Signaling Noise Underlies Switching Behavior of the Bacterial Flagellum

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SUPPORTING MATERIAL

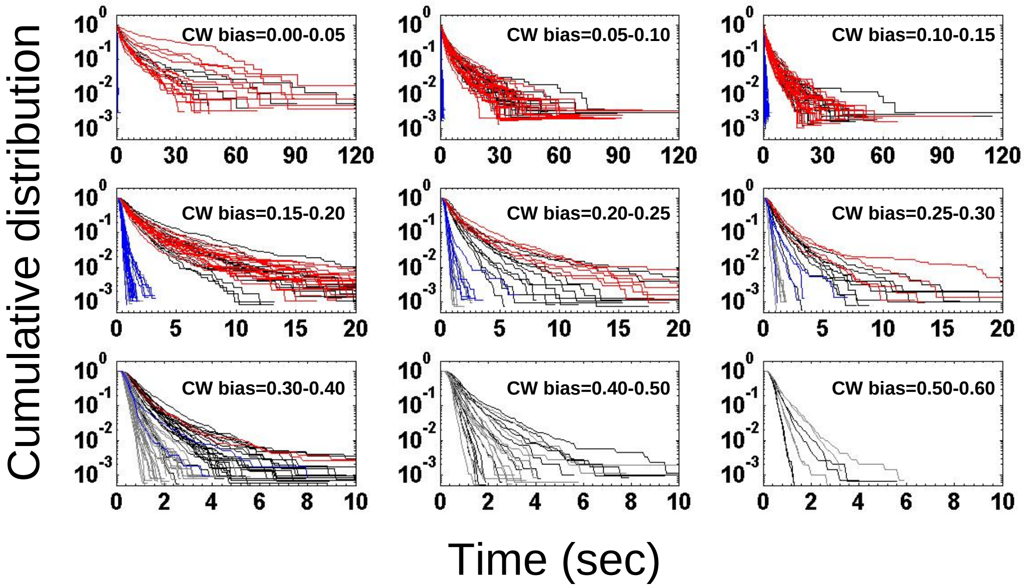

Fig. S1. Cumulative distributions of CCW and CW interval lengths from wild-type cells. Intervals are obtained from 1500-second binary time series in RP437 wild-type cells (CCW: red, CW: blue) and RP437 cells expressing extra copies of CheR from pZE21-CheR plasmid (CCW: black, CW: grey). We binned cells by their CW bias: 0.00-0.05 (14, 4), 0.05-0.10 (26, 18), 0.10-0.15 (26, 15), 0.15-0.20 (20, 13), 0.20-0.25 (6, 11), 0.25-0.30 (4, 9), 0.30-0.40 (2, 24), 0.40-0.50 (0, 12), and 0.50-0.60 (0, 4), where the numbers in parentheses are the number of cells (left: RP437, right: RP437 with pZE21-CheR) in each bin.

Table S1. Variance (σ^2_{CheYp}) and characteristic time scale (τ_{CheYp}) of fluctuating [CheY-P] for wild-type cells with a specific CW bias calculated from the binary time-series in (*1*).

	CW bias								
	0.00-0.05	0.05-0.10	0.10-0.15	0.15-0.20	0.20-0.25	0.25-0.30	0.30-0.40	0.40-0.50	0.50-0.60
$\sigma^2_{CheYp}\left(\mu M^2\right)$	0.05(0.02)	0.043(0.005)	0.038(0.005)	0.027(0.003)	0.023(0.005)	0.020(0.006)	0.015(0.003)	0.012(0.005)	0..008(0.007)
$\tau_{CheYp}(\mathrm{sec})$	15(3)	14(2)	9(1)	5.5(0.7)	5.6(0.6)	2.0(0.5)	3.6(0.3)	1.5(0.3)	1.0(0.2)

For σ^2_{CheYp} , the values in parentheses are the standard errors.

For τ_{CheYp} , the values in parentheses are the average half-lengths of the first uncorrelated CCW intervals.

