# Bats in Flight: An Educational Animation on the Anatomy, Aerodynamics, and Flight Morphology of Bats for the General Public

Carmen Burroughs

**Research Committee:**
*Supervisor*: David Mazierski (BMC)
*Content Advisor*: Dr. Burton Lim (ROM)
*Second Voting Member*: Marc Dryer (BMC)

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## ABSTRACT

The ongoing and complex study of bat flight anatomy, aerodynamics, and kinematics is not something easily understood by the general public, especially considering the overall negative perceptions and misconceptions many people hold about bats. The goal of my master's research project (MRP) is to create a 3D/2D animation which will convey the basic information needed to understand bat flight (anatomy, aerodynamics, morphology, etc.) in an engaging and explicit way so that the general public can understand these complex concepts. This animation will further educate the public on bats in hopes of decreasing negative perceptions and myth beliefs. I will use specimens provided by the Royal Ontario Museum through Dr. Burton Lim and previously filmed bat flight videos to aid in my 3D reconstructions and animations.

## INTRODUCTION

The study of bat flight in regard to anatomy, aerodynamics, kinematics and flight morphology is complex and still ongoing, with new discoveries constantly being made. Bats, being the only true flying mammal, have many adaptions and specialties that truly make their

flight unique and aerodynamically sound. One of these adaptations – a highly compliant wing that undergoes continuous morphological change in flight – has even lead researchers to agree that fully reliable and analytical aerodynamic analysis of is not currently possible (Hedenstrom and Johansson, 2015). For the general public, much of this research into bat flight is either inaccessible or unsuitable. Concepts such as lift, drag, camber, and airfoils when combined together can become highly complex and hard to understand (Pietsch, Bohland, & Schmale, 2015). Another obstacle to address with the general public besides the comprehension of complex scientific subject matter is that bats are often misunderstood, and several negative myths or perceptions of bats are still prevalent (Hoffmaster, Vonk, & Mies, 2016). It is key to attempt to alter these negative perceptions and to debunk common myths as bats are both key to the environment and many species are currently endangered. Providing the general public with accessible information on bats would ideally increase their factual knowledge about bats and hopefully lead to decreased negative perceptions and an increased willingness to support conservation efforts for bats. Research shows that knowing more about a subject or gaining knowledge about a subject can possibly lead to an increase in positive perceptions of that subject (Prokop, Fancovicova, & Kubiatko, 2009; Reid, 2016). The current visual media for this topic is limited: most of what exists are still images used as figures in research papers or real-life video with little to no annotations to guide a viewer through.

To educate the general public about this complex topic, I propose the creation of a short 3 minute animation that integrates subtle interactivity (pausing and a scrub bar), visual cues, and a combination of 2D and 3D rendering styles.

## BACKGROUND

***Brief summary of research topic***

Wing anatomy and how it relates to flying function is essential in understanding bat locomotion. Visual representations of these topics could enhance the general public's learning of these topics. Many of the aerodynamic topics such as weight, thrust, drag, lift, camber, etc., cannot be seen by the human eye, so creating a visual media to explain them could decrease the mental work of trying to imagine these concepts, especially for those with low-spatial ability. While most anatomy can be simply observed, many of bats' anatomical adaptations for flight, such as the thin skin with intricate muscles, elongated and flexible bones, and small membrane hairs, can be hard to or not possible to capture in detail while in motion with just real-life video. To further clarify this anatomy and engage the viewer, comparisons of anatomy can be shown. For example, stating how the wing of a bat and the human arm have the same bones – just adapted for different uses – could aid in understanding because it builds upon a familiar concept people may already understand and connect to, decreasing the mental work of the viewer. After the subject matter and what needs to be conveyed is taken into consideration, one can go on to decide which form of media would be the most appropriate to deliver these concepts to a general public audience.

