWIMMERS represent species that once walked on land, but have returned to the sea. How is this possible? Typical shark documentaries, containing the line "the shark, nature's perfect eating machine", make it seem that clumsy air-breathers could not possibly survive in shark-infested waters, let alone compete with them for the apex marine predator slot. And yet they did, over and over again. Mosasaurs, plesiosaurs, ichthyosaurs, lizards, snakes, turtles, pinnipeds, otters, dolphins, whales, and penguins have taken over slots that sharks once enjoyed. It's a mystery (at least to me) why landlubber tetrapods so effortlessly defeat predators "perfectly adapted" to the oceans since the Ordovician. My best guess is my "Achterbahn" (roller-coaster) hypothesis, which theorizes that any biological order able to survive in the harsh and swiny terrestrial environment can become dominant anywhere. Supporting this hypothesis is the fact that the earliest sharks are freshwater xenacanth, so even sharks evolved in a semi-terrestrial environment. Against this hypothesis is the fact that the other skeletal types have not re-invaded the ocean from the land. Offhand, I can't think of a single marine air-breathing invertebrate, unless you count the seagrasses (a flowering plant) as an invertebrate.

³⁶ MASSIVE RAFTS dislodged from the Amazon jungle have been observed to include monkeys and jaguars. However, on the scale of this game, the rafts are mainly "lost world" islands or subcontinents that rift from the mainland, and travel via plate tectonics to fetch up on a foreign shore. This can happen because the island is attached to an oceanic slab of lithosphere which is being subducted at the foreign shore. Examples include Iberia and India. The latter rifted from Madagascar, and traveled northward to hit Asia at speeds of up to 15 cm/year, something of a plate tectonic speed record.

³⁷ THE PREDOMINANTLY EASTERLY GLOBAL WIND would have been reversed on the western coast of a supercontinent. During the Triassic, surface convergence of these winds with the Pangea high pressure system brought increased seasonality and megamonsoons, leaving the Pangea interior so dry as to be virtually uninhabitable.

³⁸ CHEWING, the preprocessing of vegetation with teeth, is one of the most dramatic herbivore inventions of all time. Reptiles, both herbivore and carnivore, do very little chewing. But both dinosaurs and mammal herbivores normally masticate their

an herbivore present, then there will be an immediate **herbivore contest (Part G)**.

- c. **Settling Down.** Assuming your Creeple wins its contest (if any), unless it becomes an **endotherm (I1)** it will never move from that Biome again, until its death. It may only make a **trophic shift (G8)** from Herbivore to Carnivore.

Example: Your armored newborn invades a forest where your opponent has an Archetype herbivore and a flyer carnivore. Both have more red organs than you, so if you invade as a carnivore, you will lose the carnivore contest because of the roadrunner niche. But if you invade as an herbivore, you win because you are inedible to the flying carnivore.

G. HERBIVORE HABITABILITY & CONTESTS

G1. HERBIVORE HABITABILITY

An Herbivore becomes Endangered immediately if the biome it is in is **uninhabitable** (see **F3c**). Endangered Creeples are ignored in contests, as if they were not there.

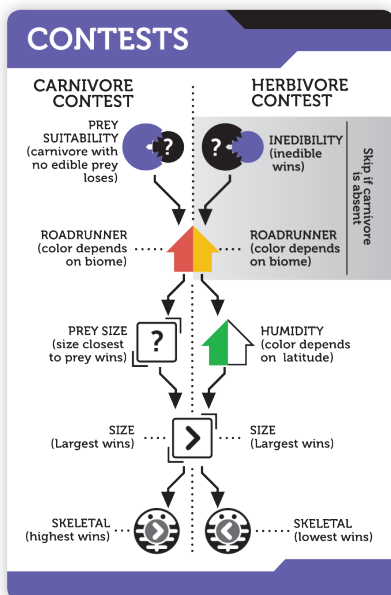
G2. HERBIVORE CONTESTS

Each Biome can support one Herbivore Creeple. If after a dispersal a Biome has two herbivores, perform an **herbivore contest** by following steps **G3** through **G7** below to identify the losers that become Endangered. In case of a tie, go to the next step, until only one Herbivore Creeple is left standing.

G3. EDIBILITY CONTEST LOSERS

If (and only if) there is a Carnivore present, both Herbivores check to see if they are inedible (because of Shape or venom, see **F4**). If only one is edible, it becomes Endangered.³⁹

Example: A moose and squirrel (both Archetypes) sit in the weeds. Since a Biome can only support one Herbivore, one must die. Suppose the moose is venomous and a predatory pterodactyl too small to eat the moose is present. Thus the squirrel is the only edible prey and it dies (and the pterodactyl will starve in the carnivore contest, since only the poisonous moose remains as prey). However, suppose a large carnivore was also present, able to eat the moose. Therefore no winner can be declared, and the contest continues with **G4**.



G4. ROADRUNNER NICHE LOSERS

Each Biome has a **roadrunner niche** indicated by the color of the **arrow icon** on the Biome, either red (ambush) or yellow (pursuit). See Diagram in **F2**. If (and only if) there is a carnivore present, both Herbivores check to see how many Organs of this color they have. If one Herbivore has more than the other, the one with fewer becomes Endangered. If they are tied, or if there are no carnivores, skip this step.

Example: The moose and squirrel from the previous example are vying for dominance in the weeds, and there is a carnivore that can eat both. This biome has roadrunner yellow, and the squirrel is faster with one yellow Organ. Therefore the moose dies. However, if there were no carnivore, then no winner can be declared, and the contest continues with **G5**.

G5. TEMPERATURE NICHE LOSERS

Each Latitude has a **humidity niche** indicated by the color of the **dice icon** on the Latitude Strips, either green (humid) or white (arid). Both Herbivores check to see how many Organs of this color they have. If one Herbivore has more than the other, the one with fewer becomes Endangered. If tied, skip this step.

- a. **Tooth & Claw Game:** Since the climate is always **humid (A8f)**, the humidity niche is always green.

vegetables thoroughly, or in the case of ruminants, rechew them. Cheeks are used to keep the bolus of food in place while chewing, contrasted to reptiles that allow pieces of food to fall to the ground when bitten. Dinosaurs continuously replace their teeth throughout their lives, like sharks, as contrasted to mammals, who have only one adult set of teeth that must last their entire lives. An old elephant, for instance, is doomed when finally her last tooth wears away to nothing. The battery of teeth and tooth-making apparatus in ceratopsids helps make the Triceratops skull among the heaviest in terrestrial history. The conveyor belt molars in hadrosaurs are such that its duckbill mouth can support a thousand teeth, although only the outer edge of each of the four tooth batteries are active. The skulls of dinosaur carnivores, in contrast, are very light and gracile. Chewing is unimportant for carnivores, and their jaws only move fore and aft, the better to shear meat off the bone. If the jaws could move from side to side, like herbivore jaws, it would be like trying to shear paper with scissors with a loose joint. The difference in dentition is the most defining physiological trait that distinguishes dinosaurs from mammals, a theme explored in my game **American Megafauna**.

³⁹ ENDANGERED SPECIES are normally threatened by habitat loss or by niche competition. Unless they evolved on a predator-free island, carnivores are only a factor in extirpation, with the major factor being starvation in competition with herbivores bearing anti-predator defenses. In this game, herbivores are more afraid of other herbivores than they are of carnivores.

Example: The moose and squirrel from the previous example are vying for dominance in the weeds. The climate is hothouse and the weeds are in a humid latitude. The squirrel has 3 green Organs, and the moose only 2, so the moose dies. But if instead it is an Ice Age with a white dice icon, and neither moose nor squirrel have any white organs, then the contest continues with **G6**.

G6. SIZE MATTERS.

If still tied, the smaller Herbivore becomes Endangered.

G7. TIE-BREAKER SKELETAL LOSERS



As a final tie-breaker, the Herbivore with the lower **Skeletal Number** survives and the other becomes Endangered.

a. Same Color Final Tie-breaker. If two Creeples Species of the same color are competing, and are tied in an Herbivore contest, then the owner chooses which Shape wins.

Example: The moose and squirrel from the previous example are tied in the herbivore contest. But the moose is controlled by Player Green (skeletal number = 1), and the squirrel by Player Black (skeletal number = 3). Therefore the squirrel dies.

G8. TROPHIC SHIFT SURVIVAL

If an Herbivore Cripple loses an Herbivore contest or if the biome is not habitable, it is allowed to shift to becoming a Carnivore instead of becoming Endangered, if it meets **prey suitability (F4)**. If there is already a Carnivore there, they are involved in an immediate Carnivore contest. Note that this shift is only allowed from herbivore to carnivore, and not the other way around.⁴⁰

H. CARNIVORE PREY SUITABILITY & CONTESTS

H1. CARNIVORE PREY SUITABILITY⁴¹



A Carnivore becomes Endangered if at any time it has no Herbivores to eat that are **suitable (F4)**. This could be because the Carnivore is the wrong Shape, or (in the case of venomous prey) the wrong size. Endangered Creeples are ignored in contests, as if they were not there.

H2. CARNIVORE CONTESTS

Each predator triangle can support one Carnivore. If after a dispersal a Biome has two Carnivores, perform a **carnivore contest** by applying rules **H3** through **H6** below to identify the loser. In case of a tie, go to the next rule, until only one Carnivore is left standing. If a Carnivore loses a contest, it becomes Endangered.

Important (circle of life): Herbivore Creeples represent thousands of individuals and are never endangered by being eaten by Carnivores. They can be endangered by competing Herbivores. See "Scale" in the glossary, or look up the Lotka–Volterra equations on predator-prey population dynamics.

H3. ROADRUNNER NICHE LOSERS



Each Biome has a **roadrunner niche** indicated by the color of the **arrow icon** on the Biome, either red (ambush) or yellow (pursuit). See Table **F2**. Both Carnivores check to see how many Organs of this color they have. If one Carnivore has more than the other, the one with fewer becomes Endangered. If they are tied, skip this step.

Example: On an offshore green disk, a dolphin and a crocodile are both trying to be the carnivore. The roadrunner in the sea is always yellow therefore, if the dolphin only has one yellow organ and the croc has two, the dolphin dies.⁴²

H4. PREY SIZE LOSERS



A Carnivore that has a size difference with its prey loses to one who has a lesser size difference to the prey.⁴³ Losers become Endangered. If tied, skip this step.

⁴⁰ CARNIVORES have a very short digestive system compared to herbivores. Vegetation consumed by a small carnivore would simply pass through without being digested. Large carnivores have an advantage, because food spends more time in their digestive systems. Whereas an herbivore might actually benefit from nibbling on a carcass. Indeed, herbivores with simple vat stomachs, such as elephants, horses, and giant sloths, occasionally eat meat, if they have the opportunity.

⁴¹ PREDATOR'S DILEMMA (strategy tip). Imagine a forest with two herbivores: a caterpillar and a porcupine. Without predators, it seems peaceful. But it's not. The herbivores are locked in a deadly eating contest, and the caterpillars are winning since they are better adapted to eating trees than porcupines. Give them 10 million years, and the porcupines are extinct. But suppose you are a bird entering the forest, eating the caterpillars. With fewer caterpillars eating the trees, the porcupines enjoy a population boom, and in 10 million years, both the caterpillars and the birds have starved. This is the predator's dilemma. If you fly into the forest, you kill both your favored prey and yourself, so it is better to stay out until the porcupines are extinct. (This fable is not a rule, it's a consequence of the rules).

