On the Transformation of Humans into Vampires in *Buffy the Vampire Slayer*: A Viral Disease Model

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Introduction

Buffy the Vampire Slayer (1997-2003) and its companion series *Angel* (1999-2004) are fictional American television shows featuring humans, vampires, and the complex interactions between them. Vampires contrast strongly from humans via their significant physical advantage and tendency to act without guilt or remorse, yet vampires retain many deeply human qualities (Magnusson, 2011; Geller 2011). This dichotomy—between the human and nonhuman parts of vampires—is frequently referenced and explored throughout both series (*Angel*, "Hero" 1.9; *BtVS*, "Who Are You?" 4.16). Yet what precisely distinguishes a vampire from a human, and can we sufficiently describe such differences through a scientific lens? As an avenue for analysis, we can closely interrogate special

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cases within the Buffyverse known as siring. Siring occurs when a human is transformed into a vampire, a process which must take place over the course of several hours or more. Closely addressing variations that occur between a human and their vampiric form highlights specific changes to human physiology and behavior, enabling us to better understand vampires across *Buffy* and other fictional works.

Here, we used clinical and biological evidence to design a scientifically-driven model for the siring process. We then performed a series of numerical simulations on our model to better gauge how vampirism is introduced into humans over 24 hours. Finally, we assessed the specific changes to human physiology and behavior that might allow vampirism to seem plausible. We find that through a scientific approach, much of the siring process and vampire physiology can be sufficiently explained.

The success of such models highlights the importance of logical consistency across fictional narratives. [1] Applying scientific perspectives to fantastical systems can also aid pedagogy by introducing fandoms and students to current trends in scientific research (e.g., viral models and simulations). Additionally, while fiction often requires some suspension of disbelief, plausible scientific explanations can identify nuances that greatly add to the viewing experience and can aid in the future contextual analyses of vampire-based fiction within and beyond the Buffyverse.

The Siring Process in *Buffy the Vampire Slayer* and *Angel*

The act of turning a human into a vampire ("siring") in both *Buffy the Vampire Slayer* and *Angel* is a two-step process. First, a vampire physically bites a human and draws blood for several seconds. Then, the vampire self-inflicts a wound and forces the human to drink their blood for some length of time. In the immortal words of Buffy:

> "They have to suck your blood. And then you have to suck their blood. It's like a whole big sucking thing." (*BtVS* "Welcome to the Hellmouth" 1.1, 17:20-26).

Once completed, the human will rise as a newly undead vampire the following night. The exact time at which this occurs is variable, and no additional preparations, such as a burial, need to be made (*Angel* "Reunion" 2.10). This suggests that a two-step siring process captures the minimal criteria required to transform a human into a vampire.

Of these two steps, the human consumption of vampire blood acts as a main driver for siring, since vampires can freely feed on humans without consequence (*BtVS* "Angel" 1.7). Over the course of several hours, ingested vampire blood will introduce several vampiric traits into humans, among them enhanced strength, craving the consumption of blood, aggressive behavior, and changes to facial musculature. Such a process is analogous to a human drinking a contaminated liquid (vampire blood) and contracting a chronic illness (vampirism).

Although characterizing vampirism as a disease may hardly seem appropriate, it may have precedence within the Buffyverse. Giles describes vampires as "a human form […] infected by the demon's soul," and medically-focused interpretations of the term "infected" provide a useful framework through which to approach the siring process (*BtVS* "The Harvest" 1.2, 3:29-32). Additionally, infection-based approaches to vampirism are present in other fictional works (such as *I am Legend* [2007], *Blade* [1998], and *V-Wars* [2019]), suggesting that disease models built for the Buffyverse may generalize to other literary works with vampires. Herein, we will analyze vampirism as a virus type infectious agent.

While infection-based approaches predict that only the human consumption of vampire blood (step 2 of siring) is essential for initiating the siring process, siring is always preceded with a vampire bite to the human's external jugular vein (step 1 of siring). This is curious and may simply represent an easy opportunity for vampires to feed. Alternatively, a vampire's initial bite may carry a larger cultural importance—as noted during Drusilla's (vampire) siring of Darla (human).

> Angel: "Drusilla will want to put the body [of the newly-sired Darla] in the ground."
> Wesley: "Angel, are you certain about this? A burial isn't necessary for a newly made vampire to..."
> Angel: "It would be for Drusilla. She's a classicist."
> (*Angel* "Reunion" 2.10, 8:31-39)

We, however, suggest another purpose that directly aids the siring process.

