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Supplementary Table 1. Alignment tensor of ubiquitin-SH_6 as a function of pH.[a]

pH	conc.[c]	α	β	γ	$10^4 A_{zz}$	$10^4 A_{yy}$	$10^4 A_{xx}$
4.65	5%	37.5	21.2	34.4	-6.20	3.76	2.44
6.18	4.8%	33.0	23.2	29.6	-7.48	4.88	2.60
6.75	4.6%	32.0	27.5	25.5	-7.26	4.77	2.49
7.50	5.0%	31.3	31.1	27.8	-10.86	7.02	3.84

[a] Using bicelles in 93% H_2O, 7% D_2O, with a 30:10:1 ratio of DMPC:DHPC:CTAB, at 310 K. The Euler angles α, β, and γ define the alignment tensor relative to the coordinate frame of the 1.8-Å X-ray structure.[16]

[b] Molar ratios of lipids. M = [DMPC]; H = [DHPC];.C = [CTAB]; MA = [myristic acid].

[c] Weight by volume for M+H+C in water.

Supplementary Table 2. Alignment tensor of aprotinin in charged bicelles.[a]

M:H:C[b]	conc.[c]	α	β	γ	$10^4 A_{zz}$	$10^4 A_{yy}$	$10^4 A_{xx}$
30:10:0	5%	153.3	92.7	58.7	5.47	-0.93	-4.54
30:10:1	3.5%	154.6	86.0	77.1	1.92	-0.58	-1.33
30:10:2	4.5%	154.8	77.8	93.6	2.53	-0.51	-2.02

[a] Using bicelles in 93% H_2O, 7% D_2O, at pH 6.75, 310 K. The Euler angles α, β, and γ define the alignment tensor relative to the coordinate frame of the crystal X-ray/neutron structure (Wlodawer, A.; Walter, J.; Huber, R.; Sjolin, L. *J. Mol. Biol.* **1984**, *180*, 301-329).

[b] Molar ratios of lipids. M = [DMPC]; H = [DHPC];.C = [CTAB].

[c] Weight by volume for M+H+C+MA in water.

Supplementary Table 3. Angles of intersection for the two cones of N-H vector orientations compatible with the D_{NH} dipolar couplings measured in ubiquitin in liquid crystalline phases consisting of 3:1:0 and 30:10:1 ratios of DMPC:DHPC:CTAB. Only the angle for the intersection closest to the true N-H orientation is given.

Q2	1
I3	-25
F4	32
V5	19
K6	-3
T7	-14
L8	2
G10	73
K11	11
T12	-19
I13	6
T14	-25
L15	29
E16	-14
V17	-6
E18	1
S20	12
D21	-13
T22	63
I23	-83
N25	-9
V26	-2
K27	-59
A28	31
K29	0
I30	-84
D32	-28
K33	24
E34	-64
G35	-17
I36	-3
D39	-43
Q40	-29
Q41	14
R42	83
L43	29
I44	72
F45	21
G47	-77
K48	-9
Q49	-9
L50	-73
E51	-4
D52	-50
R54	9
T55	1
L56	50
S57	-27
D58	-26
Y59	-21
N60	-23
I61	-2
Q62	-15
K63	-24
E64	-53
S65	-8
T66	45
L67	42
H68	-51
L69	-43
V70	-55
L71	44

Supplementary Table 4. Angles of intersection for the two cones of N-H vector orientations compatible with the D_{NH} dipolar couplings measured in aprotinin in liquid crystalline phases consisting of 3:1:0 and 15:5:1 ratios of DMPC:DHPC:CTAB. Only the angle for the intersection closest to the true N-H orientation is given.

Residue	Angle (°)
F4	16
C5	-3
L6	51
E7	47
Y10	61
G12	-34
C14	50
A16	-31
R17	-33
I18	25
I19	-13
R20	-80
Y21	24
F22	2
Y23	72
N24	5
A25	22
K26	25
A27	20
G28	15
L29	-32
C30	17
Q31	-37
T32	-47
F33	79
V34	-52
Y35	56
G36	-6
C38	13
A40	-30
K41	57
R42	17
N43	28
N44	7
F45	11
S47	-25
A48	18
E49	-8
D50	9
C51	-17
M52	5
R53	-1
T54	15
C55	18
G56	47