⁴² EPEIRIC SEAS were common in the Paleozoic and Mesozoic, when sea levels were high enough to reduce Baltica to a smattering of small islands and bisect Laurentia (now North America). The shallow (<200 meter) waters over flooded continental shelves provided habitat for over 90% of marine species, then as now. One reason for the high biodiversity is that sea life depends upon nutrients washed down from the continents, and another reason is that ocean photosynthesis is confined to the surface. Accordingly, sea life suffers in an Ice Age, when the sea levels drop exposing the shelves, and there is little run-off. Ocean biodiversity also suffers if there is a supercontinent, which has limited coastlines and whose nutrient supply is seasonally limited. Most of the animal classes of the Mesozoic Epeiric Seas, such as ammonites, ichthyosaurs, mosasaurs, and plesiosaurs, are now extinct.

⁴³ PREY SIZE is about the same as predator size in today's African Serengeti or in dinosaur assemblages. Solitary hunters can attack animals up to 3X their size, or 5X in the case of pack hunting. This is a one step size difference in the game. In Africa, herbivores over 1-tonne (i.e. sizes 5 & 6) are generally immune to predators, although their eggs and young are attacked. Extreme size differences between predator and prey, such as between echolocating bats or whales and their prey, are rare.

H5. SIZE MATTERS.

If still tied, the smaller Carnivore becomes Endangered.

H6. TIE-BREAKER SKELETAL LOSERS⁴⁴



As a final tie-breaker, the carnivore with the higher Skeletal Number survives and the other becomes Endangered.

- a. **Same Color Final Tie-breaker.** If two Creeples species of the same color are competing, and are tied in a carnivore contest, then the owner chooses which Shape wins.⁴⁵

I. BURIALS & FOSSIL AWARDS

I1. DISPERSAL OF ENDOTHERMS⁴⁶

An **endotherm** is a Species with at least one white organ or is size 6.⁴⁷ In **player order (A5)**, each player may move his Endangered Endotherm Creeples to uninhabited habitable Biomes or Trophic Levels, using its **dispersal points** and moving per **F3, F4, F5, & F6**. He buries any endotherms that cannot find any spot to live, and stands the survivors upright.

Example: An event drops ice on your flyer creeples, making all of them endangered. During your actions, you promote a flyer mutation to gain a white cube. This allows all your endangered flyers to flee to safety during Phase A4.

I2. BURIAL OF ENDANGERED

If a Creeples is Endangered (i.e. lying on its side), stand it upright if it is in an uncontested habitable Trophic Level. Otherwise, **bury** all Endangered Creeples by placing them onto their Genotype card as Unborns. Also bury any Creeples in an uninhabitable biome.

- **Trophic Shift.** An Endangered Creeples is not buried if it can survive by performing a **trophic shift (G8)**.

I3. EXTINCTIONS⁴⁸

Your Species becomes **extinct** if it loses its Genotype card, any Basal Organs, or all its Living Creeples. Discard its Mutations, and return its dice, cubes, disks, and tools to the general pool. All its Creeples go to your pool.

- a. **Extinct Archetype.** If your Archetype goes extinct, the Archetype card goes into your Fossil Record. It can be reused by becoming a **kiwi (E6b)** or Lazarus.
- b. **Fossils.** If any card in the Tableau of the extinct species has a **fossil icon** in the upper right corner, including its Genotype Card and tools, put the card in your Fossil Record. Each will be a victory point at the **game's end (A7c)**. Do not put it into your Fossil Record if the fossil icon is upside-down.
- c. **Lazarus Exception.** If this is your last Species, so that you have no more **Living Creeples** of any Species, then you become a **Lazarus**. This allows you to use the **resurrection** action (**E7**).⁴⁹

I4. FOSSIL AWARDS



If the last ET Event of an Era has been drawn, at the end of that turn (phase **A4**) each player counts his population and receives fossil awards. If it's the **final era (A6)**, instead score as per **A7**.

⁴⁴ SCAVENGERS. The lower the skeletal number, the more likely it is to adopt a scavenger or detritivorous (decomposer) ecological role. Most terrestrial scavenging is by Player Green, especially the hyphae of fungi. Second place is by earthworms, one of Darwin's pet creatures. Third place goes to Player Black, and the larvae of beetles and flies dominate rotting compost piles and corpses. Vertebrates have very few scavengers. Hyenas, for instance, get most of their nutrition from hunting, not scavenging.

⁴⁵ CARNIVORY is a "hakuna matata", almost parasitical, lifestyle. Some herbivore has already done the hard part of transforming salad into fresh meat so similar to your own tissues. Most of the animals that made the Ordovician beachhead were carnivores, including marine snails, arachnids, amphibians, and reptiles. Even today these groups remain almost totally carnivorous. One wonders just what it was that was eating the plants, or were the first land animals only scavenging beached remains of ocean life?

⁴⁶ ENDOTHERMS are "warm-blooded" creatures with high metabolic rates, bringing the body temperature to an ideal for muscle performance. This temperature is often maintained by the insulation of fur or feathers. The basal metabolic rates of small endotherms such as birds and mammals are at least 10X than those of equally-sized ectotherms such as reptiles, fish, and mollusks. Endotherms are considered keystone species in this game, with a disproportionately large effect on their environment.

⁴⁷ GIGANTOTHERMY refers to the high volume to surface area ratio of megafauna, conferring an advantage when the outside temperature is too hot or too cold for efficient metabolism. Since an animal loses heat through its surface area, and generates or stores heat with its volume, it can maintain an ideal temperature with its mass alone. This "inertial homeothermy" is helpful for both endotherms and ectotherms. High metabolism would have been a disadvantage to big dinosaurs, which would have had trouble getting rid of excess heat. Elephants are prone to heat stroke, and help avoid this with radiative ears and spraying water. The dinosaur metabolism, whatever it was, certainly partially depended on gigantothermy: size 3 dinosaurs (20 kg) are very rare, and there are no size 1 (mouse-sized) dinosaurs (that are not birds). This dependency very likely led to their sudden extinction.

⁴⁸ EXTINCTIONS are rare at the scale of this game, where players are phyla and Creeples are classes. While species rarely last the length of one game turn, phyla and classes have proven to be practically immortal.

⁴⁹ POLAR BEARS seem headed for extinction as global warming melts the Arctic ice, but not all is as it seems. The polar bear is actually not a distinct species, but a subspecies of brown bear. Brown bears and polar bears can mate, and the hybrid offspring is called a "Pizzly" (so-named because brown bears are called "Grizzlies" in the USA). During the last 2 million years, the earth has generally been in a deep freeze, but punctuated by a dozen or so brief interglacials warm enough to melt the polar ice. We live in the latest such interglacial. An isotope analysis of a 130,000 year old fossil jaw, combined with a molecular clock study of living polar bears and brown bears, suggests that polar bears switched from an omnivorous forest diet to a diet of seals in just 20,000 years. At the time, the ice was just forming after the Eemian interglacial, the most recent interglacial with a climate rather warmer than today's. How can a totally new lifestyle evolve so quickly? I believe the answer lies in the latent genetic blueprint carried by brown bears, containing the genes for the polar bear's behavior, sealing jaw, and white coat. This genotype has been perfected during the millions of years of the present Ice Age, but introgresses during each interglacial when the ice melts, only to be resurrected again during the next deep freeze. (Introgression is a gene flow between species by backcrossing of hybrids.) Thus the polar bear is a type of Ice Age Lazarus, and for its extinction is not necessarily forever. This story of the polar bear is similar to that of the peppered moth in Industrial Britain, a famous tale of evolution in action.

- a. Population Count.** Each player counts his **Living Creeples** (i.e. all those of his color on the map, counting all Species). Also count as your population any **Host Creeples (J2)** that are on mutualism cards in your Tableau.
- b. Fossil Awards.** For each player that has fewer Creeples than you, take one fossil token from the public pool and put it into your personal Fossil Record as a permanent record of your earned VP.

Example: The first era ends in a 3-player game. At the end of the turn, Players White and Orange have 3 Creeples each, and Player Green has only 2. Players White and Orange each get 1 fossil token, but Player Green gets no fossils.

J. TRAITS

Traits are non-heritable adaptations depicted by an icon on a Mutation.

J1. MAXIMUM SIZE



The dice depicted in the upper right corner of all promotions indicates its **maximum size**. If a Genotype grows to a size beyond the maximum size shown on one of its Mutations, you must discard the Mutation and all its cubes. If it is a **Cheshire Cat (J6g)**, it loses its cubes but is not discarded. If a Genotype grows beyond the maximum size listed on its card, it either goes extinct or becomes a **kiwi (E6b)**.

J2. MUTUALISM



When you promote to an Orientation with the **mutualism** ability, and only then, you must choose a **host**. A host is another Species which shares a Biome with your promoting Species (as predator or prey). Take one Creeple from either the Unborn or Newborn Creeples (your choice) of the host species and put it on your mutualism mutation card. This Creeple is called a **Host Creeple**.

- a. Limit.** You may not choose a Species as a host which has no Unborn or Newborn Creeples to steal. With 2 mutualism cards, you may mutualize the same species twice, etc. If you promote with no suitable host, then no Host Creeple is placed.
- b. Population Bonus.** Each Host Creeple on your mutualism card counts as 1 population during **fossil awards (I4b)** and gives you 1VP at the end of the game (**A7d**).
- c. Magic Mushroom Rule.** Player Green can choose any Species with an unpromoted Mutation with the Horror-plant icon as a host, even if not co-located.⁵⁰
- d. Loss of Mutualism.** If the host goes extinct, return the Creeple from the card to the Unborn of its color.

J3. VENOM



Venom is a Trait conferred to a Species by the black widow icon on one of its Mutations. A venomous herbivore cannot be eaten by a Carnivore unless the Carnivore is either venomous itself, or larger (**F4b**).

J4. MONSTER



A **monster** is a Trait that places a monster token on the Mutation. This token is a Plus Organ considered to be multiple cubes, as many cubes as the Size Dice of the Species. This monster token, of the specified color, is placed during **promotion (E2d)** to a monster. If a monster token Atrophies, e.g. during radiation or mutagens, the species size is reduced instead, see "Atrophy". A monster cannot be removed until the Species is at size 1. The monsters are Godzilla, Kong, Kraken, Dragon, and Yeti, with apologies to the monsters too many to mention.

J5. HAUSTORIUM.



If a Species has a promoted **haustorium** mutation (card 56), this Species has a specific Skeletal Number (either 0 or 5) that overrides the player's normal skeletal number for this Species only. Thus in **contests (G7, H6)**, this Species always has the lowest number (if parasitic plant), or the highest (if parasitic fungus).

- a. Mutagen.** During a **mutagen event**, a Species with a haustorium Skeletal Number of 5 must use the **dark heart limit (D7b)** and a Species with a haustorium Skeletal Number of 0 must use the **green heart limit (D7c)**.



⁵⁰ THE DOMINANT HERBIVORE in today's New World tropics is not a vertebrate but the leaf-cutting ant Atta. I have seen my garden in Arizona being carried away like the Great Birnam Wood in Macbeth. The ant doesn't actually eat the leaves, but instead feeds them to subterranean gardens of fungi (once again, the real dominant herbivore). Thus the ants have invented agriculture. The fungi they harvest is a unique coadapted species, which like maize could not survive without the farmers who have bioengineered them.