In the case of Darla's siring, several seconds after being initially bitten by a vampire, Darla appears lethargic (*Angel* "The Trial" 2.9) with minimally bleeding wounds. Such effects are typical after vampire feedings within the Buffyverse (*BtVS* "Angel" 1.7, *BtVS* "Doppelgangland" 3.16). Using flow measurements gathered from a typical human jugular vein, however, we show that Darla's lethargy cannot be due to blood loss alone—even in extreme cases, a vampire would only be able to remove <10% of the 2000 mL of blood required to explain such symptoms (*Appendix A*).

The intent of a vampire's initial bite, and the effects it causes, may serve a similar purpose to other blood-feeding organisms in the animal kingdom. Vampire bats, ticks, leeches, and other blood-feeding organisms contain compounds in their saliva that allow them to feed efficiently by decreasing pain and inflammation, preventing the clotting of blood, and dilating (expanding) blood vessels to keep blood flowing (Simo; Singh). Of particular interest is a compound in vampire bat saliva (vCGRP) that dilates blood vessels (Kakumanu et al.). In large doses, a similar compound injected by vampires would lower blood pressure and induce the same symptoms we observe in Darla's siring (Ando et al.; Yu et al.). The physiological effects of such a compound would be rapid: as blood vessels expand and increase their volume, the overall amount of blood within a vein remains the same, immediately decreasing overall blood pressure.

Inducing low-blood pressure in humans may provide favorable conditions for siring. Under normal circumstances, the stomach is able to neutralize infectious pathogens (i.e., viruses, bacteria, and perhaps vampire blood), potentially impeding the siring process (Brenchley and Douek). Patients with low blood pressure are far more vulnerable to disease, however, and have been observed to have gut bacteria circulating through the bloodstream (Derikx et al.; Deitch). The specific mechanisms that allow for the transition of infectious vampiric material from the gut to the bloodstream are too nuanced to describe here without fully characterizing vampire blood, but can be extrapolated from similar infections (e.g., eating undercooked meat) (Deitch).

The introduction of vampiric compounds (or "venom," a catch-all term) in humans during siring would likely produce several physiological changes simultaneously. Leech saliva alone contains 100 different bioactive compounds that perform a variety of physiological functions in the host's bloodstream (Singh). Such effects can be loosely tied to the Buffyverse. For instance, pain- and inflammation-inhibiting compounds in tick saliva could explain the lack of pain—and in some cases, pleasure—experienced by humans during feeding (Simo) (*BtVS* "Graduation Day, Part 1" 2.21; *BtVS* "Into the Woods" 5.10). Variations of immune-suppressant compounds found in tick saliva (i.e., cystatins, serpins, metalloproteinases, and lipocalins) can further aid the siring process (Sajiki et al). Utilizing a diverse collection of blood-related compounds can also aid writers in the development of novel ideas and approaches to vampirism.

We can synthesize our ideas into a single model to describe the siring process within the Buffyverse. First, a vampire bites a human and injects a venom (containing a collection of compounds) that, among other effects, quickly drops the human's blood pressure. As a consequence, the human immediately becomes lethargic and docile, lowering their physical and immune defenses. Secondly, the human is encouraged to ingest vampire blood, which readily spreads as an infectious agent throughout the bloodstream and begins the siring process. We refer to this model as our "viral hypothesis."

Simulating Viral Spread

After ingesting vampire blood, a vampiric infectious entity quickly enters the human's bloodstream and infects nearby cells. According to our model, this infection process drives the physiological transformation of a human into vampire which, within the Buffyverse, is typically completed within 24 hours.[2] If we assume vampirism infects humans similarly to a bloodborne virus, we can simulate the infection of vampirism in the context of other known and well-understood bloodborne diseases such as dengue virus (Nuraini et al.).

In building our simulation, we considered four key populations: viruses, healthy cells, infected cells, and immune cells. Viruses infect healthy cells. Infected cells then produce more viruses. In response, the human body increases production of immune cells that actively remove viruses and infected cells. We also considered death and regeneration rates for appropriate cells. All described mechanisms were simulated simultaneously by numerically approximating solutions to four ordinary differential equations. An in-depth description of our model is available in *Appendix C* and all simulations used in this investigation are available on GitHub as MATLAB code (Freedland *Jfreedland/VirusModeling*).

Since vampiric infections (and their interaction with human immune systems) are not shown or described within the Buffyverse, we relied on the use of dengue-like disease parameters paired with exposure rates from a case of siring from *Angel* (*Appendix B*). The results of this simulation are available in Figure 1.

