

# Supplemental Material

*CBE—Life Sciences Education*

Randa *et al.*

## Supplementary material

**Table S1.** Interview protocol

<p>Section 1 <i>Introductory Questions</i></p>	<p>Consider the following functional groups/protein structures. Would you expect the following molecules to stabilize or destabilize a <math>K^+</math> ion in the center of a membrane bilayer? Briefly explain your answers.</p> <ol style="list-style-type: none"> <li>C-terminus of an alpha helix</li> <li>N-terminus of an alpha helix</li> <li>Water molecules</li> <li>Hydrophobic molecules</li> <li>Basic amino acid side chains (like Lys, Arg)</li> <li>Acidic amino acid side chains (like Glu, Asp)</li> </ol>
	<p>Keep in mind that MacKinnon and colleagues observed that the <math>K^+</math> ions are able to traverse very rapidly through the channel, indicating that they were not bound too tightly in the internal pore / cavity. At the same time, the cavity is wide enough to accommodate water molecules in addition to a <math>K^+</math> ion. After leaving the cavity, the internal pore constricts such that any ion entering the selectivity filter must completely dehydrate.</p> <ol style="list-style-type: none"> <li>With the above information, could you propose a model of how the <math>K^+</math> ions traverse through the channel?</li> <li>Can metal ions smaller than <math>K^+</math>, for example <math>Na^+</math> ions, pass through the KcsA channel? Why?</li> </ol>
<p>Section 2 <i>Getting familiar with BiochemAR</i></p>	<p>Have you used BioChemAR before? Take your time to look over the structure and familiarize yourself with the color key.</p>
	<p>Could you describe the structures that you see?</p>
<p>Section 3 <i>Revisiting previous models</i></p>	<p>Now let's revisit your hypotheses. Does what you see in the structure support or disprove your hypotheses with regards to the molecular elements you thought about in Q1? (Ask them to use the model explicitly to justify their answer)</p>
	<p>Does what you see in the structure support or disprove your hypothesis with regards to your proposed model for <math>K^+</math> channel function in Q2? (Ask about both how the <math>K^+</math> ion traverse and whether the sodium ion passes through)</p> <ol style="list-style-type: none"> <li>If support: how does the structure support your hypothesis?</li> <li>If disprove: why do you think it disproves your hypothesis? How would you change your original hypothesis. Why do you think the structure support your alternative hypothesis?</li> </ol>

**Table S2.** Description of student produced gestures, grouped by topic and motion type. In the case of certain gestures that were used across multiple topics, the gesture name is followed by an abbreviation of the topic name.

Topic	Moton Type	Gesture Name	Description
Ion depiction (ID)	Motion	Air drawing ID	One or both hands are used to "draw" a specific image in the air
		Claw	Hand is curved, but open, almost like holding a ball
	Static	Fist	All fingers curve in tightly into palm
		Hang loose	Thumb and pinky are extended with all other fingers closed. Hand may rotate or shake back and forth with emphasis
		Pinch	Thumb and pointer come about an inch apart (pinching motion)
Channel Depiction (CD)	Motion	Air drawing CD	One or both hands are used to "draw" a specific image in the air
		Attract CD	One hand pushes into the other
		Chop CD	Hand(s) make one or more small chopping motions
		Clap	Both hands come together in a clapping motion
		Collapse CD	Both hands are in open formation and move inwards towards each other
		Come on CD	Hand makes a big sweeping curved motion that may involve arm, sort of like "come on"
		Up and down CD	Vertical motion that encompasses either the hand moving from top to bottom or bottom to top or repeatedly
		Exit	Hand quickly moves away from body (and possibly off-screen)
		Expansion CD	<b>ITALIAN PINCH:</b> All fingers come together, but palm of hand is open; both hands move away from each other <b>FINGERS:</b> 2 fingers move towards and away from each other
		Insert CD	One hand is placed into a previously formed shape, made by the other hand
		Pinball CD	Both hands simultaneously flap back and forth, hinging at the wrists
		Pulsing	<b>BOWL:</b> Both hands (palms facing one another) move closer and away from one another repeatedly <b>CLAWS:</b> Both hands (held in "claw" shapes) move closer and away from one another repeatedly