16. EMOTIONS⁵¹

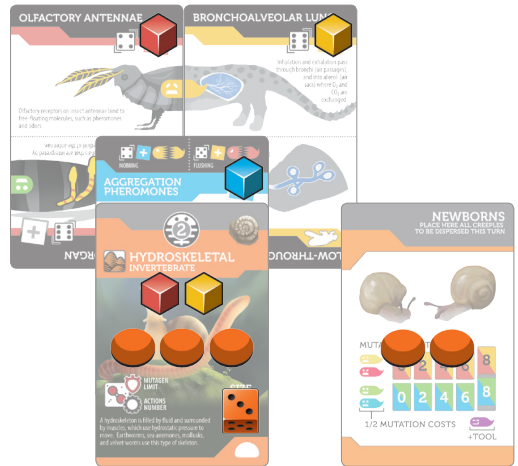


Many promoted cards depict one or two “half-emoticons”. Each right-left match establishes an **Emotion**, either anger (red), fear (yellow), happiness (green), jealousy (blue), or curiosity (purple).

a. Heads, Tails, Brains. There are 3 kinds of cards in a Personality: **heads**, **tails**, and **brains**. **Heads** have their half-emoticon to the right edge of the card, while **tails** have it on the left edge. **Brains** have half-emoticons on both edges.

b. Personality Formation. A

Personality is a row of 2 or more cards forming emotions arranged in a row including the top Mutation of a Species. Each adjacent card in the Personality must have established at least one Emotion, by providing for the right or left half of its emoticon. During each **promotion** of a Mutation (**E2g**), examine the Species repertoire of promoted cards to see if you have both halves of one color of Emotion. If so, you may use them (with their Organs) to form a Personality to the right of the Tableau column. Note that upside-down emoticons are not in play.



Example: You have a Tableau with 3 Mutations and 5 Organs. For one action, you promote your air sacs into a bronchoalveolar lung. During this same action, you combine this lung with the olfactory antenna, also in your Tableau, to form the “fear” emoticon, with the cards arranged as shown above. You imagine this strange beast using its antenna to sense danger, and its lungs to timidly flee from danger. With another action, you could promote your aggregation pheromones into a mobbing behavior, and insert it as a “brain” between the antennae head and the lunged tail. This duplicated emotion gives it an additional bonus for purchasing yellow cards and increases the number of cards you have with Cheshire Cat immunity and endgame VP value.

c. Multiple Personalities Forbidden. Each Species is allowed one Personality (remember, each Personality can have multiple Emotions), which can contain only one head and one tail. Allowed configurations include head-tail, head-brain-tail, brain-brain-tail, etc.

Example: Your bird species has two promoted cards with head emoticons, and one limbic system brain that accepts an angry head and a fear tail. You form a Personality for it by joining an angry horned head to the brain, making it an angry bird. Now that it has a head in its Personality, its other head cannot be added. But if it promotes adrenal glands brain, which accepts a fear head, this could be added to the limbic system to form a Personality with one head and two brains.

d. Personality Insertion. New cards can be added to the Personality to form new emotions. However, cards can never be ejected from the Personality to make room for new ones.

e. Reduced Cost. Once a Species has one of the anger (red), fear (yellow), happiness (green)⁵², or jealousy (blue) Emotions, halve the **cost (E1a)** when acquiring that color of card for the Species. If it has two or more Emotions of a color, all cards except for the leftmost (free) card have a cost of 1.

Example: When acquiring red Mutations for your angry bird of the previous example (and not for your other Species), the Cost (**E1a**) is halved.

f. Language. If one of your Species gets 3 total Emotions consisting of two or more colors, you acquire language and end the game per **A6**.⁵³

⁵¹ EMOTIONS are a primitive form of language, defining “language” as a cognitive tool for organizing sense data and thereby setting a behavioral mode. This mode sets an imperative: “eat”, “mate”, “fight”, “flee”, along with the complex algorithms for accomplishing these biological functions. In all vertebrates since jawed fish, emotions are programmed by the limbic system. The decision-making algorithms of invertebrates are often heavily influenced by pheromones. In tense mating situations between carnivores like spiders, the emotional state of the female determines whether her suitor gets eaten or not. The decisions in eusocial insects like honeybees are also state-dependent — they interpret ambiguous stimuli more negatively following experience of an aversive event.

⁵² HAPPINESS here is less Aristotle’s eudaemonia and more the satisfaction of a full belly. Accordingly, the green emotion is the hunger drive, the blue emotion is the sex drive, the yellow emotion is flight, and the red emotion is fight.

⁵³ LANGUAGE has nothing to do with communication. The two have very different functions, and creatures can have one without the other. Only in the genus Homo are the two so intimately intertwined as to be inseparable. As modeled in Bios: Genesis, communication can be between cells or individuals, using a variety of chemical or sensory means. Most animal communications are variations of “come hither!”, “stay away!”, or “take cover everyone!”. Language, on the other hand, is a tool of cognition. Its function is to organize the kaleidoscopic succession of sensory material, the “blooming, buzzing confusion” as William James calls it, and integrate them into cognitive units called concepts. Language is useful, even essential, for a man alone on a desert island. These ideas are developed further in the third game of the Bios trilogy: *Bios: Origins*.

g. Cheshire Cat.⁵⁴ Personalities can lose their Organs during Atrophy, but they cannot be demoted or discarded unless the Species goes extinct.

J7. TOOLS



For every purple (curiosity) Emotion acquired, you may immediately choose one of the **tool public cards (C1b)**.⁵⁵

Each tool is a predator weapon allowing it to hunt the Shape shown on the card. It can also be used by Herbivores per **J7c**. Choose one side of the card to play into the Tableau of the tool-using creature.



a. Fossil Tools. A tool goes into your Fossil Record if the Species using it goes extinct.

b. Diving Bells. The diving bell tool allows you to inhabit as a Carnivore any Biome with swimming prey. This allows the Carnivore to inhabit normally **uninhabitable (F3c)** seas and Offshores. However, the Diving Bell does not allow an Herbivore to inhabit seas or Offshores.

c. Tool-using Herbivores. An Herbivore with a tool cannot be preyed upon by Carnivores of that Shape, unless the Carnivore has a tool allowing it to hunt the Herbivore's Shape. As soon as your Species gets a tool, perform a **prey suitability** check (**F4**) on any Carnivores preying on them to see if they become Endangered.

d. Antivenom. All tools allow your Carnivore to ignore venom.

Example: A swimmer moves from a swamp and over a forest, in order to inhabit a sea as an Herbivore. This requires 3 DP. A burrower also moves from the swamp to the sea, but as a carnivore. Normally a burrower cannot inhabit a sea, but since he has a diving bell and is able to eat the swimmer, this is allowed. Note that the diving bell does not allow it to survive as an Herbivore in the sea.

J8. EXPERIMENTAL APOMORPHIES

These rules are optional and experimental. They can be used, for instance, to help a newbie player, or one that is "sandwiched" (i.e. an intermediate Skeletal Number that is neither the highest nor the lowest in the game).

a. Player Orange Radiation Immunity. Due to the reduced nervous system needed for hydraulics, Player Orange (hydroskeletal) is immune to **Darwinian Radiation** (green/blue icon, see **D8**).

b. Players White and Green Growth. Due to their ever-growth, Players White (vertebrate) and Green (plant-fungi) can perform one free **resize (E6)** once per their action phase. If they resizes an Herbivore however, any of its predators also get one free optional resize, at the same time.

c. Player Black Metamorphosis. Due to the proven ability of insects to shrug off mass extinctions, Player Black (exoskeletal) can perform one **Neoteny (E5)** per game turn without expending an action. This can be at any time, even to avoid extinction during a mutagen event. However, he must always surrender one fossil to do so.⁵⁶



K. MARS SOLITAIRE GAME (ACHTERBAHN GAME)

Both Venus and Mars seem to have started out like Earth, with oceans and a CO₂ atmosphere, but then plate tectonics and thus continent formation stalled, and their oceans were somehow

⁵⁴ CHESHIRE CAT refers to the smile left behind when the cat is gone, likened here to the persistence of a personality.

⁵⁵ CURIOSITY, the purple emoticon in this game, is associated with experimentation and learning, otherwise known as intelligence. It is associated with the cerebral cortex in mammals and the corpora striata in birds. These structures of the nervous system allow expectations based upon generalities, a type of percept formation and subconscious induction. However, associative learning is a universal adaptive mechanism shared by plants and animals, as proven, for example, by experiments with pea seedlings in a Y-maze. The psychologist Julian Jaynes argues that intelligence has nothing to do with consciousness, the strange ability to review a collection of past experiences in a mental re-enactment. This distinguishes tools, and tool-use, from technology, i.e. a tool whose function can be visualized even before it is made. This distinction will be explored further in Bios:Origins, the third game in the Bios trilogy.

⁵⁶ A RIGID EXOSKELETON is vulnerable to impacts since it is filled with incompressible body fluids. Small arthropods may survive falls due to a very low terminal velocity, but larger spiders and millipedes split open if they fall. The giant cricket called the weta cannot survive jumping stresses that a similar-sized mouse can easily handle.

lost.⁵⁷ If organisms had gotten started, they would have to cope with sluggish Cratons and dwindling super-salty oceans. In the one-player game, you play both an animal and a semi-automated plant (Player Green) on Mars (optionally Venus or Earth). The goal for your animals is to gain VP while keeping the oceans from drying up. You will need the plant to stay alive, but it could turn on you as a horror plant.

- a. The Plant.** Player Green, hereafter known as the *plant*, follows all the Horror Plant rules: action maximum (**A2b**), *green heart limit* (**D7c**), cannot select metabolic cards without the horror plant icon (**E1d**), and *magic mushroom* (**J2c**).
- b. The Animal.** You start as any other color you wish, and will be hereafter referred to as the *animal*.
- c. Game Ends in Era III per A6a.** It also ends on phase I of any turn if either the seas are gone or if there is a *moist greenhouse runaway* (**K5e**).
- d. Victory.** Win by surviving and keeping the seas from evaporating away (**K5a**, **K5c**). To decisively win, you must obtain 15 VP (**J6f**).
- e. Plant Protagonist Variant.** You may alternatively play as the plant, while controlling one animal player (as sort of a parasite). This could be useful for campaign games in which you ended the Genesis game as a plant. Since the plant is a player, skip the *semi-automated plant rules* (**K8**). To decisively win, you must obtain 15 VP.

K1. SEQUENCE OF PLAY - SPECIAL FOR SOLITAIRE GAME

- a. Events.** Ignore *climax events* (**D5**). Ignore events (such as craters) that strike Cratons not in the game. Ignore *deluge events* (**D6**), unless it's too hot, then Liberate a white disk (**K5c**). If a Reservoir Event marked with the rain-shadow icon occurs, then Liberate a white disk (**K5a**). Ignore events that transfer green disks, except for gun events that liberate green disks (**K5d**). With the *Raindance superpower* (**K6**), you can expend one plant action to make it rain during the end of the event phase.
- b. Actions.** On the plant's turn, first check to see if it can select any horror plant mutations in the metabolism row (**K8a**). Then check to see if it can promote any cards to venom or mutualism. Then you are free to choose any remaining actions.
- c. Mother.** On the plant's turn, first check to see if any of its Newborns can successfully disperse as Herbivores (**K8d**).
- d. Burial.** Skip the scoring rounds in the solitaire game.