We observed that under normal circumstances ("active immune system"), vampirism spread until the immune system decisively intervened after 7.2 hours. This presents vampirism as a temporary illness that was quickly cured. In the context of our model, this occurs when Buffy ingests Dracula's blood without being bitten first—Buffy is not exposed to any disruptive vampire venom, is able to maintain her immune system health, and thus avoids turning into a vampire[3] (*BtVS*

"Buffy vs. Dracula" 5.1). If we instead bypass the immune system ("inactive immune system"), however, vampirism can freely infect 80% of healthy cells in 14.8 hours. This is closer to what we would expect from the siring process. Thus, for vampirism to effectively infect a human, a human's immune system must first be weakened.

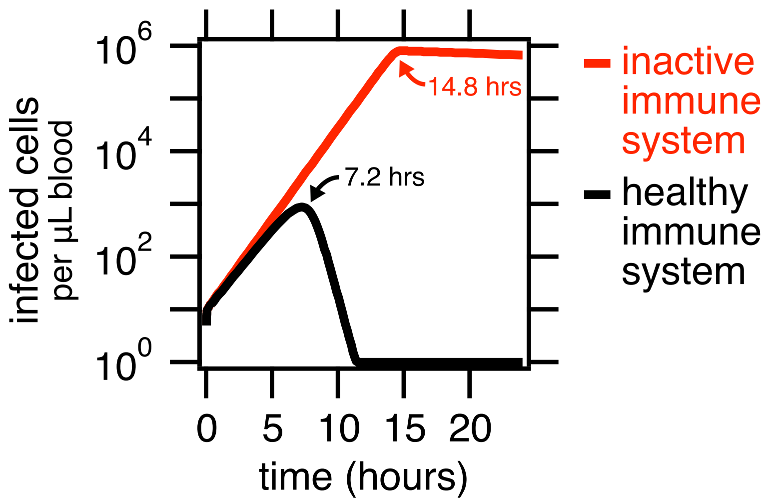


Figure 1: Simulation results for populations of infected cells (per microliter of blood) in the presence of a dengue-like virus. The black trace ("healthy immune system") uses clinically-measured parameters for healthy patients. The red trace ("inactive immune system") uses the same parameters but negates all immune cell activity.

An excellent candidate for mediating immune system health is the vampire venom that we previously hypothesized was introduced moments before (during step 1 of siring). Accounting for a vampire venom (with no quantifiable properties) in our simulations presented a challenge. We repeated our simulation for four possible vampire venoms that inhibit the human immune system at different rates (A to D, Figure 2). We observed that a natural threshold formed once 0.4% of healthy cells were infected (see: model B, which straddles this threshold)—beyond this point, vampirism could never be "cured." This strongly mimics the irreversibility of turning into a vampire. [4] Since 0.1% of healthy cells are reportedly infected in dengue-positive patients, this value appeared to represent an important criterion (Onlamoon et al.). For subsequent simulations, once 0.4% of healthy cells were infected, we considered humans to be fully-realized vampires.

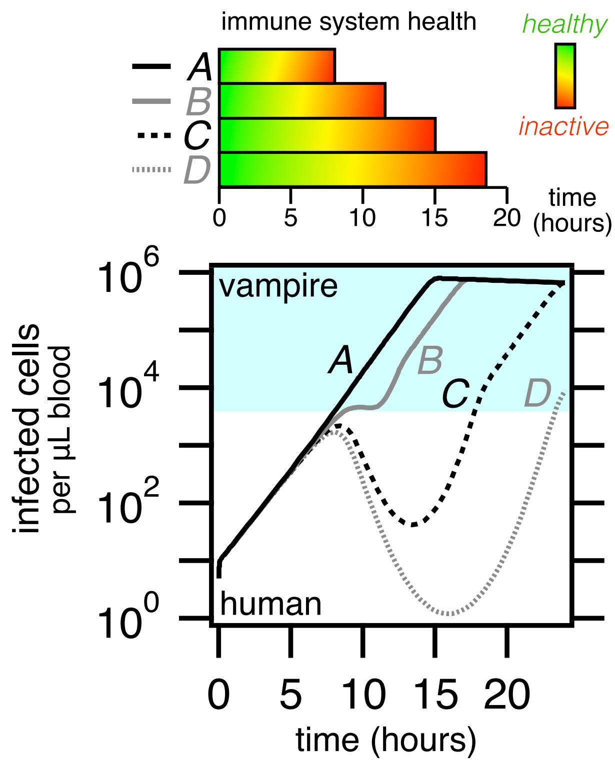


Figure 2: Simulation results for populations of infected cells as a human's immune system weakens over time (indicated by the colored bars: "immune system health"). The blue region represents a cutoff: once 0.4% of healthy cells are infected, our model considers a recently-bitten human to be a fully-transformed vampire.