		<p><b>PINCH:</b> Both hands make pinching gesture, and move closer and away from each other repeatedly</p> <p><b>POINT CD:</b> both hands (index fingers extended) move closer and away from one another repeatedly</p> <p><b>SHEETS CD:</b> Both hands are horizontal (palms facing torso), with one hand stacked behind the other. Hands move closer and away from one another repeatedly</p>
	Rainbow CD	Hand/hands open outwards and arc down
	Repel	Hand "bounces" towards opposite hand, which causes opposite hand to move away
	Ring CD	Pointer finger draws a circular figure which may be oriented horizontally or vertically
	Screw in lightbulb CD	Hand is in a C shape and rotates
	So so	Hand rotates loosely back and forth (horizontal plane)
	Open bowl CD	Both hands are set slightly apart, make curved bowl gesture; may or may not move back and forth
Either/Or	Piano CD	One or two hands are raised and held horizontally. They move back and forth and/or up and down slightly.
	Pinch CD	Thumb and pointer come about an inch apart (pinching motion)
	Stack CD	<b>PINCH:</b> Both hands make pinching gesture (index and thumb about an inch apart), with pinches closely stacked on top of one another
	Double hand mug	Both hands face one another in an open formation (small ball/thermos).
Static	Hang loose CD	Thumb and pinky are extended with all other fingers closed. Hand may rotate or shake back and forth with emphasis
	Italian pinch CD	All fingers come together, but palm of hand is open
Movement through space (MS)	Attract MS	One hand pushes into the other
	Down and Up MS	Hand starts from lower and quickly raises up
	Italian pinch MS	All fingers come together, but palm of hand is open
Motion	Lever	Hand shifts from vertical to horizontal orientation
	Membrane move MS	Forearm is horizontal, showing the membrane of the cell. The pointer finger of the other hand then moves up and down repeatedly.
	Pinball MS	Both hands simultaneously flap back and forth, hinging at the wrists

	Push	One or both hands (palms facing toward the screen) physically push forwards.	
	Seatbelt	Moving one hand diagonally (from shoulder across body) behind the other hand	
	Tide MS	Hand makes a small push downwards and towards the camera, palm down (resembles a rolling wave)	
	Trace MS	Index finger traces a line or other shape that aligns with dialogue. Other hand may or may not be involved in "staging"	
	Up and Down MS	Vertical motion that encompasses either the hand moving from top to bottom or bottom to top or repeatedly	
	Zoom	Hand briefly moves in towards the center before dropping off camera	
Either/Or	Pointing MS	Finger of hand points in an intentional direction; may or may not move as well	
Static	Bracket MS	Finger bracket: thumb and pointer finger make bracket shape, rest of hand is in a fist	
Charge-charge interaction (CC)	Air drawing CC	One or both hands are used to "draw" a specific image in the air	
	Attract CC	One hand pushes into the other	
	Chop CC	Hand(s) make one or more small chopping motions	
	Clap	Both hands come together in a clapping motion	
	Collapse CC	Both hands are in open formation and move inwards towards each other	
	Come on CC	Hand makes a big sweeping curved motion that may involve arm, sort of like "come on"	
	Up and down CC	Vertical motion that encompasses either the hand moving from top to bottom or bottom to top or repeatedly	
	Motion	Exit	Hand quickly moves away from body (and possibly off-screen)
		Expansion CC	<b>ITALIAN PINCH:</b> All fingers come together, but palm of hand is open; both hands move away from each other <b>FINGERS:</b> 2 fingers move towards and away from each other
		Insert CC	One hand is placed into a previously formed shape, made by the other hand
		Pinball CC	Both hands simultaneously flap back and forth, hinging at the wrists
		Pulsing	<b>BOWL:</b> Both hands (palms facing one another) move closer and away from one another repeatedly <b>CLAWS:</b> Both hands (held in "claw" shapes) move closer and away from one another repeatedly