K2. TROPHIC LEVELS - SOLITAIRE GAME

There are three Trophic Levels in the game: Plant, Herbivore, and Carnivore. The plant can be an Plant or an Herbivore, never a Carnivore. An animal can be an Herbivore or a Carnivore, never a plant. Creeples in a hex at these 3 Trophic Levels are lined up as follows (from bottom to top): first plants, then herbivores, then carnivores at the top.

- a. Herbivore Contests are changed to be the same as Carnivore Contests (Part H).** Therefore, an Herbivore needs to be the same Shape as the plant to eat it. See **K7b**.
- b. Cactus Eaters.** As a special rule, an Herbivore with at least 2 green organs can eat armored plants (cactus).

K3. SETUP - SOLITAIRE GAME

Setup is as per a terrestrial *Achterbahn game* (**C1**) with the following exceptions:

- a. Starting Disks.** If starting on Mars, there are only 6 black, 6 white, and 0 green disks in the game. If starting on Venus or Earth, there are 12 black, 12 white, and 0 green disks.
- b. Cratons & Seas.** For Mars, use the Tharsis and Arabia Cratons.⁵⁸ For Venus, use the Aphrodite and Ishtar Cratons.⁵⁹ For Earth, use the standard 4 Cratons. Set the Cratons in any order and separated at Latitude 4. Place a white disk into each basin or sea hex. Place a black disk into the 6 available Offshores on Mars or Venus, but on Earth place only one black Offshore per Craton. Because climax events and wind latitudes are not

⁵⁷ OCEAN LOSS on Mars and Venus dumped the water into the atmosphere, some of which made it into the ionosphere. Here it was ionized by cosmic rays, and the lighter hydrogen lost to space with the solar wind. And the leftover oxygen? This apparently combined with a carbon source to form the carbon dioxide atmospheres of both planets today. The source of the carbon is unknown. It's the same problem for the Earth. Was it mostly organic (C-H-containing molecules) to begin with, or lots of CO₂, or something else? For the Earth to have been warm early in its history, when the sun was faint, there must have been plenty of carbon-bearing molecules around. Hundreds of times more CO₂ than today, or lots of methane. Regardless, thanks to the long-term presence of oceans and the hydrologic cycle, most of that is now in the form of carbonates in the ocean seafloor or deep in the crust. On Venus or Mars, loss of ocean would have made such a sequestration impossible. Jonathan Lunine, 2017

⁵⁸ THE RUGGED SOUTHERN HIGHLANDS OF MARS tower kilometers over the smooth basins of the northern hemisphere. It is mysterious why the two hemispheres of Mars are so different, no other planet has such a division. If Mars had an ocean during its Hesperian Era, the north would have been underwater and the south high and dry. Unlike those on Venus, the Martian highlands are heavily cratered and thus ancient, making a continental origin unlikely. However, Pathfinder identified one highland rock with an elemental composition consistent with andesite, and Mars Surveyor discovered faint magnetic traces of parallel magnetic strips, perhaps ancient spreading centers. This scenario assumes that Mars still has two very slow-moving cratons, divided by Valles Marineris.

⁵⁹ THE HIGHLAND PLATEAUS OF VENUS may contain light-colored granites, according to recent infrared data from Venus Express. You may remember from Bios:Genesis that terrestrial granite comprises the low-density chemical "scum" of continents buoyantly supported with a deep root into the mantle. Another indication of continents on Venus are the arcuate trenches known as chasmata found around Aphrodite. Similar to trenches at terrestrial subduction zones, they may indicate ancient continents, produced by past volcanic activity and once surrounded by oceans.

used, Latitude strips are unnecessary, and the *humidity niche (G5)* is always green.

- c. Reservoirs.** Place remaining black disks into the Atmosphere, and remaining white disks split evenly between Clouds and Atmosphere. For Mars, you should end up with one white disk in the Clouds and another in the Atmosphere.
- d. Plant Starting Creeples.** Starts with only 20 Creeples: 5 Archetypes, 5 burrowers, 5 swimmers, and 5 armored. For variants where the plant is player-controlled (**L1**), it starts out with 17 Creeples: 5 Archetypes, 4 burrowers, 4 swimmers, and 4 armored. The extra Creeples including all the green flyers are put aside and will not be used. The plant cannot speciate into flyers.
- e. Plant Creepie Setup.** The plant places 2 Archetype Creeples onto the map, into any hex that is adjacent to a sea (hex with a white disk).
- f. Animal Setup.** The animal starts as a Lazarus, so no setup required.
- g. Green Disks are not used in the solitaire game!** Place all the Unborn green Creeples on the Oxygen, as if they were green disks. This yields 3% Oxygen.

K4. OXYGEN MANAGEMENT

Green Creeples take the place of green disks for all purposes! Unborn Creeples reside on the Oxygen to indicate the animal action maximum. Place dead green Creeples into the Oxygen as if they were green disks, i.e., one Creepie per slot, loaded from the bottom up.

- a. Birth.** Remove green Creeples for Newborns from the Oxygen.
- b. Offshore Seaweed.** A green swimmer can inhabit a black offshore disk, becoming a bloom. If there is a green swimmer in an Offshore, the hex it is adjacent to is considered to be a habitat (**K7b**) that is 1 hex from water.
- c. Breathtaking Rule.** On an animal's turn, the oxygen level at that instant tells how many actions it has.

K5. EVENT PHASE

The Events are modified as follows:

- a. Rain-shadow Sublimation.** If a Reservoir Event with the rain-shadow icon occurs, do not perform the specified action. Instead simply Liberate one white disk.
- b. Anticlimactic.** Always ignore climax events.
- c. Deluge Evaporation.** Ignore a *deluge event (D6)*, unless the Latitude Strip is too hot. If so, then Liberate one white disk.
- d. No Greening Events & Plant Extinction.** Ignore all Events that would transfer green disks, except a gun event that Liberates green will always destroy one Species of plant (the owner's choice). Place dead green Creeples into the Oxygen. The plant populations are ignored in *crowd diseases (D9)*.
- e. Moist Greenhouse Runaway.**⁶⁰ A *runaway greenhouse (D10h)* cannot occur on Mars, and only occurs on Earth or Venus if the Clouds and Atmosphere contain all 24 white and black disks.
- f. Radiation.** Mars and Venus have no protective magnetic field, so radiation events, instead of being either red or yellow, or blue or green, are instead red and yellow, or blue and green.
- g. Olympus Mons.** The black disk in the northernmost Offshore of Tharsis cannot be removed except by a collision that subducts it. Exceptionally for an Offshore, it is uninhabitable by Creeples or plankton. All volcanic craters on Mars automatically occur on the hex adjacent to Olympus Mons.
- h. Snail Tectonics.** Mars and Venus Cratons move extremely slowly, so that no rifts, collisions, drift-bys, or Latitude moves occur when the event card is resolved. Instead, the "biosphere stable" icon additionally indicates that if the previous turn had a rift, collision drift-by, or latitudinal drift, it is performed now. Note that the first card of each era, even if it does have a "biosphere stable" icon, does not generate snail tectonics.^{61 62}

⁶⁰ MOIST GREENHOUSE RUNAWAY occurs if water vapor from overheated oceans increases the troposphere humidity to 20%. Water vapor is the biggest driver of the greenhouse effect and unless it is lost to space rapidly, it allows the atmosphere to accumulate even more water. The atmospheric temperature could rise to 1000°C, enough to melt the surface and decompose limestone. The runaway greenhouse threshold is largely independent of CO₂, since the IR opacity is overwhelmed by the greenhouse of water vapor.

⁶¹ SNAIL TECTONICS ON MARS may be due to the small size of the cooling Martian core. Around 4.1 Gya, this also shut down its magnetic field and halted most volcanism.

⁶² SNAIL TECTONICS ON VENUS may have been responsible for its global resurfacing 300–600 Mya ago, estimated from cratering records and the time of the Late Heavy Bombardment as dated by lunar rocks brought back from the Apollo mission. But the tectonics then halted, possibly because Venus became so dry and hot. Dry rocks retain greater strength at high temperatures than do wet rocks, and dry melts have viscosities that are orders of magnitude higher than those of wet melts. Moreover, a surface temperature a couple of hundred Kelvin hotter than Earth and a thick basaltic crust make the lithosphere less dense than the underlying convecting mantle. And instead of splitting into cratons as on Earth, the hotter cracks healed faster. Both factors may have halted plate bending and subduction. Once subduction stopped, there was nothing to stop the buildup of CO₂ in the Venusian atmosphere.

i. Valles Marineris.⁶³ A Pangea rift event will always split the two Cratons if they are joined.

K6. EVENT PHASE - RAINDANCE SUPERPOWER

Medea enjoys this superpower only if its **population (I4a)** is greater than its **heart limit**, either dark (D7b) or green (D7c) as appropriate. If so, you can make it rain during the end of an event phase by degassing one white disk from the Clouds to any sea hex. You may additionally choose to move one mountain from any Continent to any Offshore, which represents erosion. This can be done only once per event phase. If you choose this action, the plant has one less action during the following action phase.













a. Medea controls the superpowers.⁶⁴ In the solo game, this is always the solo player.

K7. MOTHER PHASE - BIOME ENTRY

The Biomes are either highlands or basins. Both are wastelands, costing 1 DP to enter (2 DP for swimmers). Nothing grows there until they are occupied by a green Creeple. You may only enter a Biome as an Herbivore if there is a plant there (i.e., a green Creeple). As usual, you may only enter a Biome as a Carnivore if there is an Herbivore to eat.

a. Land and Sea are the only two habitable Biomes. If the Biome has no white disk, it is land. If it has a white disk, or if it is Offshore, it is **sea (F3)**. (If it has a black disk, it is a mountain.)

b. Alien Plants. The green Creeples are plants with the following **habitats** and roadrunners:

Alien Plant	Swamp Plant	Seaweed	Tuber	Cactus
				
Habitat	1 hex from water 	In water or carbon offshore 	1 hex from water 	1 or 2 hexes from water 
Roadrunner Niche (G4, H3)				

c. Wilt Rule. A plant that is not in its proper **habitat** will die and be removed during the **burial phase (I2)**. Note if the seas lose all their white disks (water), the planet dies and everyone loses.

d. Winds. On Mars, the Winds are Earth normal. On Venus, the Winds are easterlies, always blowing from right to left in all Latitudes.⁶⁵

Example: A seaweed lives on a white disk. During a rain-shadow, the white disk disappears. During the action phase, the seaweed populates, and during the mother phase its daughter moves to a remaining white disk. The wilted mother then dies and is buried in **Phase A4**.

K8. SEMI-AUTOMATED PLANT RULES - SOLITAIRE GAME

a. Event Phase. During radiation or mutagen events, you may choose horror plant mutations only if there are no other cards to legally take losses from.

b. Action Phase. On the plant turn, you may perform actions as you wish, except:

- If there is a card available with the horror plant icon, the plant must select it if it can, starting with the cheapest (leftmost). You choose the acquiring Species.
- If it has an unpromoted card with venom or mutualism in its Tableau, the plant must promote it to that trait.
- You can only resize up, not down with a plant. Furthermore, you can only pass with a plant action if all its Species are at the maximum size for its mutations.