Equipped with a model that accounts for the effects of vampire venom and a threshold for distinguishing whether a sired character is a human or vampire, we then simulated the entire siring process (Fig. 3). Specifically, we asked how quickly the 0.4% infectivity threshold is crossed in response to two variables: (1) how potently vampire venom inhibits the human immune system (see: cases A to D in Fig. 2), and (2) how much vampire blood a human is initially exposed to.

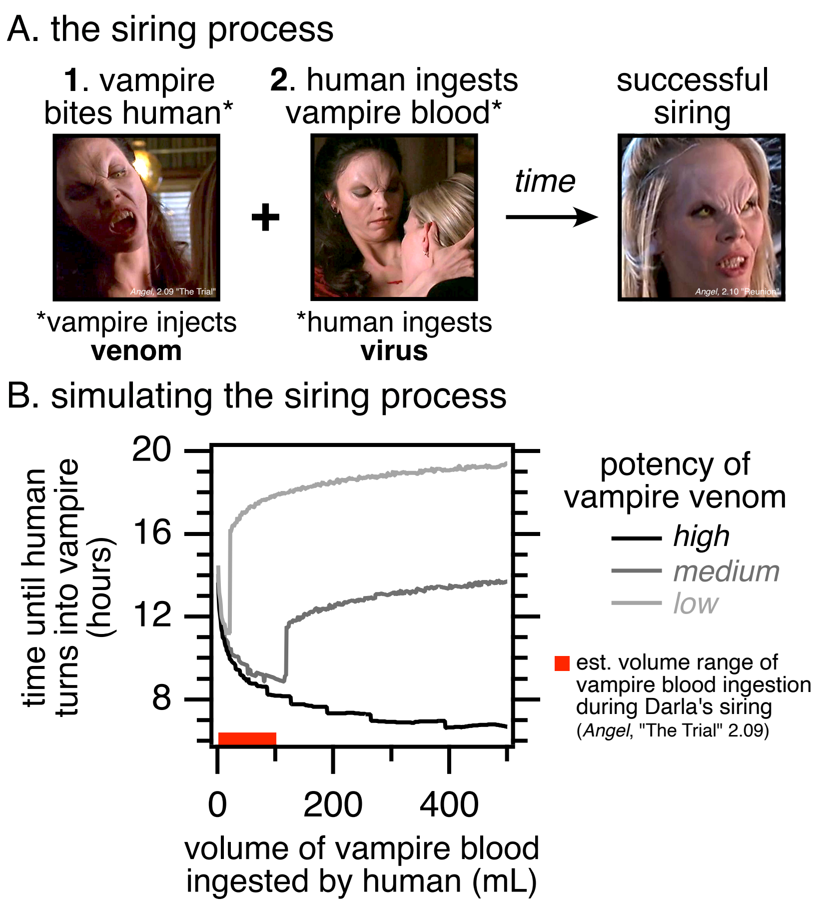


Figure 3: (A) A "successful" siring process is dependent on two variables: the potency of a venom injected by a vampire's initial bite (which inhibits a human's immune system, allowing the infection to proceed) and the amount of vampire blood ingested by the human. (B) Time until 0.4% of healthy cells become infected in response to both variables. The red

region denotes an estimated range of volumes (≤ 100mL) of vampire blood ingested by Darla in (*Angel* "The Trial" 2.9) (*Appendix B*).

Many of our simulations returned expected results. If vampire venom is potent (black trace in Fig. 3B), the siring process will severely disrupt the human immune system. In such cases, ingesting more viruses (by encouraging the human to drink more vampire blood) will cause the infection to proceed faster, turning a human into a vampire more quickly. This can occur in as quickly as 8 hours, on par with the siring of Alonna Gunn (*Angel* "War Zone" 1.20), who is bitten by three vampires simultaneously and thus exposed to high quantities of vampire venom.

If vampire venom is not highly potent (gray traces in Fig. 3B), however, siring becomes much more nuanced. These cases reveal an intricate interplay between actively-spreading viruses and a partially-inhibited immune system. If too much vampire blood is ingested by a human, the immune system will quickly mount a strong defense before vampire venom can efficiently inhibit it, resulting in a delayed siring. This highlights why it is difficult to predict exactly when a vampire will rise (*Angel* "Reunion" 2.10). Improved models could help vampire slayers such as Buffy Summers predict when vampires rise and help adjust their slaying efforts accordingly. However, population-based approaches (such as collecting data and identifying the likeliest time-of-day that vampires tend to rise) are less computationally expensive and would reveal much of the same information.

