UNDERSTANDING REAL-WORLD OPEN-ENDED SYSTEMS: A LEAGUE OF LEGENDS ADVENTURE. A. M. Adams[1,2,3] and S. I. Walker[1,4,5,6], [1]Beyond Center for Fundamental Concepts in Science, Arizona State University, [2]Department of Physics, Arizona State University, [3]Algorithmic Nature Group, LABORES (alys-sa.gp.adams@gmail.com), [4]School of Earth and Space Exploration, Arizona State University, [5]ASU-SFI Center for Biosocial Complex Systems, Arizona State University, [6]Blue Marble Space Institute of Science (sara.i.walker@asu.edu).

Introduction: A prominent feature of life on Earth is the evolution of biological complexity: over evolutionary history the biosphere has displayed continual adaptation and innovation, giving rise to an apparent open-ended increase in its complexity. The capacity for open-ended evolution has been cited as a hallmark feature of life, and also characterizes human and technological systems. Yet, the underlying drivers of open-ended evolution remain poorly understood. While abstract models have proven useful in understanding key biological concepts such as open-ended evolution [1], they are rarely validated empirically.

League of Legends (LoL) is an online team-based strategy game that has become immensely popular over the last six years [2]. Because new characters (called "champions") are regularly added and the game is updated every few weeks by the game's developer Riot, the game never settles into an equilibrium. Innovative strategies are required for players to succeed, so the game seems to have open-ended aspects. In-game data is available to the public, including a complete set of statistics for every individual game instance played across the world during the last five years. This makes LoL an excellent platform for studying complex social systems.

Understanding open-endedness is crucial to understanding how living systems operate and distinguish themselves from non-living systems [3]. This set of data can provide insights into open-endedness that can be applied to a wide range of fields, including astrobiology and evolutionary systems.

Parallels to Living Systems: Absent of game updates introduced by Riot, internal mechanisms from the players seem to resemble a negative frequency-dependent selection strategy. This type of frequency-dependent selection is well-known in population dynamics of competing species [4]. In LoL, this can be seen with rotating player strategies: when tanks become popular, anti-tanks gain popularity and tanks are no longer the popular strategy to use. Over time, the counter-strategy to the anti-tanks becomes popular, and anti-tanks are no longer used. In other words, the most desirable strategy changes over time as a function of current player trends, recent player trends, and game updates introduced by Riot. This is akin to dynamical models that produce open-ended evolution. In those models, innovative patterns emerge as a function of the current state of the global system [1].

In addition to game properties coded by Riot, game dynmaics are also determined by human social factors. Professional players set many trends that most other players work to imitate. For example, one professional player started effectively using the champion "Teemo" using a particular strategy. Since many people watch this player's behavior, many imitated this player's Teemo strategy which is a popular trend that continues four years later.

External game changes introduced by Riot modifies the landscape of possible strategies. The frequency of changes highly influences the internal dynamics of gameplay. Both internal and external mechanisms are what make LoL popular, since it keeps the game out of a static state. No single strategy reigns supreme.

Creating a Network: At any given time, a network can be constructed to show which champion beats (counters) another champion based on the win/loss outcomes of players who play those champions. According to counterstats.net [5], Teemo wins more often than Renekton in the Mid position so Teemo is considered to counter Renekton. This abstraction is useful in understanding how champion heirarchies change before and after a game update, much like social systems in animals [6]. This directed network is completely determined by player interactions and is dynamic, since its edges, weights, and nodes change over time.

Applications to Evolution: Using data from only North America's top 200 players, the following questions are addressed in order to understand living systems: (a) Is the data predictive of future external changes and visa versa? (b) How do hierarchy dynamics form after external changes are introduced? (c) Is the local scale or global scale more relevant in player's understanding of where a champion stands on the "totem pole"? In other words, these questions will address the relationship between external and internal mechanisms in a real-world open-ended system.

Outreach Impact: All data, code, and findings are organized in an easily accessible way on the public website NostraTeemo.com. This will be a fun and engaging way for League of Legends enthusiasts to become aware of complex systems science.

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