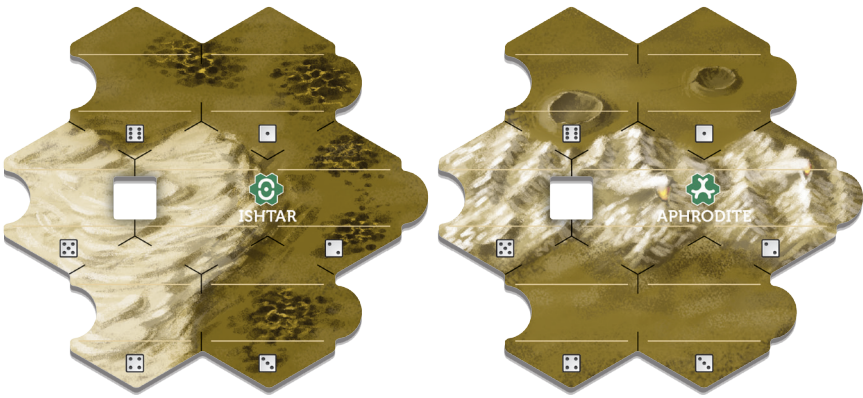
c. Extinction is Forever. No resurrection is allowed in the solitaire game.

d. Mother Phase - Plant Dispersal. On the plant turn, you may disperse them as you wish, except that all dispersing plants (including new plant species) must become Herbivores if it is possible to do so, including competition with your own Creeples if this would be successful.

⁶³ VALLES MARINERIS, possibly a huge tectonic subduction valley, divides the two equatorial cratons Tharsis to the west and Arabia to the east.

⁶⁴ MEDEA is alive and well on Mars! Sporadic releases of methane are a possible indication of clathrate hydrates in a Mars cryosphere, which makes a gun episode possible. The source of methane is likely not volcanic, due to the lack of sulfur dioxides. One possible source are Martian methanogens living deep in the crust.

⁶⁵ HURRICANE WINDS blow constantly on Venus in a westerly direction, the same backwards direction that Venus rotates. At some altitudes, the winds blow at 700 km/hr, twice that of Earth jet streams. Although the surface winds are only a few km/hr, at 93X Earth density this is enough to move small rocks. Winds on Mars are occasionally 300 km/hr, yet with an atmospheric density only 0.6% that of Earth at sea level, such winds feel like a gentle breeze of around two kilometers per hour—hardly enough to move fine dust. The game assumes the atmosphere of Mars was once far thicker.



L. VENUS MULTIPLAYER VARIANTS⁶⁶ (ACHTERBAHN GAME)

Special rules for Venus: Setup disks (K3a), Cratons (K3b), Winds (K7d).⁶⁷

L1. VENUS PLANT VS. ANIMAL GAME

This is a 2-player game, with one player being the plant, and the other player his choice of orange, black, or white. Use all the Solitaire Game rules (K1 - K7), but skipping K8, since the plant is not-automated.

- a. **Superpowers.** The plant always holds the Medea card, but the animal always controls the *cloud-seed superpower* (D13).⁶⁸ If the animal goes extinct, no more black disks can enter the atmosphere (because the animals which exhale carbon are dead).
- b. **Scoring Rounds.** Each animal creple counts as 2 population when awarding fossils, but only 1 population in the end scoring (A7).
- c. **Victory.** Win if by the end of the game you have the most VP and if the seas are not lost (i.e., there are still white disks remaining on the map). However, neither player wins if one is extinct at the end of the game.

L2. VENUS ANIMAL GAME

This variant is the same as the *plant vs. animal game* (L1), except it plays with two or three players, who are all animals. Therefore, the plant is *semi-automated*, using rule K8.

- a. **Start Color.** All players randomly select their colors and start as Lazarus.
- b. **Claim Medea.** Although the lowest skeletal initially hold the Medea card, it can be claimed per E8. Medea controls the plant as well as the superpowers.
- c. **Victory.** Win if by the end of the game you have the most VP and if the seas are not lost.

M. EXAMPLE TURN 2-PLAYER (ACHTERBAHN GAME, ADAM GASTONGUAY)

GARY

BRENDA

Brenda is content because she won the previous scoring round and holds the bonus *fossil token* (I4b). Being east of Gary on Siberia at latitudes 3 and 4, she is able to raft her creples over to invade as she wishes. Gary is happy because the planet has been heating up, resulting in more humid rainforests. Most

⁶⁶ WET VENUS is assumed to have started in a state similar to Mars and Earth: hot from accretion and wet from the impacts of aqueous bodies from beyond the solar system's snowline. The simplest interpretation of the D/H ratios of Venus:Mars:Earth:Sun (2000:70:10:1) is that Venus has lost the vast majority of its water, while Mars lost about 85% of its water to space, with the rest sequestered into polar ice-caps and subsurface permafrost.

⁶⁷ HOT VENUS is closer to Sol than Earth, yet its Bond albedo is so high (0.8), its surface actually receives less solar energy as does Earth. So why is Venus so hot? The molecular weight of diatomic gases such as O₂ and N₂ is only 2/3 that of a triatomic gases, such as CO₂. In a column of atmosphere a hundred kilometers high on a planet the size of Venus or Earth, the heavy gas CO₂ leads to a pressure of 93 bar, versus 1 bar under a diatomic atmosphere. Gas under high pressure is hotter, just touch your bicycle pump after vigorous pumping. The greenhouse effect should be larger on Venus, mainly because higher density atmospheres have a larger thermal backscatter. The almost pure CO₂ air of Venus cannot have much of an effect on the greenhouse, since the day and night surface temperature of Venus are the same. See the next footnote for the effect of clouds on Venus.

⁶⁸ VENUSIAN CLOUDS have accumulated into 3 thick banks, a greenhouse blanket preventing the radiation of heat into space. As players of High Frontier recall, radiation losses increase as the 4th power of temperature increases, so one terraforming strategy on Venus would be to remove the clouds so that it can come to a much cooler temperature. One reason that the clouds can accumulate so thick is that the planet rotates so slowly: 2 m/s on the equator compared to 1700 m/s on Earth.

of his lifeforms have more red cubes than Brenda, which give him an edge under their canopy. A few attacks have been going back and forth on Baltica, but it is now turn 9, and Brenda needs to finish Gary off now to ensure the earlier Fossil token wasn't for naught.

M1. EVENTS

Gary turns over the next event card revealing flood basalt traps (7). This is not a stable biosphere, so Brenda checks the Atmosphere. It's Eden, so she flips a goldilocks biosphere card, placing silicate weathering (33) beside the basalt traps. Reading the card from top to bottom, we see:

- a. Basalt Traps explode somewhere in Siberia.** A roll of the d6 shows a crater location in hex 6, and the 1 black disk in the Atmosphere is degassed there. The 2 creeples in hex 6, a Black archetype and its Black burrowing predator, are inverted to show their new, endangered status.
- b. Gondwana shifts West,** smashing the newly damaged Siberia in the north. A Siberian mountain grows in hex 1, inverting another Black Archetype.
- c. Climax spawns some more forests.** A boon for Brenda as it raises her black heart limit to six!
- d. A mountain** (chosen by Gary, who holds the Medea card) is liberated into the Atmosphere. This replenishes disks degassed in the previous Event.
- e. Biosphere Event.** Gary uses Medea to his advantage with the silicate weathering card, removing a mountain between himself and Brenda, allowing for greater attack potential. He also adds a carbon and a plankton bloom disk on an offshore near his swimmers so they can expand there. It's good to be the Medea.

M2. ACTIONS PHASE

Looking at the top of Flood Basalt Traps again, we see Gary is set to go first (**A5**).

Gary has 2 actions in the Eden climate. He uses the first to populate his armored, adding two armored newborns (two because of the inherited blue basal cube). His plan is to attack Brenda's flyers preying upon his archetypes on Baltica hexes 4 & 5. He uses his other action to resize his armored plants to size 3, so that he won't be poisoned should he have to increase his own archetype's size later for mobility or defense purposes.

Brenda is worried now. She just took a big hit, losing 3 Creeples. Right now all she can think of doing is getting as much population on the board as possible to regain her footing. Looking at the display, she sees that yolky eggs (74) is available and she has enough unborn to select it. She grabs the card and adds two blue cubes to her burrowers. Next she populates them, but limits the newborns to 2 so she retains enough unborns to possibly buy sparring dimorphism (92) next turn, which is coming down the line. At 12% oxygen, she has one last action this turn, which she uses to populate her flyers. She only gets one, but they are the most agile of shapes, so she'll be able to disperse them somewhere.

M3. MOTHER & DISPERSAL PHASE

Gary disperses his two armored creeples on the 2 forest hexes where Brenda's flyers sit. In the ferocious carnivore contest, Gary's armored plants have more red cubes and drive both flyers into endangered status (**H3**).

Brenda is lucky to be able to place her one Newborn flyer the next hex over, again becoming a Carnivore to Gary's Archetype. She then sends her Burrowers east, away from Gary, realizing that Siberia is ruled by the plants, and she'll have to rethink next turn on how to take it back.

M4. BURIAL & FOSSIL AWARD PHASE

Brenda loses 5 Creeples off the map: 2 flyers, 2 Archetypes and a Burrower. She puts them into her Unborn. This is not a scoring round, so the players go to the next turn.

N. FLOWING BIOS:MEGAFUNA INTO ORIGINS: HOW WE BECAME HUMAN

At the end of Era III (**A6a**), you may decide to enter Era IV and start either a *Origins: How We Became Human* game (Sierra Madre Games, 2007), or a *Bios:Origins* game. Note that Era IV in the *Bios:Megafauna* game is the same as Epoch I (Pleistocene) in either *Origins* or *Bios:Origins*. Use one of your Species and its acquired emoticons as your starting hominid in the game.

- a. Brainmap Assignment.** The winner in Megafauna is awarded first choice of Brainmaps; the runner-up has second choice, etc.
- b. Starting Encephalization.** All Brainmaps start with the instinct icons uncovered according to the emoticons achieved in Megafauna: red or yellow = alpha, green = natural history, blue = language, purple = manual dexterity. Players without Emoticons start with all instincts covered on the
- c. Brainmap.** Extra cubes needed to cover icons come from population, and excess cubes not needed on the Brainmap go into the innovation track.
- d. Greenhouse.** The Origins game starts in an Ice Age if the Megafauna Greenhouse ended at "too cold", and in a Tropical Age otherwise.⁶⁹

⁶⁹ ICE AGE is a period when ice exists on the planet. Through most of Earth's history, ice was unknown. But recently, less than 1/10 of a game turn ago, Earth was plunged into an Ice Age, with a series of periods with carbon dioxide levels so low, the planet came close to killing off its plants. For the last 15,000 years, the climate has been thankfully climbing out of the last deep freeze. But if it follows the last dozen cycles, it will soon peak and fall into the next deep freeze. Anthropogenic

THE CARBON CYCLE (PHIL EKLUND)

This essay discusses the controversial relationship between climate and carbon. I avoid talking about the human impact on the carbon cycle, because humans don't make an appearance until the next game in the series: Bios:Origins. This game takes a timid mainstream approach: it treats CO₂ as a mild greenhouse gas (20% of Earth's greenhouse effect according to NASA), and makes greenhouse a significant factor in biosphere climate. Both claims are uncertain, and I hasten to say that mainstream does not make something true, or is even an indication that it is true. Only evidence does that.