An interesting observation from our models is the prediction that a sired human can be "cured." To our knowledge, this has never been discussed in the Buffyverse but can occur in our model if the number of infected cells never crosses the 0.4% infectivity threshold. To better investigate this phenomenon, we introduced a simple recovery mechanism to our model that asks whether prompt medical intervention can circumvent siring (Fig. S-1). We find that in cases where vampires inject "potent" venom, humans can avoid turning into a vampire by seeking medical intervention within 6 hours. This window elongates considerably if the immune system is not fully inhibited by less-potent venom, reaching a maximum of 14 hours. In the context of our model, the use of medications such as vasopressin (which constricts blood vessels) may improve patient outcomes by reversing the vasodilatory effects of vampire venom. Other immune-stimulating medications may also aid in clearing the vampiric infection.

Physiological Changes after Viral Spread

As the vampiric agent spreads, recently sired humans gain a series of physiological and psychological traits: increased strength, a newfound urge for blood consumption, prominent cranial ridges ("vamp face"), and protruding incisors (vampire fangs). Here, we will attempt to rationalize each of these traits and assess their viability within a medical framework.

Enhanced Strength

Within the Buffyverse, there are no visible changes between the musculature of a human and their newly-sired vampire counterpart. Their vampiric form is considerably stronger, however, implying that strength arises from increased efficiency in the vampire's native musculature (as opposed to increased muscle mass). This could extend from neuronal improvements observed in muscle fibers during typical human strength training or the development of muscle fibers that become optimized for bursts of strength rather than endurance (Del Vecchio et al.; O'Neill et al.). (Vampires do not typically run marathons yet regularly attack foes in short battles. This suggests an evolutionary preference for strength.) This source of strength is similar to what is seen in chimpanzees and other apes (Del Vecchio et al., O'Neill et al.).

Increased strength in vampires can also be attributed to mechanisms similar to "excited delirium," a condition by which individuals enter a state of agitation often characterized by feats of immense strength (Takeuchi et al.). It is often observed after the use of dopaminergic drugs such as PCP (an excuse used by Principal Snyder to explain a vampire attack [*BtVS* "School Hard" 2.3]). Typically, this effect is short-lived and is followed by sudden death, thought to be due to hyperthermia, tachycardia, and respiratory suppression—all non-issues for vampires with no body heat, detectable beating hearts, and limited requirements to breathe (for vampire properties, see the upcoming section *Caloric Requirements*). Excited delirium can also be quite painful and is typically counteracted by the increased endorphins associated with drug use (Mash). With the majority of bodily functions impaired in vampires, however, pain receptors may similarly be less effective, making these large feats of strength relatively painless.

Blood Lust

It is well-documented that blood is the only food source necessary for vampires. Vampires also have strong natural compulsion to consume human blood—here, we argue this behavior points to a more complex behavior than simply seeking a source of nourishment.

Blood lust occurs in newly-sired vampires immediately after rising (*BtVS* "The Harvest" 1.2; *BtVS* "Conversations with

Dead People" 7.7). This behavior may be driven by nutritional deficiencies. Iron deficiency, for instance, can lead to odd cravings for non-nutritional substances such as ice or even dirt, clay, or stones (Borgna-Pignatti et al.). From this perspective, a vampire's craving for blood could stem from a physiological reaction to seek necessary nutrients in blood such as iron. However, Angel, Darla, and Spike all note that drinking pig blood is far inferior to human blood (*BtVS* "Angel " 1.7, *BtVS* "Something Blue" 4.9). Pig blood contains many of the same nutritional components (including iron) in human blood, and pig red blood cells have a similar structure, size, and density to human red blood cells (Cooper). The main difference between pig and human red blood cells is that pig red blood cells have a ~30% shorter lifespan and different biological binding sites, which are unlikely to underscore the strong preference for human blood (Smood). Thus, we propose that a vampire's desire for human blood is not solely based on its unique nutritional value.

Vampires often seek human blood with aggressive behaviors more strongly associated with addiction. Angel develops a stronger desire for human blood after consuming Buffy and Connor's blood (*BtVS* "Graduation Day, Part 2" 3.22; *Angel* "Sleep Tight" 3.16). Addictive desires may also be closely tied to the violent behaviors of vampires. The Master, watching fellow vampires feeding, describes his "lust for the kill," broadening a definition of blood lust beyond the act of feeding (*BtVS* "The Wish" 3.9).