		<p><b>PINCH:</b> Both hands make pinching gesture, and move closer and away from each other repeatedly</p> <p><b>POINT CC:</b> both hands (index fingers extended) move closer and away from one another repeatedly</p> <p><b>SHEETS CC:</b> Both hands are horizontal (palms facing torso), with one hand stacked behind the other. Hands move closer and away from one another repeatedly</p>
	Rainbow CC	Hand/hands open outwards and arc down
	Repel	Hand "bounces" towards opposite hand, which causes opposite hand to move away
	Ring CC	Pointer finger draws a circular figure which may be oriented horizontally or vertically
	Screw in lightbulb CC	Hand is in a C shape and rotates
	So so	Hand rotates loosely back and forth (horizontal plane)
	Open bowl CC	Both hands are set slightly apart, make curved bowl gesture; may or may not move back and forth
Either/Or	Piano CC	One or two hands are raised and held horizontally. They move back and forth and/or up and down slightly.
	Pinch CC	Thumb and pointer come about an inch apart (pinching motion)
	Stack CC	<b>PINCH:</b> Both hands make pinching gesture (index and thumb about an inch apart), with pinches closely stacked on top of one another
	Double hand mug	Both hands face one another in an open formation (small ball/thermos).
Static	Hang loose CC	Thumb and pinky are extended with all other fingers closed. Hand may rotate or shake back and forth with emphasis
	Italian pinch CC	All fingers come together, but palm of hand is open
Channel-ion interaction (CI)	Attract CI	One hand pushes into the other
	Boundary	Hand(s) is held flat (either horizontally or vertically), then repeatedly moves in a linear back and forth motion to define a line/plane/level
	Chop CI	Hand(s) make one or more small chopping motions
	Collapse CI	Both hands are in open formation and move inwards towards each other
	Come on CI	Hand makes a big sweeping curved motion that involves arm, sort of like "come on"

	Down and up CI	Single hand raises and lowers, with fingers held vertically
	Expansion CI	Hands expand outwards
	Flash CI	Fingers are constricted, then expand outwards in a flashing movement
	Insert CI	One hand is placed into a previously formed shape, made by the other hand
	Platform shift CI	Single hand is held flat; may or may not move up and down
	Pulsing	<b>Pinch ci:</b> both hands make pinching gesture, and move closer and away from each other repeatedly
		<b>POINT CI:</b> both hands (index fingers extended) move closer and away from one another repeatedly
		<b>SHEETS CI:</b> Both hands are horizontal (palms facing torso), with one hand stacked behind the other. Hands move closer and away from one another repeatedly
	Rainbow CI	Hand/hands open outwards and arc down
	Ring CI	Pointer finger draws a circular figure which may be oriented horizontally or vertically
	Screw in lightbulb CI	Hand is in a C shape and rotates
	Tube CI	Hand(s) makes a C shape and moves up and down vertically to illustrate barrel shape
		<b>INSIDE OUT:</b> arm is extended with hand twisted and curled outward with C shape
	Trace CI	Index finger traces a line or other shape that aligns with dialogue. Other hand may or may not be involved in "staging"
	Up and down CI	Vertical motion that encompasses either the hand moving from top to bottom or bottom to top or repeatedly
Either/or	Open bowl ci	Both hands are set slightly apart, make curved bowl gesture; may or may not move back and forth
	Stack CI	<b>PINCH:</b> Both hands make pinching gesture (index and thumb about an inch apart), with pinches closely stacked on top of one another
	Vertical pipe CI	Hands are vertical, parallel to each other and set apart, they may or may not move.
Static	Ball	Hands constrict into rounded open ball shape
	Italian pinch CI	All fingers come together, but palm of hand is open
	Ok ci	Thumb and index fingers make a circle. Other fingers are open