Although the carbon cycle in this game uses mainstream data, it is not "carbon only". Like most paleoclimatologists, I see the fossil record as evidence that Earth is driven by mighty events rather than carbon: the crash of continents, the impact of asteroids, continent-wide flood basalts, and tremendous solar eruptions. I call this view "Achterbahnist", from the German word for "roller coaster". If you have played any of my other games, and watched your hard work and grand planning die in scientifically interesting but no less heartbreaking ways, this term needs no further explanation.

One such Achterbahnist is Syun-Ichi Akasofu of the International Arctic Research Center. He looks at recent big and little chill events like the "Little Ice Age" (LIA), the Younger Dryas, and the "Big Ice Age" (i.e. the last Glacial Maximum). These three events (see diagram below, adapted from NOAA) are so recent that humans suffered through them.

Abrupt climate changes are common in the record, even during the greenhouse dinosaur days. But the most recent "gun" is the Younger Dryas of 12,800 years ago. Sedimentology in Ireland reveals temperatures plummeted 10°C in months, not years. Then after a brief deep freeze of 1300 years, temperatures skyrocketed 15°C in just a decade or two.

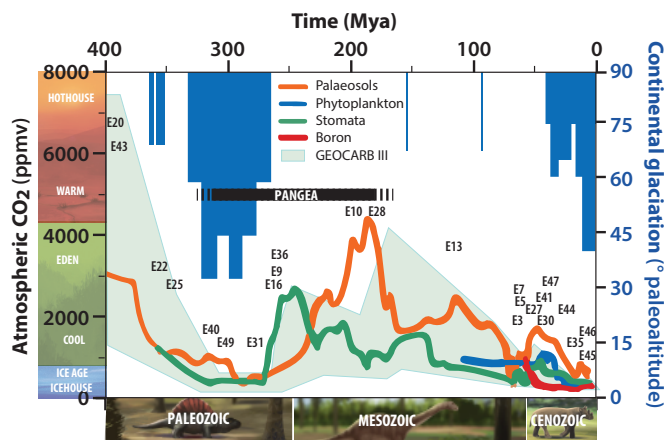
Thus humans experienced Achterbahn swings in the late Pleistocene, a "gun" event far beyond today's warming rates of fractions of a degree. In game terms this took Earth from Ice Age to Icehouse, and back again, converting Europe from forests to an uninhabitable ice sheet in just a few seasons, and recovering even faster.

The cause of both these guns (the plunge and the skyrocket recovery) is unknown. In my game Origins (2009), I suggested a solar-driven Dansgaard-Oeschger event as a cause. Or a huge ice dam may have busted, interfering with ocean currents. Whatever the cause, the Earth is still recovering from this very recent catastrophe, less than 0.0005 game turns ago. Even more recent is the LIA, and we are still in this recovery, which is about a half a degree rise per century. Dr. Akasofu has demonstrated that the temperature oscillates around this trend line in multi-decadal wavelengths, which has shown great predictive power.

As opposed to the very long-range traditional paleoclimate change studies, programmers of "GCM" computer climate simulations rely on accurate digital data only available since 1970. These hope to forecast the weather the same way that the 9-day weather forecast is produced. And this suffers the same shortcomings, namely that it is useless beyond a few weeks due to the chaotic nature of the atmosphere, the massive computational power required, and the fragmentary understanding of atmospheric processes. Such models have failed both long-range forecasting and hindcasting.

Gamers may have the impression, in today's propaganda blizzard, that the CO₂ level today are tremendously high and climate change is unprecedented. Much of the carbon debate is between the paleoclimatologists and the GCM programmers. The programmers assume that carbon is the sole driver of climate, and dismiss paleodata as inaccurate. However, the total range of "accurate" data the programmers work with would be but a tiny dot on the far right of the graph. Any understanding of the Earth requires a study of its deep past, and the solar, cosmic, and geological factors that drive it.

One such factor is the LIA, which the programmers claim never existed. Look at the most publicised versions of the "MBH hockey stick" graphs, such as the one reproduced in my game Origins. Each shows a sharp bend and a long flat stick going backwards in time. Because the stick is flat, such graphs claim that neither the Little Ice Age nor the Medieval Warming ever existed, and thus global warming is only a few decades old. But studies of glaciers the world over show that they were in retreat during the Medieval warming, but advanced during the LIA, and started to retreat



carbon releases from the industrial era are sometimes said to prevent this from happening, but this may be a false hope. First, climate records clearly show brief Ice Ages occurring even with carbon dioxide levels 15X today's (e.g. in the Jurassic and Cretaceous). Second, over the long run the loss of Earth's precious carbon dioxide is inexorable, and the small increases due to cars and factories will not change this. The situation is like a brisk September morning. In the short run it will get hotter as midday approaches, yet over the longer run it will get colder as winter sets in.

again beginning in 1600. Studies of sea levels and ice cover follow this scenario closely. Indeed, my game Greenland was designed around the LIA and its likely causal agent, the Maunder Minimum.

The abrupt recovery from the Younger Dryas is equally contentious. Atmospheric carbon began rising sluggishly a thousand years after the skyrocket. The most straightforward explanation is that this was an effect, not a cause of the event, as carbon is released from the warmed land and sea. Nothing about the Younger Dryas can be explained by carbon.

A design goal in this game was to model the greenhouse climate of Mars and Venus using the same rules and reservoir scale as on planet Earth. I failed, and thus was unable to put a scale bar on the Atmosphere Reservoir. Earth currently has 400 ppmv CO₂ in a 1 bar atmosphere, so that's about 1/2 millibar of CO₂. Compare this to Mars, with 6 millibar pressure and all CO₂. So Mars should have 10X the greenhouse effect from carbon than the Earth does. Even with Mars getting only 40% the solar energy, it still should be warmer than the Earth. Or take Venus at an altitude of 55 km, above the haze but below the clouds. In my game High Frontier, it is clement enough to establish manned floating Xities here. In spite of the 1000 millibar pressure (Earth normal) and 95% CO₂, the temperature is a pleasant afternoon on Earth, the same temperature as calculated with no greenhouse effect.

I wrote to a planetary scientist asking why my game models failed to link carbon and greenhouse. His reply: "you've stumbled on one of the central problems in planetary atmospheres...Good luck."

The carbon greenhouse effect is supposed to work because a CO₂ intercepts an escaping IR beam and backscatters it. A problem is that CO₂ is so rare that it is measured in parts per million on Earth, and parts per 10 on Mars or Venus. An escaping IR beam on Earth would encounter 2600 other molecules for every CO₂ molecule it encountered, and including hundreds of water molecules that backscatter in the same range as CO₂. And the configuration of carbon and oxygen in the CO₂ molecule make it a very weak greenhouse effect. A terrestrial greenhouse scale won't work on Venus or Mars.

Why is the surface of Venus so hot, is it greenhouse or pressure? If it's greenhouse, there should be a difference between the day and night temperatures. This is because the greenhouse effect is a result of IR backscatter: the more sunlight, the more backscatter. But the temperature of Venus is isothermal, even in the dead of a night that lasts 58 Earth-days! Because of the geometry of a sphere, a planetary equator gets more sunlight than the poles. But everywhere on Venus is 462°C, north and south, day and night. There should be Hadley circulation cells on Venus (event 37), transferring warm equatorial air to the poles. But there isn't. I conclude that the hell on Venus comes from the pressure of its heavy CO₂ atmosphere, like how hot your bike pump gets from inflating a tire. The carbon greenhouse effect does not scale to other planets.

This essay explains why I am not on the "carbon only" bandwagon, instead including other climatic drivers ranging from bolides to CMEs. This is a "lukewarm" position similar to that of Matt Ridley, the author of *The Red Queen*, a book which dominated parasite theory in the predecessor game *Bios:Genesis*.

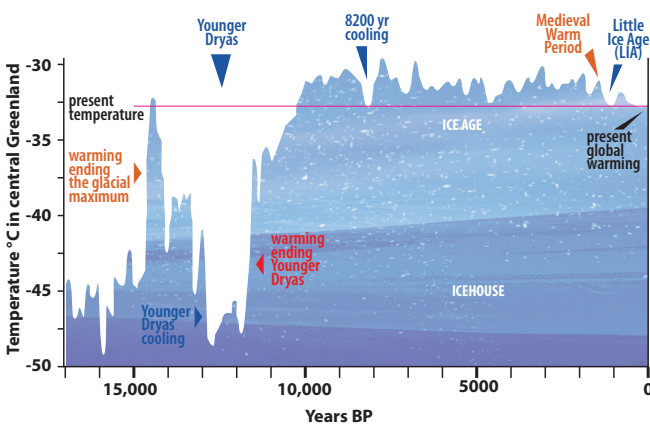
The objectivity of science is threatened by its funding source, whether this source is oil companies or the government. And the "carbon only" researchers are funded hugely by politicians whose regulatory careers and revenues depend on created crises. There are trillions at stake, and the

politicians have absolute control over their employees. Even with no overt threats, the pressure to please the boss is tremendous, with fame and fortune coming to those who support carbon only, and loss of grants, telescope time, and careers to those opposed.

And the threats are not always so covert, as the 2009 climate-gate proves. These leaked emails

showed a collaboration to withhold data, prevent papers being published, get journal editors sacked, and evade freedom-of-information requests. And the extremely short-ranged climate graphs are so easy to manipulate, as I discovered when considering various versions of the hockey stick while I was collaborating on a book on the planet Earth in 1998. Just give a different weight to some data, and you can bend it wherever way you like. The National Academy of Sciences in the USA has discredited the hockey stick as a deliberate distortion. The high-level whistleblower John Bates of the NOAA has shown how the pause-buster data was falsified. And the IPCC has adopted the shabby tactic of increasing the error bands on their prediction, in effect presenting their data as more certain by making it less certain. Politics and science do not mix.

Phil Eklund



GLOSSARY AND INDEX

Definitions of Capitalized game terms:



Archetype (C1c, C1l). It is the original forerunner of your plant or animal dynasty. Both your starting Genotype card and its corresponding dome Creeples are called **Archetypes**.



Atmosphere (C1j). It is a Reservoir indicating Earth's greenhouse gases: water (white disks) and carbon dioxide (black disks). It sets the Latitude strip and the **green action maximum (A2a)**. If the Atmosphere is full, **runaway greenhouse** can happen (**D10h**) and additional Liberated disks (if white) go into the Clouds or (if black) into the Atmosphere, displacing white disks into the Clouds. The lowermost scale, labeled "icehouse", corresponds to about 1500 ppmv H₂O and 175 ppmv CO₂ (ppmv = parts per million volume).

Atrophy (D7). It is the process of removing cards and cubes during mutagen events (**D7**). It can also occur as a result of radiation (**D8**) or resize (**J1, J4**). If the last Organ of a Mutation is lost, then the card is discarded unless it is a Cheshire Cat (see below).

Atrophy Extinction. *If a Basal Organ on a Genotype (E2c) is removed, the Species goes extinct.*

Atrophy Dwarfism. *If an Atrophy is taken from a Monster (E2d), instantly reduce the size of the Species to get rid of the desired number of cubes. This resize is instant and free. For instance, if a mutagen event with a dark heart 4 occurs, a size 6 megafauna with one Monster token and one blue cube can reduce instantly to size 3 to get rid of its excess cubes.*

Cheshire Cat Rule (J6g). *Cards in your Personality are immune from discarding during Atrophy. If they lose their cubes, the cards remain so as to preserve the Emotion. Personality cards are never lost unless the Species goes extinct.*

Promoted Mutations that do not have Plus Organs are unaffected by Atrophy.