Blood lust is ubiquitous amongst vampires even if their human form was nonviolent (*BtVS* "Conversations with Dead People" 7.7). There may be biological precedence to tie this sudden change in behavior to our viral hypothesis. The virus *Baculoviridae*, for instance, can influence the behavior of infected caterpillars by increasing their food consumption, providing nutrients that allow the virus to quickly replicate. Once the virus has sufficiently replicated ~~is completed~~, the infected caterpillar will then travel to an elevated area where it becomes liquefied and can disperse the virus to other caterpillars (Hamblin and Tanaka; Goulson). At a larger scale in humans, chronic infections with the parasite *Toxoplasma gondii* can lead to increased aggression and impulsiveness; however, parasitic infections typically occur on much slower timescale than the time required to complete the siring process (Cook et al).

Thus, we can conclude that a lust for human blood is more strongly tied to behavior than nutrition. These aggressive behaviors are introduced during the siring process, after which nonviolent humans begin to exhibit highly violent behaviors that are common across vampires. However, the exact mechanisms that alter behavior are unclear and may point to an extra-natural phenomenon that our viral hypothesis cannot reach.

Caloric Requirements

A vampire's diet must provide enough energy to keep the body alive. Yet the caloric needs of a vampire are likely very different from humans. For instance, a lack of body heat and the seemingly-optional ability to breathe decrease caloric requires significantly. Here, we suggest that an exclusively blood-based diet may provide just enough energy for vampires in the Buffyverse to survive (*BtVS* "The Initiative" 4.7, *BtVS* "Prophecy Girl" 1.12).

Vampiric breathing is a contentious issue in the Buffyverse. When an unconscious Buffy requires CPR, Angel (a vampire) looks at Xander (a human) and states, "You have to do it. I have no breath" (*BtVS* "Prophecy Girl" 1.12, 35:07-9). Yet vampires can speak, smoke cigarettes, drown, and be rendered unconscious by restricting their airflow (*BtVS* "Innocence" 2.14; *BtVS* "Bring on the Night" 7.10; *BtVS* "Becoming, Part 2" 2.22). One approach to resolve these discrepancies is to hypothesize that vampires have weak breaths that are sufficient for small tasks (speaking) but insufficient for others (CPR). This has merit in the context of other human functions that are similarly impaired in vampires, such as a lack of heartbeat and a reduced ability to taste (*Angel* "I Will Remember You" 1.8).

If we generalize our predictions and suggest that most vampire functions operate at a very minimal level (or not at all), vampires could survive with 60-70% fewer calories than a normal human (Ruggiero et al.). The exact caloric value of whole blood is not clear; using soft estimates (0.68 cal/mL of blood), vampires could minimally survive with approximately one coffee mug's worth of blood per day (as seen by Spike in *BtVS* "Hush" 4.10) or one medically donated bag of blood (as seen in Angel's refrigerator in *BtVS* "Angel" 1.7) (Fung). However, it is likely that more blood is required to compensate for the energy requirements of strenuous activities such as fighting. A vampirism virus may also alter how consumed human blood is metabolized into usable energy for vampires, requiring adjusted calculations that account for the effects of the siring process.

Cranial Ridges and Enlarged Dentition

Vampires within the Buffyverse exhibit remarkable control over their facial features, particularly in their pronounced cranial ridges ("vamp face") and elongated incisors (vampire fangs). The ability to rapidly switch between a human and vampire face is a distinctive feature of Buffyverse vampires not often shared in other vampire-based literature. Such changes occur before a vampire begins to feed, but also appear during an act of aggression and may directly improve a vampire's strength.[5]

The speed at which vampires can switch between a human and vamp face likely implicates some form of enhanced neuromuscular signaling, a process previously suggested to contribute to their slayage (Freedland "Vampire"). To execute vamp face, a vampire would need to quickly and robustly contract their facial musculature. Such contractions can be directly tied to the enhanced strength of vampires, allowing for a greater force of contraction in some muscles (arms and legs) and sustained contractions in others (facial musculature).

Enhanced incisors (vampire fangs), however, are more difficult to explain via a scientific framework and may be extra-natural in nature. There are genetic conditions that lead to more pointed teeth such as ectodermal dysplasia, and it is feasible that a viral model of siring would alter genes that affect maxillary incisors (teeth associated with vampire fangs). However, it is unlikely that tooth reformation occurs on the timescale of siring or "vamping out" (though it may explain why older vampires like The Master have sharper and more prominent fangs [*Angel* "Darla" 2.7]). To achieve the speed required to turn on/off vamp face, it is more likely that vampire fangs consist of retractable incisors, similar to a snake, with the extension of these teeth linked to the same muscular contractions responsible for vamp face. The development of vampire fangs may be possible: muscles and tendons can reattach incorrectly after trauma, and the siring process may weaken gums enough to loosen teeth and provide mobility (Arora et al.).