***Literature on dynamic media (animation) vs static media***

When looking into using dynamic media or static media, it is important to take into account the content being used in the animation and the way the animation is being utilized. Bat flight, being a highly dynamic and complex process that involves constant movement and spatiotemporal changes, would be well suited for a dynamic visualization as opposed to static

illustration. It is argued that when it comes to representing movement or spatiotemporal changes that dynamic visualization would have an advantage (Hoffler, 2010). More research shows that animations can help learners visualize concepts that involve changes in direction, speed, and path of travel (Lin and Dwyer, 2009). It is also essential to think of how the choice of static vs dynamic media affects the cognitive load of the viewer depending on their spatial ability; studies have shown that, in contrast to what was expected, learners with low-spatial ability learned better with animations; this could be due to the animations doing the cognitive work for them by showing a ready-made dynamic mental model of the process (Hoffler, 2010; Lee and Shin, 2011). Using animation to focus on the flight of bats could aid in doing the mental modeling work that is involved in understanding anatomy during flight and the invisible aerodynamic forces taking place so that low-spatial ability learners could learn the material better alongside those with high-spatial ability learners.

All of this is not to say, though, that the insertion of a static image (or several images) within the animation would not be helpful when part of the animation proves to be more distracting than educational or helpful. Learners controlling their own pace and order of presentation and the reduction of extraneous processing from viewers only seeing critical frames shows the strengths of using static media of dynamic media (Mayer, Hegarty, Sarah Mayer, & Campbell, 2005). These strengths of static media can also be implemented into animation by adding elements such as the ability for the viewer to pause the animation and use of a slider bar would let viewers go at their own pace, making the animation subtly interactive. (Mayer, Hegarty, Sarah Mayer, & Campbell, 2005). The amount of extraneous information within an animation can be minimized by making sure to allow the viewer to focus on only

critical aspects; this can be done by emphasizing only key parts of a concept, utilizing animation techniques, and incorporating visual cues.

***Literature on 2D vs 3D animation***

A decision one must look into when forming effective dynamic media is looking into the advantages and disadvantages of 2D and 3D animation. Not only is it important to take into account what your subject matter is and if it is suitable for 3D animation (i.e. is an understanding of depth and spatial relationships required?), but to also consider that within the same animation, transitions or shifts between 3D and 2D styles can be made when discussing a concept where 3D may be inappropriate and distracting or a concept where 2D animation does not provide the details of depth or space. Research has shown that 2D animations are equally as, if not more, effective than 3D animation in regards to processes where spatial relationships are not required for understanding (Huk, Steike, & Floto, 2009). As previously stated, this could be due to the extraneous information that can be added with an animation, especially a 3D one where no explanation of depth was needed in the first place. When looking further into the use of 3D for understanding of depth and special relationships, It was found that 3D animations were helpful during a study done with kinesiology students using 3D animations to observe anatomy in regard to spatial ability (Hoyek, Collet, Rienzo, Almeida, & Guillot, 2014). Therefore, 2D animation could be used when explaining aerodynamic terms or very basic anatomy, while 3D animation could be used when visualizing the complex spatial relationships (wingbeat, 3D form of wing/wake vortices, camber, lift, etc.) of bat flight, which is happening on multiple spatial planes.

***Literature on animation techniques that can lead to effective public engagement in science***

Once the choice has been made concerning animation type, it is essential to determine what elements of animation are going to make it the most effective. When making a dynamic media piece for a general audience, especially one of a more complex subject matter, one does not want to overwhelm the viewer. If there is too much extraneous detail, viewers can become cognitively overwhelmed and the animation loses effectiveness (O'Day, 2011). The material and content used for the animation should be appropriate for the target audience (O'Day, 2011); since the target audience for this animation is the general public, it will be important to make sure the content is simplified and explained clearly, but remains scientifically accurate. Ways of simplifying and making the content more appropriate for the audience include the use of linking terminology used in narration with a textual representation near the indicated structure, event, or concept it is describing can enhance the learning outcome of an animation. The style of narration matters as well – more conversational narration encourages learning and might be more appealing to a general public audience as opposed to non-conversational narration (O'Day, 2011; Mayer, 2003; Lowe, 2003).