Basal Organ (E2c) is a cube on a Genotype card. Because it represents a defining phenotypic framework for that Species, if lost that Species goes extinct.

Biome (F3) is a hex on the map whose color represents a vegetation type: green = weeds, brown = swamp, blue = sea. Biologically, biomes are structurally and functionally similar vegetation units, without reference to species composition. Each Biome can support only one Herbivore plus one Carnivore Creeples. If a second arrives, a contest is performed to see who dies. On Venus or Mars, there are only two Biomes, highlands and basins, and each can support one plant, one Herbivore, and one Carnivore.

Craton Biome Disks. *A disk on a biome supersedes the hex's color: black = mountain, white = desert or ice, green = forest.*

Sea Level Falls. *Falling sea levels indicate that ocean water is being stored as ice at the poles. If a sea biome acquires a green disk during a deluge event (D6b), it is a terrestrial forest instead of a sea. Any swimmers become Endangered. If it loses the green disk, it re-floods and all Creeples that can't swim or fly become Endangered.*

Offshore Biome Disks. *An Offshore green disk (Bloom) is treated the same as a sea hex. It is entered per F3b.*

Bloom (D10g). An offshore with an overlying green disk is called a bloom, and is inhabitable by a swimmer. A bloom may only be entered (for 1 DP) by a swimmer, and only from the hex it is adjacent to or from an adjacent offshore on the same Continent to the north or south. See Offshore.

Carnivore (Part H). Any Creeples in the predator's triangle is a carnivore. Sometimes called **predator**.

Cheshire Cat (J6g). Cards in your Personality are immune from discarding during Atrophy. If they lose their cubes, the cards remain so as to preserve the Emotion. Personality cards are never lost unless the Species goes extinct. See Atrophy.



Clouds (C1k). It is a Reservoir indicating the planetary albedo. It can hold only Liberated white disks (water). It sets the **green heart limit (D7c)**, limiting how many organs a carbon-breathing Genotype (e.g. Player Green) can support, should there be a mutagen event. Plants are stressed if the albedo is too high (not enough sunlight) or too low (not enough rain).

Coast (F5). It is either the west or east edge of a Craton or Continent, with open ocean or Offshore positions beyond. Seas do not define a coast. You can embark a **raft (F5)** from a coast. Mountains form in coasts during **Craton collisions (D3a)**.

Continent (D4). Multiple Cratons are collectively called a **continent**. See Craton.



Craton (B2). A placard representing the core of a drifting block of continental crust. Multiple cratons are collectively called a **continent**. One craton of a continent will contain the **Latitude Dice (D1a)**.

Creeples (B3). A wooden figure, which represents either an Herbivore or Carnivore depending on its position in the hex. It has a player color, and one of five Shapes: Archetype, burrower (subterranean or nocturnal), flyer, swimmer, or armor. Creeples on the map are called **living creeples**, and this includes **Endangered Creeples** (those on their side or upside down). A Creeples on your mutualism card is called a **host creeples**, which counts toward your population even though it is not your color. The Creeples on your Genotype card are called unborn creeples. The Creeples on your Newborn Card are called **newborn creeples**.

Degas (D10f). Moves a disk from a Reservoir to the map (either Continental or Offshore). If the disk is black or white, it is a Disk of Damocles. If there is a choice between Clouds and Atmosphere, the Medea supervillain decides (**D13**). If the Reservoir is empty, the Medea supervillain can take the disk from anywhere (**D14**). Degas is the opposite of Liberate.

Disk of Damocles (D2, D3c, D6). A black or white disk Degassed to a Craton for any reason. This disk, which could be from a crater, orogeny, or climate change, makes Creeples Endangered and Liberates any disks already there. Note that a Disk of Damocles cannot be Degassed to a Biome that already has a disk of the same color. Note also that these disks have the hierarchy, black beats white, and either beats green. For instance, a black disk can be Degassed to a white disk, which Liberates it, but not the other way around.

Dispersal (F2a). Biologically the vector of gene flow, it is in this game the spread of a Species by taking an Unborn Creeples, choosing its mother on the map, and moving it from the mother to a habitable Biome. This movement in dispersal points (DP) is equal to the number of blue cubes plus size of the Species. For instance, a Species of size = 5 and with 1 blue organ has 6 dispersal points.

Display (C1o). The two rows of 5 cards that you may select cards from (**E1**). The top row is the **Metabolic Row**, containing yellow and red Mutations. The bottom row is the **Darwin Row**, containing green and blue mutations. The Metabolic Row is concerned with achieving a high metabolic rate, while the Darwin Row is concerned with eating and multiplying.



Emotion (J6). The behavioral mode of an animal that causes a sequence of actions and priorities when triggered by a stimulus. A completed emotion is formed from the right and left halves of an emoticon in a Species Personality row. The emotions in the game are anger (red), fear (yellow), happiness (green), jealousy (blue), or curiosity (purple). They are worth VP and give an **emotional bonus (E1b)** during the mutate action. The most basic emotions are fight or flight, corresponding to anger and fear respectively. The fight emotion couples to an angry weapon like tooth or claw, and the flight modes couple to vigilant but fearful eyes or ears.

Endangered Creeple (I2). Whenever a Creeple is killed, whether by a Disk of Damocles, a contest, or something else, lay it on its side or back to indicate it is **endangered**. A Creeple is also endangered if its food is lost or endangered. This Creeple is dying, yet still is able to be a mother during **Phase A3**, assuming it has Newborns. Endangered Creeples are ignored in contests, as if they were not there. Each endangered is converted into an Unborn Creeple during **Phase A4**, with the exception of **endotherms (I1)**. Note: If a Creeple becomes endangered and it has no Newborns, and its action phase is past so it cannot get any Newborns, then it is dead instead of dying and moved immediately to the Unborns.

ET (A1a). Short for “extraterrestrial”. Following **Bios:Genesis** tradition, this means anything from outside the biosphere of Earth.

Event (Part D). A single unique occurrence which is resolved in its entirety before resolving the next event on the event card. An event is represented by either a single icon or two icons connected by an arrow, and each event is either separated by a vertical dotted line or placed at the start of a new row.



Fossil Record (I3b, I4b). A personal stack of **fossils** (i.e. tokens and cards with the fossil icon). Fossils include tokens stored during the

fossil award phase (A4c), and dead Genotypes, Archetypes, and Tools. Each fossil counts 1 VP at the **game’s end (A6)**. Cards can only be stored here if their fossil icon was not upside-down when it was lost.

Genotype (E3a). The lowermost card in the Tableau of each Species. For the Archetype, it is your starting Archetype Card in your player color. For your other Species, it is the promoted Mutation that shows the Shape of the new Species. A Genotype card plus its Mutations, Organs, and Size Dice completely defines the characteristics of a Species on the map.



Haustorium (G7, H6). If a Species has a promoted haustorium mutation (card 56), this Species has a specific skeletal number

(either 0 or 5) that overrides the player’s normal skeletal number for that Species only. Thus this Species always the lowest number (if parasitic plant), or the highest (if parasitic fungus). During a mutagen event, a Species with a Haustorium Skeletal Number of 5 must use the **dark heart limit (D7b)** and a Species with a Haustorium Skeletal Number of 0 must use the **green heart limit (D7c)**

Herbivore (Part G). Any Creeple sitting on a Biome. Sometimes called **prey**.

Heritable (E3b). What a new Species inherits from its mother Species. A Species color, Skeletal Number, Size Dice, and Basal Organs are automatically inherited. Shape, Plus Organs, and Traits (Monsters, Venom, etc.) are not heritable.

Horror-plant (E1d). A plant-fungus hybrid that **basks green in the sunlight, lazily breathing CO₂ and making sugar like any plant, but at night switches to high metabolism oxygen and supplements its diet with plants or flesh (All plants breathe oxygen at night, and some form hybrids with aerobic fungi such as living lichens and extinct prototaxites.). All Species of Player Green are Horror-plants.**

Horrible Green Heart. Horror-plants use a green heart limit instead of a dark heart during a mutagen event (**D7c**), as shown on the Clouds. This is because a plant suffers if clouds block the sunlight, and also suffers if there are not enough clouds for rainfall.

Horrible Mutation Limits. Since Horror-plants have no aerobic muscles, Player Green is not allowed to select a red or yellow Mutation unless it has the Horror-plant icon in the upper right corner. Other players may select the Horror-plant cards normally.

Horrible Action Maximum. Unlike the other players, the number of actions Player Green has each turn is linked to cloud cover, as shown on the Clouds.

Horrible Mind Control. A Horror Plant has a “magic mushroom” advantage in mutualism (**J2c**).

Host Creeple. A Creeple on your mutualism card, which counts toward your population even though it is not your color. See Creeple.



Latitude (C1j). The 8 levels on each Latitude Strip, numbered from zero (north pole) to seven (south pole).

Every Biome on the map is in one of these latitudes.

Latitude Dice (C1g). sit on a Craton to show which Latitude its center row is in (constrained from 1 to 6). If a Craton is at latitude 4, its northern row is at latitude 3, and its southern row is at latitude 5. Each Continent has one latitude dice.

Latitude Strips (C1j). There are 3 double-sided latitude strips, each defining the 8 **latitudes** from north to south pole. The latitude colors are reddish (too hot), green (goldilocks), and blue (too cold). Furthermore, each color has two sides: icehouse and Ice Age (blue), cool and Eden (green), and warm and hothouse (reddish). The latitude strip, as set by the Atmosphere, is placed to the left side of the map, so as to define a latitude for every Biome on the map.

Latitude Indicator. The 8 dice faces each indicate a Latitude.

Dice Color. The color of this icon indicates the humidity. A green dice is humid, and a white dice is arid. This sets the the climax (**D5**) and the humidity niche (**G5**).

Wind. Some latitudes have a Wind direction, see “Wind”.

Lazarus (I3c). A player without any Living Creeples. He is assumed to have a cryptic small population of his Archetype, in numbers too small to leave a Fossil Record. Until resurrected, you may perform only the following two actions: Resurrect (**E7**) and Medea (**E8**). The name “Lazarus” comes from the Bible, and is applied in biology to species missing from the fossil record for many millions of years before reappearing as if mysteriously “rising from the dead”. This is an observational artifact caused by incomplete fossil records.

Liberate (D5). Move a disk from the map (either Continental or Offshore), to a Reservoir. Green disks always liberate to the Oxygen Reservoir and black disks always liberate to the Atmosphere Reservoir. If there is a choice between Clouds and Atmosphere, the Medea supervillain decides (**D13**). Note that if a black offshore disk is liberated, a green disk on top of it is also liberated (but not the other way around). Liberate is the opposite of Degas.

Living Creeple. Creeples on the map, including Endangered Creeples (those on their side or upside down). See Creeple.



Maximum Size (J1). A dice icon on promoted Mutations which indicates the largest size a Species can attain without sacrificing the Mutation.

Medea (E8). The player holding the Medea card, and enjoying superpowers.