		Open O CI	One or both hand forms a round "O" shape.	
		Piano CI	One or two hands are raised and held horizontally. They move back and forth and/or up and down slightly.	
Levels (L)	Either/Or	Boundary	Hand(s) is held flat (either horizontally or vertically), then repeatedly moves in a linear back and forth motion to define a line/plane/level	
		Decline	Hand travels downwards, led by fingers, in a diagonal motion (palm facing down); hand may also be laid in a straight diagonal line (fingers pointing downward)	
		Expansion L	Hands are held at a slight distance, then move outwards and away from one another	
		Incline	Hand travels upwards, lead by fingers, in a diagonal motion (palm facing down); hand may also be laid in a straight diagonal line (fingers pointing upward)	
		Platform shift L	Single hand is held flat horizontally; may or may not move up and down	
		Pointing L	Finger of hand points in an intentional direction; may or may not move towards aforementioned direction	
		Spatial relationships (SR)	Attract SR	One hand pushes into the other
			Collapse SR	Both hands are in open formation (palms facing camera) and move inwards towards each other
	Down and up SR	Hand starts from lower and quickly raises up		
	Expansion SR	Hands expand outwards <b>FINGERS:</b> 2 fingers move towards and away from each other		
	Motion	Flip	<b>Peace:</b> left index and middle finger are extended. Wrist then rotates to switch orientation of these two fingers <b>PINCH:</b> fingers held in a pinch shape, hand flips along an axis	
		Platform shift SR	Single hand is held flat; may or may not move up and down	
		Pulsing	<b>Bowl:</b> both hands (palms facing one another) move closer and away from one another repeatedly	
		Ring SR	Pointer finger draws a circular figure which may be oriented horizontally or vertically	
		Tide SR	Hand makes a small push downwards and towards the camera, palm down (resembles a rolling wave)	



	Either/Or	Open bowl SR	Both hands are set slightly apart, make curved bowl gesture; may or may not move back and forth
	Static	Bracket SR	Finger bracket: thumb and pointer finger make bracket shape, rest of hand is in a fist
		Ok SR	Thumb and index fingers make a circle. Other fingers are open
		Open O SR	One or both hand forms a round "O" shape.
		Pinch SR	Thumb and pointer come about an inch apart (pinching motion)
		Pointing SR	Finger of hand points in an intentional direction
App description (AD)	Motion	Clock	Index finger makes a choppy circular motion
		Door knob	Hand points to screen and rotates (all fingers facing up)
		Expansion AD	FINGERS: 2 fingers move towards and away from each other
		Flash AD	Fingers are constricted, then expand outwards in a flashing movement
		Flip	<b>Flat:</b> hand is held relatively flat. Wrist then rotates to switch orientation of the hand back and forth; fingers may or may not be extended <b>PINCH:</b> Index and thumb of right finger are in a pinching gesture. The hand then rotates clockwise/ counterclockwise.
		Model exploration	Student moves both device and qr code
		Swipe	Pointer finger swipes on screen
		Tap	Index finger of hand makes a tapping motion
		Air quotes	Fingers make air quotes gesture
		Counting	Counts off on fingers (using one hand to count on the fingers of other hand to enumerate list items)
Miscellaneous	Motion	Drawing demonstration	A drawing is made and is held up to camera. Aspects of the drawing are then pointed to to illustrate different concepts
		Wax on/wax off	Both hands make small circles towards each other with palms facing camera
		2d	Hand is in an flat, open formation (palm facing screen); may or may not move left and right
	Beat Gesture	Claw	Hand is curved, but open, almost like holding a ball
		Cycle	Hands move around in a cyclic motion
		I don't know	Hands come up to shoulders and shrug
		True beat	Hand is placed in front of student (palm down)

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Wishy-washy

Hand moves loosely back and forth or  
in a circle

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