Another method of simplifying the information in the animation for the audience may be using visual cues. However, the effectiveness of visual cues has been debated. Some studies report that cues such as color(s) or shape help to show events occurring (O'Day, 2011; Wilson-Pauwels, 1997) and that attention cueing aids in indicating salient aspects to be noticed (O'Day, 2011; De Koning et al., 2009). Other studies, though, have found no evidence that visual cues changed learning outcomes or cognitive load (though one study reported that there was a decrease in learning time with visual cues due to a decrease in the amount of time spent on finding keyed relevant information) (Lin and Atkinson, 2009). The De Koning study – involving

eye tracking of visual cues used in an animation on the cardiovascular system – also did not find any link between visual cues and enhanced learning, but did find that visual cues lead the eye to the area of focus (De Koning et al., 2009). The majority of the existing visual media found when researching bat wing flight dynamics either did not implement visual cues or used them poorly. For example, there were too many cues, or they were poorly placed and thus were ineffective at increasing salience . However, if visual cues are used selectively (as to not conflict with O'day's rule of extraneous detail) to decrease cognitive work and guide the viewer's eyes of where to look, learning could be enhanced.

***Literature on how education and knowledge affect and/or change perceptions, attitudes, and behaviors***

As previously stated, bats have many misconceptions and negatives myths associated with them that are still widely believed by the general public. By making such an animation accessible to the general public, their knowledge on bats will increase. More knowledge on a topic has been shown to lead to more positive perceptions and the dispelling of myths. A study done to test correlation between attitude, knowledge, and alternative concepts involving bats in school grade children showed that the higher the level of a person's alternative conceptions (belief in myths/misconceptions), the more negative their attitude would be towards bats. They also found a correlation between attitude towards bats and knowledge the person had about bats – the more knowledge someone had on bats, the better their attitude was towards them (Prokop, 2008). Another study comparing biology major (no zoology classes taken) and non-biology majors showed that there was a strong correlation between having a greater amount of knowledge in bats and less belief in myths being linked with positive attitudes towards them

(and vice versa) (Prokop, Fancovicova, & Kubiatko, 2009). A study done amongst Costa Rican men showed that the men who knew more about bat natural history due to environmental education were less likely to have intentions to kill bats indiscriminately compared to the men who knew less about bat natural history (Reid, 2016). Research done within a group of individuals already interested in bats showed that people who visited a conservation educational event or exhibit were more knowledgeable about bats and bat conservation; they also displayed more willingness to participate in conservation efforts. Due to small sample size and bias, this is a study that should be done amongst a more general audience (Hoffmaster, Vonk, & Mies, 2016). Another study that took place in the western Indian Ocean Islands where both schools and community groups were shown environmental education programs (that included videos) showed that exposure to these programs caused an increased awareness about bats, bat conservation, and inclusion of bat conservation into school curricula (Trewhella et al., 2005). While not necessarily about a typically negatively viewed animal, a study was conducted by presenting two educational visual media presentations on orangutans to university students. The cumulative effect of both presentations correlated with an increase in knowledge, positive attitude, and behavior change (further researching issues, checking products for palm oil, other conservation efforts). It is important to consider, though, that this was a study involving educated university students and not the general public (Pearson, Dorrian, & Litchfield, 2011). With these results taken into account, providing clear and accurate knowledge about bats could lead to the general public changing negative perceptions into more positive ones. Positive perceptions could lead to more interest amongst the general public and

those already interested in bats to participate in conservation efforts which are greatly needed at the time.