Monster (E2d). A token that represents a special Plus Organ considered to be multiple cubes, as many cubes as the Size Dice of the Species. During Speciation, the daughter inherits a single Monster cube, which becomes a Basal Organ in the daughter. If a Monster Atrophies, e.g. during radiation or mutagens, the species size is reduced instead, see “Atrophy”. A Monster cannot be removed until the Species is at size 1. The monsters are Godzilla, Kong, Kraken, Dragon, and Yeti, with apologies to the monsters too many to mention.

Mutation (B1). A card that indicates adaptations, including Organs, Traits, and Emotions. If in the Display, it can be selected per **E1**. If placed in a Tableau, it adds the Plus Organs indicated to the Mutation card. If promoted, it may add Traits, Emotions, or more Plus Organs.

Mutation Promotion. While in the Tableau, a Mutation can be flipped to its promoted side (**E2**), whereupon it may confer Traits, Emotions, and Size Limits. All former Organs become Basal Organs, and new Plus Organs (if any) are placed on its card where indicated.



Mutualism (J2). A trait which steals an opponent’s Creeple, and stores it on your card with this icon. This Creeple is worth a VP, and represents some sort of mutualistic or parasitic relationship between the two Species.

Newborn Card (E3d, E4). A card where you place Creeples generated as a result of the populate action. Move these Creeples from this card to the map during the mother phase.

Newborn Creeple. The Creeples on your Newborn Card are called newborn creeples. See Creeple.

Niche (G4, G5, H3). A winning Organ color in a contest (Parts G, H). There are two types: **Roadrunner** and **humidity**. The first is set by the Biome cube icon, and the second is set by the Latitude Strip dice icon. For instance, if there are carnivores, the Niche for a forest is the red Roadrunner, giving a competitive advantage to those with red Organs. If the forest is carnivore-free, but is very polar, the humidity niche is white, giving a competitive advantage to those with white Organs.



Offshore (D10g). One of the three shelf positions on the east coast of each Craton. Each can contain one black disk or one black disk with a green disk over it. An offshore with an overlying green disk is called a bloom, and is inhabitable by a swimmer. A bloom may only be entered (for 1 DP) by a swimmer, and only from the hex it is adjacent to or from an adjacent offshore on the same Continent to the north or south. Other than this, offshores have no effect on dispersal or rafting.

Organ (E2c). A cube on a Genotype or Mutation. It indicates an adaptation for that Species according to its color: red (nervous system), yellow (circulatory system), green (digestive system), blue (reproductive system), or white (cold adaptations). It can be one of two types: **Plus Organ** or **Basal Organ**. Plus organs, representing “derived” traits, are found on the “+” icon on Mutations. Basal Organs are found on Genotype cards.



Oxygen (C1k). A Reservoir for Liberated green disks that indicates how much oxygen is in the Atmosphere (which is today at 21%). The more green disks, the less oxygen there is. Because all macroorganisms burn oxygen for their metabolism, the oxygen level determines how many **actions (A2a)** Players Orange, Black, and White receive during each action phase. It sets the **dark heart limit (D7b)**, limiting how many organs an oxygen-breathing Genotype can support, should there be a mutagen event. If oxygen is too high, no “microbe” biosphere events occur, and if too low, no “conflagration” events occur (**D10b**).

Personality (J6). A row of 2 or more promoted cards in the Tableau of a Genotype. Each adjacent card in the personality must have established at least one Emotion, by providing for the right or left half of its emoticon. A personality is allowed only one head and one tail, but can have multiple brains (**J6b**), representing one bigger brain.



Plus Organ (E2c). Plus organs represent “derived” traits, and are found on Mutations. See Organ.



Radiation. Each Species Atrophies one Plus Organ of any of the colors of the icon.

Reservoir (D10). The placard where disks are stored in the Clouds, Oxygen, and Atmosphere.

Reservoir Disk Management. Disks are stored in Reservoirs starting at the spot just above the one labeled “NO DISKS”. The uncovered values immediately above the highest disk indicate the current parameters. For instance, if there is one disk in the Clouds, the albedo is 0.1 and the green heart is 2.

PAL. Stands for “Present Atmospheric Levels”, and shows today’s climate values. This has no effect on game play.



Roadrunner (G4, H3). A predatory mode as set by the color of the roadrunner icon on each Biome. Roadrunners can either be red (meaning that the prey is ambushed), or yellow (meaning the prey is pursued). Red roadrunners are in biomes where there are many hiding places, such as forests, or swamps. Yellow roadrunners are found in biomes out in the open, such as weeds, seas, or blooms. The name is inspired by the Warner Brothers cartoon.

Scale (B2). Each turn is 30 million years, and the whole game is two Gal-years (1 Gal-year = time it takes Sol to orbit the galaxy, almost 250 million years). Each Biome is 2500 km across, containing 4000 Mt of vegetation. Each Creeple is 60 Mt of animals if herbivorous, or 2 Mt if predatory (Mt = megatonnes, or 10^{12} kg). On the map, each black disk is 1000 Gt C (Gt = gigatonnes, or 10^{15} kg), and each green disk is 1 Gt of plankton (Despite having a biomass 1000X lower than terrestrial plants, marine phytoplankton produce nearly as much - 55 Gt C/yr. This is because the turnaround time of plankton is days instead of years.) In the atmosphere, each black disk is 700 Gt carbon and each white disk is 12,000 Gt water vapor. Note that 700 Gt is comparable to the total amount of carbon in today’s atmosphere, about a third of which can be attributed to humans. This is trifling compared to past “gun” episodes which dumped from 5000 to 13,000 Gt into the atmosphere.

Shape (B3). Each player has 7 Creeples of 5 Shapes: Archetype (dome), armor (snail), flyer (fly), swimmer (ichthyosaur), and burrower (worm). Except for the Archetype, each represents a different Species phenotype adapted to a particular ecological domain. Worms, for instance, are subterranean/nocturnal.

Size Dice. A 1d6 placed on the Genotype of each Species when it is created (**E3b**) and indicates the size (from 1 to 6) of that Species. A Size Dice can be altered as an action (**E6**). A size dice icon depicted on a promoted Mutation indicates the maximum size a Species can be, and still retain that Mutation.

Size 1 = 200 grams - rats, largest spiders & extinct insects, living amphibians.

Size 2 = 2 kg - largest land arthropods (coconut crabs, extinct scorpions & millipedes), largest living snails & giant earthworms, largest extinct frogs.

Size 3 = 20 kg - beavers, velociraptors, largest lagomorphs (extinct rabbits), largest living burrowing armadillos, badgers & tortoises, largest flying birds & pterosaurs.

Size 4 = 200 kg - *Dimetrodon*, largest burrowers (extinct armadillos), largest living ratites (ostriches), deer (reindeer & moose), primates (gorillas), and felines (tigers).

Size 5 = 2 tonnes - largest foregut digesters (giraffe, cattle & extinct deer), largest riverine mammals (hippos), largest carnivora (bears & seals), largest living crocodiles, largest armored turtles, ammonites, glyptodonts, and thyreophorans (stegosaurus & ankylosaurus).

Size 6 = 20 tonnes - largest land carnivores (theropods such as tyrannosaurs), largest marine predators (sperm whales), largest hindgut digesters (straight-tusked elephants, *Indricotherium*, ornithomylids, & typical sauropods).



Skeletal Number (C1d). Listed on the fishbone icon on your Archetype: Player Green = 1, Player Orange = 2, Player Black = 3, and Player White = 4. This number is in effect for all your Species except for a Species with a promoted **haustorium** mutation (J5). It is used in herbivore (G7) and carnivore (H6) contests. The first Medea player is the one with the lowest Skeletal. The lower skeletal numbers are best for herbivory, and the higher are better for carnivory.

Species. All of the Creeples of a particular color and Shape, plus its corresponding Tableau which defines its Mutations, Size, Organs, and Traits. Each player can have up to 5 species: archetypes, swimmers, flyers, burrowers, and armored. The game scale is such that each "species" is actually more like a phylum of many species.

Tableau. A column of cards that defines all characteristics of a Species. It starts with the Genotype above, and continues with any Mutations staggered behind. Personality cards are part of the Tableau, and are in a row that includes the uppermost Mutation in the column. The Genotype contains Basal Organs, and the size dice. The Mutations contain Plus Organs. See illustration in J6b.

Traits (Part J). Non-heritable adaptations for a Species depicted by an icon on a Mutation. They include **maximum size (J1)**, **mutualism (J2)**, **venom (J3)**, **monster (J4)**, **haustorium (J5)**, **emotions (J6)**, **tools (J7)**, and **apomorphies (J8)**.

Trophic Levels (F6). Describe a nutritional hierarchy of life: with carnivores at the top, feeding on the next lower trophic level - the herbivores. The herbivores in turn consume the lowest trophic level - the energy-producing plants. All Species in the standard game are either carnivores or herbivores, and can easily switch between the two. A single Species can even have both carnivore and herbivore creeples present (this is called **omnivory**). Alien ecologies have all 3 trophic levels.

Unborn Creeples (E1a). The Creeples on your Genotype card are called unborn creeples. See Creeples.



Venom (J3). A Trait conferred to a Species by the black widow icon on one of its Mutations. A venomous Herbivore cannot be eaten by a Carnivore unless the Carnivore is either venomous itself, or larger (F4). The largest venomous creature known is *Megalania*, an extinct size 4 version of the venomous Komodo dragon.







Wind. Blows from either the east or west as indicated by the Latitude Strip. Wind only blows in Latitudes 1, 3, 4, and 6. This represents easterly and westerly trade winds and currents. Wind affects **rain-shadow (D12a)** and **rafts (F5)**.






ROSETTA STONE


EVENTS (D)


-    Player order (A5)


-  Biosphere Stable (A1b).


-   Latitudinal Drift (D1).


-  Crater (D2).



-  Collision or Drift-by (D3).


-  Pangea Rift (D4).


-  Climax (D5).


-  Deluge (D6).


-  Mutagen (D7)


-   Metabolism/Darwinian Radiation (D8).


-  Crowd Disease (D9).


-  Atmosphere Reservoir (D10)


-  Cloud Seed Superpower (D13)


-  Cloud Reservoir (D10)


-  Oxygen Reservoir (D10)




-  Offshore Reservoir (D10)


-  Continent Reservoir (D10)


-  Conflagration Event condition (D10)

-  Cloud-covered Event condition (D10)


-  Precipitation Event condition (D10)


-    Triggerhappy superpower (D10)


-  Windy (D11).


-  Rain-Shadow Constraint (D12a).


MUTATIONS PURCHASE & PROMOTION (E1 & E2)


-  Plus Organs (E1).

-  Horror-plant (E1d).


-  Maximum Size (J1).

-  Mutualism (J2).



-  Venom (J3).


-  Plus Organ Monsters (J4).



-  Haustorium (J5).


-  Emotions (J6).


HERBIVORE AND CARNIVORE CONTEST (G & H)

-   Roadrunner (G4 / G3).


-  Humidity Niche (G5)


-   Edibility / Prey contest (G3 / H1).


-  Skeletal number (G7 / H5).


-  Fossil (I4).


CRATONS (D)



-  Laurentia / Aphrodite (Venus)

-  Siberia / Ishtar (Venus)

-  Gondwana / Tharsis (Mars)

-  Baltica / Arabia (Mars)

-  Direction dice

-   Roadrunner (G4 / G3).

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