Conclusions

The turning of a human into a vampire ("siring") in both *Buffy the Vampire Slayer* and *Angel* is a complex and nuanced process. Here, we analyzed siring through a scientific lens to better identify differences between humans and their vampiric counterparts. We introduced a physiological model that predicts the existence of a vampire "venom" that inhibits a human's immune system. The subsequent human ingestion of vampire blood introduces a bloodborne virus that drives the transformation from human to vampire. Numerical simulations suggest that siring may be preventable with medical intervention within six hours of a vampire bite; specifically, the application of blood pressure medication such as vasopressin may help counter the effects of vampiric venom and improve patient outcomes. Finally, we discussed a series of mechanisms that predict how a human might physically and psychologically transform into a vampire. Surprisingly, much of this process was explainable, but much of it was not, encouraging work into how specific feats can be rationalized as extra-natural phenomena. We hope this study serves as a reference for future contextual and scientific analyses of *Buffy the Vampire Slayer*, *Angel*, and other fictional works.[6]

Appendices

Appendix A: Blood loss alone cannot explain lethargy in humans.

Vampire bites intend to quickly remove blood from a human's body. Over several seconds, this blood loss will cause the human to enter one of four classes of hemorrhagic shock (Kobayashi et al.). Class IV shock is classified by lethargic behavior and is the result of more than 2000mL of blood loss (Gutierrez et al.). In the case of Darla's siring (*Angel* "The Trial" 2.9), Drusilla (10.8-15.1 seconds of contact) must ingest blood at a rate of at least 130mL per second to induce class IV hemorrhagic shock in her human.

The jugular vein, however, only provides blood at 0.12mL per second (Liu). Assuming constant flow and no suction, Drusilla would need to remove over 1000 times more blood during her bite to induce fatigue. (Even a nearby artery would only supply 5% of the blood required [Likittanasombut et al.]). If we assume Drusilla does provide suction during her bite, she can only drink as fast as she can swallow. We estimate that this value hovers around 14mL per second when accounting for the viscosity of blood (which limits drinking speed) (Nathadwarawala et al.; Weijnen). Even with suction, Drusilla drinks blood 9 times slower than is required to induce lethargy.

Since the jugular vein supplies several orders of magnitude less blood than is required and Drusilla cannot physiologically drink fast enough, we conclude that blood loss alone cannot explain lethargy in humans.

Appendix B: Initial conditions for simulating vampirism

Darla (*Angel* "The Trial" 2.9) ingests blood for at least 9.7 seconds before a camera cut obscures our measurements. We can use our previous estimate for Drusilla's drinking rate (Appendix A) to predict that Darla drinks, at most, 100mL of vampire blood. Patients with dengue virus have approximately 10^6 viruses per mL of blood (Onlamoon et al.). Extending this to vampirism allows us to calculate that Darla ingests 10^8 total viruses. Using red blood cell densities from healthy humans, we conclude that after spreading evenly throughout the body, every microliter (□L) of blood contains 5 viruses and 10^6 healthy cells (Ballas).

Since 100mL serves as an upper bound for exposure, we also repeated our simulations for cases where Darla is exposed to less vampire blood. These cases only shift our x-axis in Figs. 1 and 2 rightward (slowing down the overall infection). In healthy humans, their immune system decisively intervenes and begins to "cure" vampirism after 7.2 hours (Fig. 1), 10.6 hours, and 13.8 hours at exposure rates of 100mL (Fig. 1), 10mL, and 1mL, respectively.

Appendix C: Modeling architecture

Our model used a series of four differential equations (as outlined in Nuraini et al.),

$$\frac{dS}{dt} = \mu - \alpha S - aSV$$

$$\frac{dI}{dt} = aSV - \beta I - \nu IZ$$

$$\frac{dV}{dt} = kI - \gamma V - aSV$$

$$\frac{dZ}{dt} = \eta + cI + dIZ - \delta Z$$

In brief, viruses (V) spread by infecting healthy cells (S) at rate a. Infected cells (I) then produce more viruses at rate k. Immune cells (Z) react by increasing production (c, d) and continuously clearing viruses (γ) and infected cells (ν). This model considers death rates for healthy cells ($1/\alpha$), infected cells ($1/\beta$), and immune cells ($1/\delta$), as well as production rates of healthy cells (μ) and immune cells (η).

