

**Table S1. Insect studies of aerodynamic mechanisms.** The studies represented in the insect columns of Figure 7 are listed with the same color-coding system based on study methodology, e.g. black – *in vivo*, red – physical model or robot, orange – computational fluid dynamics (CFD), blue – theory. Asterisks denote qualitative studies. NOTE: This list is not meant to be all-inclusive, and is only meant to provide a general understanding of where gaps lie in our knowledge of aerodynamic mechanisms for insect flapping flight. Included studies were not evaluated based on quality or impact, and are thus not listed in any particular order. We simply scored if a study existed in the literature and stopped searching when we found one.

INSECTS		
		Slow/hovering flight
		Forward Flight
Absence of stall	<ul style="list-style-type: none"> <li>• Lehmann and Dickinson, 1998 (tethered drosophila); Dickinson and Gotz, 1996 (tethered drosophila)</li> <li>• Dickinson and Gotz, 1993 (model wing); Ellington and Usherwood, 2001 (model hawkmoth wing); Birch et al., 2004 (robofly); Lentink and Dickinson, 2009 (model drosophila wing); Sane and Dickinson, 2002 (robofly); Sane and Dickinson, 2001 (robofly); Dickinson et al., 1999 (robofly); Birch and Dickinson, 2003 (robofly); Ellington et al., 1996 (hawkmoth flapper); van den Berg and Ellington, 1997 (model hawkmoth flapper); Kliss et al., 1989 (flat plate dragonfly model); Maxworthy, 1979 (model wings); Savage et al., 1979 (model wings); Usherwood and Ellington, 2002 (model mayfly and bumblebee wings)</li> <li>• Wang and Sun, 2005 (dragonfly); Sun and Tang, 2002 (drosophila); Liu et al., 1998 (hawkmoth)</li> <li>• Savage et al., 1979 (dragonfly); Weis-Fogh, 1972 (drosophila); Ellington, 1984</li> </ul>	<ul style="list-style-type: none"> <li>• Willmott et al., 1997 (hawkmoth)</li> <li>• Ellington and Usherwood, 2001 (hawkmoth)</li> <li>• Wang and Sun, 2005 (dragonfly)</li> <li>• Dickinson et al., 1999</li> </ul>
Rotational effects	<ul style="list-style-type: none"> <li>• Zanker and Gotz, 1990 (drosophila); Ennos, 1989 (free-flying diptera)</li> <li>• Lehmann and Pick, 2007 (robofly); Lentink and Dickinson, 2009 (robofly); Sane and Dickinson, 2002 (robofly); Sane and Dickinson, 2001 (robofly); Dickinson et al., 1999 (robofly); Savage et al., 1979 (flat plate dragonfly)</li> <li>• Sun and Tang, 2002 (drosophila); Kang and Shyy, 2014</li> <li>• Kang and Shyy, 2014; Savage et al., 1979 (dragonflies); Ellington, 1984</li> </ul>	<ul style="list-style-type: none"> <li>• Zanker and Gotz, 1990 (drosophila)</li> <li>• Ennos, 1989 (diptera)</li> </ul>
Added mass	<ul style="list-style-type: none"> <li>• Dickinson and Gotz, 1990 (drosophila)</li> <li>• Dickson and Dickinson, 2004 (robofly); Sunada, 1993 (flat plate)</li> <li>• Kang and Shyy, 2014; Sun and Tang, 2002 (drosophila); Sunada, 1993 (numerical)</li> <li>• Kang and Shyy, 2014; Ellington, 1984</li> </ul>	<ul style="list-style-type: none"> <li>• Dickson and Dickinson, 2004 (Robofly)</li> </ul>
Clap and fling	<ul style="list-style-type: none"> <li>• Zanker and Gotz, 1990 (drosophila); Wakeling and Ellington, 1997 (dragonfly); Weis-Fogh, 1973 (chalcid wasp); Ennos, 1989 (diptera)</li> <li>• Spedding and Maxworthy, 1986 (model wing); Lehmann et al., 2005 (robofly); Sunada, 1993 (flat plate); Lehmann and Pick, 2007 (robofly); Maxworthy, 1979 (model wings); Bennett, 1977 (flat plate)</li> <li>• Sunada, 1993</li> <li>• Lighthill, 1973; Edwards and Cheng, 1982; Ellington, 1984</li> </ul>	<ul style="list-style-type: none"> <li>• Willmott et al., 1997 (hawkmoth)</li> <li>• Ennos, 1989 (diptera)</li> </ul>
Wing-wake interaction	<ul style="list-style-type: none"> <li>• *Srygley and Thomas, 2002 (butterflies)</li> <li>• Lehmann and Pick, 2007 (robofly); Sane and Dickinson, 2002 (robofly); Sane and Dickinson, 2001 (robofly); Dickinson et al. 1999 (robofly); Birch and Dickinson, 2003 (robofly)</li> </ul>	
Wing morphology	<ul style="list-style-type: none"> <li>• Mountcastle and Combes, 2013 (bumblebees); Zheng, 2009 (butterfly and hawkmoth)</li> <li>• Kang and Shyy, 2014; Zheng, 2009 (butterfly and hawkmoth)</li> <li>• Kang and Shyy, 2014</li> </ul>	<ul style="list-style-type: none"> <li>• Usherwood and Ellington, 2002 (model mayfly and bumblebee wings)</li> </ul>
Body/ tail/ hindwing	<ul style="list-style-type: none"> <li>• *Bomphrey et al., 2009 (bumblebee thorax effect on LEV)</li> <li>• Usherwood and Lehmann, 2008 (dragonfly wing phasing)</li> <li>• Wang and Sun, 2005 (dragonfly)</li> </ul>	<ul style="list-style-type: none"> <li>• Wang and Sun, 2005 (dragonfly)</li> </ul>