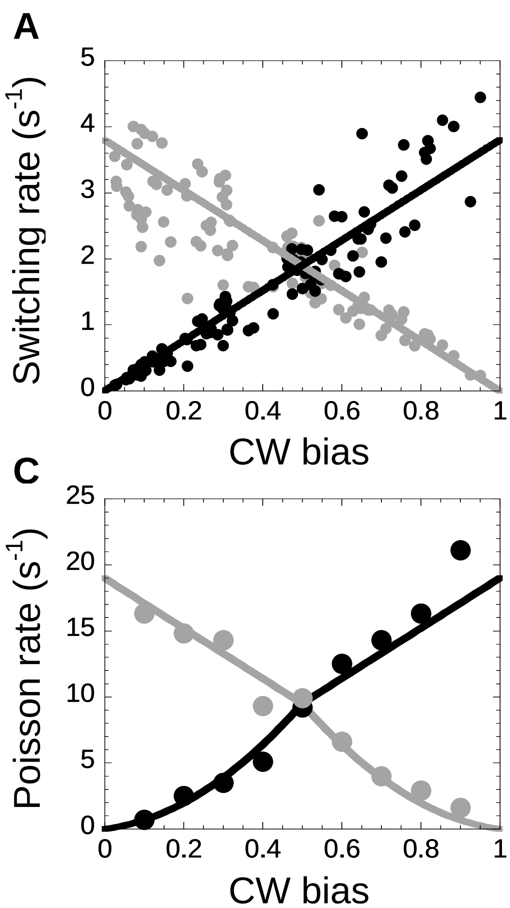

Fig. S2. Experimental characteristics of the bacterial flagella motor in the absence of a functional chemotactic network but a steady level of active CheY mutant. **(A)** Switching rates of the motor as a function of the CW bias**,** k_{01} for CCW to CW (black) and k_{10} for CW to CCW (grey). Each line has a functional form given by: $k_{01} = 2\omega_o \cdot b$ and $k_{10} = 2\omega_o \cdot (1-b)$, where ω_o is the maximum total switching frequency (1.9 sec^{-1} (*2*)) and b is the CW bias. The CW bias was calculated from a 300-second binary time series in each cell. We ignored cells with extremely low CW biases (<0.02) which have very low statistics. Data points were obtained from the binary time series in ref. (*2*). **(B)** Hidden step (r) in the gamma distributions as a function of the CW bias. The original data points (dots, Fig. 2A from (*2*)) were determined by fitting the experimental CCW and CW interval length distributions in each CW bias bin with gamma distribution function defined as $G_r(\nu,\tau)=\dfrac{\nu^r\tau^{r-1}\exp(-\nu\tau)}{\Gamma(r)}$, where $\Gamma(r)$ is the gamma function. We approximated the continuous functional forms (lines) for those data points for CW (grey) and CCW (black) intervals by: $r_{CCW} = 8b+1$ for $0 \le b \le 0.5$, $r_{CCW} = 5$ for $0.5 \le b < 1.0$ and $r_{CW} = 5$ for $0 \le b \le 0.5$, $r_{CW} = -8b+9$ for $0.5 \le b < 1.0$. **(C)** The Poisson rate (ν) in the gamma distributions as a function of the CW bias. The original data points (dots, Fig. 2B from (*2*)) were determined by fitting with gamma distribution function defined as $G_r(\nu,\tau)=\dfrac{\nu^r\tau^{r-1}\exp(-\nu\tau)}{\Gamma(r)}$. The fit (lines) for those data points are given by the relationships between the functional forms from the hidden steps and the switching rates as a function of the CW bias for CW (grey) and CCW (black) intervals: From $\nu_{CCW} = k_{01}\cdot r_{CCW}$ and $\nu_{CW} = k_{10}\cdot r_{CW}$ we obtained $\nu_{CCW} = 2\omega_o\cdot b\cdot(8b+1)$ for $0 \le b \le 0.5$, $\nu_{CCW} = 2\omega_o\cdot b\cdot 5$ for $0.5 \le b < 1.0$ and $\nu_{CW} = 2\omega_o\cdot(1-b)\cdot 5$ for $0 \le b \le 0.5$, $\nu_{CW} = 2\omega_o\cdot(1-b)\cdot(-8b+9)$ for $0.5 \le b < 1.0$.

References:

1. Park, H., W. Pontius, C. C. Guet, J. F. Marko, T. Emonet, P. Cluzel, Interdependence of behavioural variability and response to small stimuli in bacteria. *Nature* **468**, 819 (Dec 9).
2. Korobkova, E. A., T. Emonet, H. Park, P. Cluzel, Hidden stochastic nature of a single bacterial motor. *Phys Rev Lett* **96**, 058105 (Feb 10, 2006).