To investigate vampirism, we consider four specific cases of the model.

- Case A consists of a healthy immune system using clinical parameters from Nuraini et al. and initial conditions from *Appendix B*.
- Case B assumes that a lengthy vampire bite completely immobilizes a human's immune system. We use the same parameters as case A, except for $\nu = \gamma = c = d = 0$.
- Case C considers initial bites of various lengths that linearly degrade the human's immune system such that,

$$\frac{d\nu}{dt} = -\frac{\nu_0}{\tau}$$

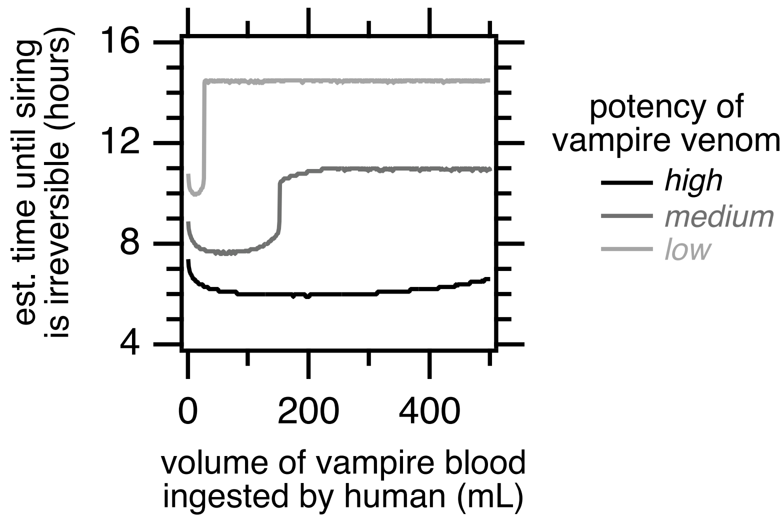
Where τ is our deterioration time (in days, according to Nuraini et al.) and ν_0 is our clinically held value for ν in case A. Variables γ, c, d receive the same treatment. Here, $\nu(t = 0) = \nu_0$ and $\nu(t = \tau) = 0$, our nulled value in case B. We require that $\nu(t) \geq 0$ throughout the entire simulation.

- Case D features a very simplified recovery such that,

$$\begin{cases} \dfrac{d\nu}{dt} = -\dfrac{\nu_0}{\tau} & t < r \\ \dfrac{d\nu}{dt} = +\dfrac{\nu_0}{\tau} & t \geq r \end{cases}$$

where r is the time at which recovery begins. Variables γ, c, d receive the same treatment. This represents an immediate turnaround; as soon as a human receives treatment, they begin to recover at the same speed they were originally declining. We require that $0 < v(t) \leq v(t = 0)$ throughout the entire simulation.

Appendix D



Appendix D: The time by which siring is reversible as a function of the vampire venom potency and the amount of vampire blood ingested by a human. Results are based on a simple recovery model (case D, Appendix C). The minimum window for recovery after a bite with potent venom is 5.9 hours after 174mL of ingestion.

Notes

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[1] Editors' note: Compare Philip E. Devine's "The Logic of Fiction."

[2] Alonna Gunn (*Angel* "War Zone" 1.20) is bitten by three vampires during daylight hours and is completely turned by that evening. Kralik (*BtVS*, "Helpless" 3.12) sires a prison guard before a subsequent personnel shift, saying "Ah, you're up. I was afraid I drained you too much. I do that sometimes." This might suggest a lengthier drainage can lead to a lengthier time until rising.

[3] Buffy has turned into a vampire previously (albeit temporarily and from a non-vampiric source), suggesting that Buffy's failed siring by Dracula may not extend from her Slayer powers alone (*BtVS* "Nightmares" 1.10).

[4] There are some cases where a vampire can revert back to their human form, but require external factors (such as the blood of a Mohra demon, for instance) (*Angel* "I Will Remember You" 1.8).

[5] Doyle, a half-demon, mentions that he is physically stronger in his demon form (*Angel* "The Bachelor Party" 1.7; *Angel* "Hero" 1.9)). However, this may not generalize to vampires.

[6] The authors would like to express sincere thanks to P. Mardoum for kindly critiquing an early version of this manuscript and to B. Sperry for aiding the development of ideas. They also thank the peer reviewers at *Slayage*, whose feedback was extremely valuable for improving the communication of scientific ideas to a multidisciplinary audience.

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