**Table S2. Vertebrate studies of aerodynamic mechanisms.** The studies represented in the bat, hummingbird, and generalist bird columns of Figure 7 are listed with the same color-coding system based on study methodology, e.g. black – *in vivo*, green – prepared real wing, red – physical model or robot, orange – computational fluid dynamics (CFD), blue – theory. Asterisks denote qualitative studies. This list is not meant to be all-inclusive, and is only meant to provide a general understanding of where gaps lie in our knowledge of aerodynamic mechanisms for vertebrate flapping flight. Included studies were not evaluated based on quality or impact, and are thus not listed in any particular order. We simply scored if a study existed in the literature and stopped searching when we found one.

	BATS		HUMMINGBIRDS	BIRDS	
	Slow/hovering flight	Forward Flight	Slow/hovering flight	Slow/hovering flight	Forward Flight
Absence of stall	• Hedenstrom et. al., 2007 (G. soricina); Muijres et. al., 2008 (G. soricina)	• Hedenstrom et. al., 2007 (G. soricina); Muijres et. al., 2014 (L. yerbabuenae) • Song et. al., 2008 (membrane wings)	• Warrick et. al., 2009 (rufous) • Altshuler et. al., 2004 (rufous) • Altshuler et. al., 2004 (model wing) • Song et. al., 2014 (ruby-throated) • Weis-Fogh, 1972	• Muijres et. al., 2012 (pied flycatchers) • Usherwood and Ellington, 2002 (quail wing); Usherwood, 2008 (pigeon wing). • Usherwood and Ellington, 2002 (model quail wing)	• Hubel and Tropea, 2010 (goose-sized flapper)
Rotational effects			• Warrick et. al., 2009 (rufous) • Weis-Fogh, 1972	• Hedrick et. al., 2004 (cockatiels); Hedrick et. al., 2002 (cockatiels and doves)	• Hedrick et. al., 2004 (cockatiels); Hedrick et. al., 2002 (cockatiels and doves)
Added mass		• Iriarte-Diaz et. al., 2011 (C. brachyotis) • Bahlman et. al., 2013 (robotic bat wing) • Watts et. al., 2001	• Weis-Fogh, 1972	• Hedrick et. al., 2004 (cockatiels)	• Hedrick et. al., 2004 (cockatiels)
Clap and fling				• *Crandell and Tobalske, 2015 (diamond dove)	
Wing-wake interaction			• Song et. al., 2014 (ruby-throated)	• *Usherwood and Ellington, 2002 (coefficients were measured before and after quail propeller wake)	
Upstroke effects	• Hedenstrom et. al., 2007 (G. soricina); Muijres et. al., 2011 (G. soricina, L. yerbabuenae); Rayner, 1987; Tian et. al., 2006 (C. brachyotis); Wolf et. al., 2010 (G. soricina)	• Iriarte-Diaz et. al., 2011 (C. brachyotis); Hedenstrom et. al., 2007 (G. soricina); Muijres et. al., 2011 (G. soricina, L. yerbabuenae); Rayner, 1987; Tian et. al., 2006 (C. brachyotis); Wolf et. al., 2010 (G. soricina); Hubel et. al., 2010 (C. brachyotis)	• Warrick et. al., 2005 (rufous)	• Hedrick et. al., 2004 (cockatiels); Hedrick et. al., 2002 (cockatiels and doves) • Crandell and Tobalske, 2011 (pigeon wing)	• Hedrick et. al., 2004 (cockatiels); Hedrick et. al., 2002 (cockatiels and doves)
Wing morphology	*Norberg, 1972 (comparative reasoning)	• Bahlman et. al., 2013 (robotic bat wing) • *Norberg, 1972 (comparative reasoning)	• Warrick et. al., 2005 (rufous) • Altshuler et. al., 2004 (rufous) • Altshuler et. al., 2004 (rufous)	• Crandell and Tobalske, 2011 (pigeon wing); Lee et. al., 2015 (magpie wings) • Drovetski, 1996 (model galliform wings w/ trailing edge notch)	* Maybury and Rayner, 2001 (Frozen starlings); Alvarez et. al., 2001 (live and dead pigeons + measurements of other bird wings)
Body/ tail/ hindwing			*Altshuler et. al., 2009. (Anna's tail)	• Usherwood et. al., 2005 (pigeon tails) • *Thomas and Balmford, 1995 (tails)	• Henningsson et. al., 2011 (swift body effect on vortices) • Maybury et. al., 2001 (frozen starlings, tail effects) • Thomas, 1993 (tails)

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Note: Animal avatars were adapted from Dickson *et. al.*, 2008 (insect), Hedenstrom *et. al.*, 2007 (bat), Warrick *et. al.*, 2005 (hummingbird), and Brown, 1963 (bird).