***Brief analysis of existing media in relation to literature review***

The current existing visual media relating to bat flight is extremely limited. There is not only very little of it, but often the media is either too short, poorly annotated, not detailed enough, too static, or a combination of all of these. “How Bats Fly” by HowStuffWorks Animations is one of the overall good examples of a 2D animation for the general public that implements visual cues: text is included to accompany the very conversational and entertaining narration, the animations are simple and clear, motion graphics are utilized appropriately, and color is used to provide salience to draw attention. The animation is too short, though, and overall too general – there is not enough detailed information about the anatomy or flight process. An opposite to this example would be that of “Bats Take Flight” by SciFri. This is a real-life video media piece that provides thoroughly detailed but clear information on the subject matter while showing the topic in an interesting mixture of straightforward shots showing bat flight with more artistic shots to provide visual interest. While some motion graphics are used here along with visual cues to provide salience of where to focus and clarity of some topics, it is lacking in other places and some topics are still not explained well enough for the intended general public audience.

## RESEARCH OBJECTIVES

My master’s research project (MRP) will address communicating the topic of bat flight to the general public. My research objectives are to:

- Improve the general public's understanding of the complex concept of bat flight so to further their overall bat knowledge and interests in bats and therefore decrease their negative perceptions.
- Create a 3 minute 3D/2D animation that conveys the anatomy of bats, the aerodynamics involved in bat flight, and how bats' morphological adaptions aid them in flight.
- Utilize animation techniques such as subtle interactive elements (pausing and scrub bar) and visual cueing which will aid in conveying the basic information needed to understand bat flight (anatomy, aerodynamics, morphology, etc.) in an engaging and explicit way so that the general public can understand the complex concepts.
- Develop a script using conversational narration along with a visual style that is both engaging for the general public but does not compromise the accuracy of the research and subject matter.

## METHODS

### *Target Audience*

The target audience of this animation will be the general public. The final animation will likely be uploaded through video sharing sites such as YouTube or Vimeo and be placed on the ROM website, possibly within Dr. Burton Lim's profile to promote Dr. Lim's research and the Bat Cave exhibit while providing an accessible education source. Ideally the animation could be used on display within the Bat Cave exhibit, but this involves different departments within the ROM that are not currently associated with this MRP.

***Materials***

- ZBrush: Used to sculpt 3D models of bat(s) and bat(s) anatomy.
- Maya/Cinema 4D: Used for additional modeling, rigging, lighting, and animation.
- After Effects: Used for compositing, 2D animation, and motion graphics.
- Program for sound recording and processing for the animation narration.

***Procedure***

*Scripting and Storyboarding*

A script outline to be developed with supervision from David Mazierski (BMC), Marc Dryer (BMC), and Dr. Burton Lim (ROM). Emphasis on making sure language and tone are appropriate for the general public but maintains scientific accuracy. Possible topics to cover:

- Anatomy of the bat: bone and wing structure.
- Aerodynamics of flight: lift, drag, airfoils, camber, etc.
- Comparison of anatomy and flight: how is bat flight different from bird flight and insect flight. Comparison to a human arm.

*Modeling and Rigging*

Using both dry and wet specimens provided by Dr. Burton Lim, I will sculpt 3D models in Z-brush. I will sculpt models of a complete bat(s), wings, bones, muscles, etc. (breaking the anatomy down). I will observe public source real-life videos of bat flight to aid in how to rig that bat and how to accurately animate a bat in flight. The models will then be imported into Maya/Cinema 4D for rigging, lighting, and animation.

*Animatic and Animating*

Once the script has been finalized and approved, a recording of it will be created. Using After Effects, an animatic will be created for approval from my MRP committee. From here, I will continue the creation and completion of assets in ZBrush, Cinema4D, and Maya to complete the animation.

## SIGNIFICANCE

This MRP animation will provide a new form of visual media to educate the general public on bat flight. The majority of existing media on this subject is stationary imagery or real-life video and some not entirely appropriate for a general public target audience; the addition of animation will provide a new and perhaps more beneficial option for education. It will be able to take complex concepts of aerodynamics and make them clear and engaging by utilizing animation tools. The increase of knowledge on bats can lead to a more positive attitudes of bats, ideally leading to more interest in conservation efforts.

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