

## Shahab Geravesh STAT 206 Lab 5

**Due Monday, November 9, 5:00 PM**

**General instructions for labs:** Labs must be completed as a pdf file. Give the commands to answer each question in its own code block, which will also produce plots that will be automatically embedded in the output file. Each answer must be supported by written statements as well as any code used.

**Agenda:** Fitting models by optimization; transforming data from one representation to another; handling missing data

Many theories of the diffusion of innovations (new technologies, practices, beliefs, etc.) suggest that the fraction of members of a group who have adopted the innovation by time  $t$ ,  $p(t)$ , should follow a logistic curve or logistic function,

$$p(t) = \frac{e^{b(t-t_0)}}{1 + e^{b(t-t_0)}}.$$

We will look at a classic data set on the diffusion of innovations, which is supposed to show such a curve. It concerns a survey of 246 doctors in four towns in Illinois in the early 1950s, and when they began prescribing (adopted) a then-new antibiotic, tetracycline, and how they became convinced that they should do so (from medical journals, from colleagues, etc.).

Load the file [[http://faculty.ucr.edu/~jfllegal/206/doctor\\_nodes.csv](http://faculty.ucr.edu/~jfllegal/206/doctor_nodes.csv)]. Each row is a doctor. The column adoption date shows how many months, after it became available, each doctor began prescribing tetracycline. Doctors who had not done so by the end of the survey, i.e., after month 17, have a value of **Inf** in this column. This information is not available (NA) for some doctors. There are twelve other variables which may also be NA.

```
ckm<- read.csv("http://faculty.ucr.edu/~jfllegal/206/ckm_nodes.csv")
ckm
```

##	city	adoption_date	medical_school	attend_meetings	medical_journals
## 1	Peoria	1	1920--1929	specialty	9
## 2	Peoria	12	1945+	none	5
## 3	Peoria	8	1935--1939	general	7
## 4	Peoria	9	1940--1944	general	6
## 5	Peoria	9	1935--1939	general	4
## 6	Peoria	10	1930--1934	none	7
## 7	Peoria	Inf	1919-	none	3
## 8	Peoria	3	1935--1939	none	9
## 9	Peoria	11	1920--1929	specialty	5
## 10	Peoria	2	1935--1939	general	4
## 11	Peoria	4	1920--1929	specialty	9
## 12	Peoria	5	1940--1944	none	4
## 13	Peoria	2	1945+	general	9
## 14	Peoria	15	1940--1944	general	3
## 15	Peoria	4	1935--1939	none	5
## 16	Peoria	15	1940--1944	specialty	5
## 17	Peoria	Inf	1935--1939	none	3
## 18	Peoria	5	1940--1944	general	5
## 19	Peoria	11	1919-	general	3
## 20	Peoria	2	1935--1939	specialty	9

## 21	Peoria	8	1940--1944	specialty	4
## 22	Peoria	7	1945+	specialty	4
## 23	Peoria	5	1935--1939	specialty	6
## 24	Peoria	4	1940--1944	general	6
## 25	Peoria	3	1945+	general	4
## 26	Peoria	6	1930--1934	general	4
## 27	Peoria	1	1935--1939	specialty	5
## 28	Peoria	5	1940--1944	specialty	9
## 29	Peoria	3	1930--1934	specialty	5
## 30	Peoria	15	1945+	general	4
## 31	Peoria	5	1940--1944	general	9
## 32	Peoria	7	1919-	general	5
## 33	Peoria	6	1940--1944	none	4
## 34	Peoria	14	1919-	none	3
## 35	Peoria	4	1935--1939	general	5
## 36	Peoria	8	1930--1934	general	6
## 37	Peoria	8	1935--1939	specialty	8
## 38	Peoria	14	1919-	none	3
## 39	Peoria	Inf	1919-	general	2
## 40	Peoria	NA	1940--1944	specialty	5
## 41	Peoria	NA	1930--1934	specialty	6
## 42	Peoria	NA	1920--1929	specialty	7
## 43	Peoria	NA	1930--1934	specialty	3
## 44	Peoria	NA	1940--1944	specialty	7
## 45	Peoria	NA	1920--1929	specialty	6
## 46	Peoria	NA	1930--1934	specialty	9
## 47	Peoria	NA	1920--1929	specialty	8
## 48	Peoria	NA	1930--1934	general	4
## 49	Peoria	NA	1930--1934	specialty	3
## 50	Peoria	NA	1935--1939	specialty	5
## 51	Peoria	NA	1935--1939	specialty	6
## 52	Peoria	NA	1935--1939	specialty	9
## 53	Peoria	NA	1920--1929	specialty	4
## 54	Peoria	NA	1940--1944	specialty	6
## 55	Peoria	NA	1930--1934	specialty	6
## 56	Peoria	NA	1919-	specialty	4
## 57	Peoria	NA	1930--1934	general	5
## 58	Peoria	4	1920--1929	general	4
## 59	Peoria	NA	1945+	none	5
## 60	Peoria	NA	1945+	specialty	3
## 61	Peoria	NA	1935--1939	specialty	5
## 62	Peoria	NA	1940--1944	general	6
## 63	Peoria	NA	1945+	specialty	5
## 64	Peoria	NA	1945+	none	7
## 65	Peoria	NA	1945+	general	3
## 66	Peoria	NA	1940--1944	specialty	5
## 67	Peoria	NA	1945+	none	5
## 68	Peoria	NA	1945+	specialty	3
## 69	Peoria	NA	1935--1939	general	3
## 70	Peoria	11	1919-	general	6
## 71	Peoria	NA	1919-	specialty	8
## 72	Peoria	Inf	1920--1929	general	4
## 73	Peoria	12	1935--1939	none	2
## 74	Peoria	12	1935--1939	none	2

## 75	Peoria	1	1930--1934	none	2
## 76	Peoria	6	1930--1934	general	6
## 77	Peoria	7	1935--1939	specialty	7
## 78	Peoria	1	1930--1934	specialty	8
## 79	Peoria	6	1935--1939	specialty	5
## 80	Peoria	Inf	1919-	general	4
## 81	Peoria	4	1935--1939	general	6
## 82	Peoria	Inf	1919-	none	7
## 83	Peoria	NA	1935--1939	specialty	5
## 84	Peoria	NA	1940--1944	specialty	4
## 85	Peoria	NA	1940--1944	none	9
## 86	Peoria	NA	1945+	none	2
## 87	Peoria	NA	1945+	specialty	6
## 88	Peoria	NA	1930--1934	specialty	9
## 89	Peoria	NA	1930--1934	specialty	4
## 90	Peoria	NA	1920--1929	general	8
## 91	Peoria	7	<NA>	<NA>	6
## 92	Peoria	6	1919-	specialty	8
## 93	Peoria	1	1920--1929	specialty	9
## 94	Peoria	2	1935--1939	general	8
## 95	Peoria	5	1940--1944	none	5
## 96	Peoria	13	1935--1939	general	3
## 97	Peoria	4	1920--1929	none	2
## 98	Peoria	3	1940--1944	none	7
## 99	Peoria	NA	1930--1934	specialty	7
## 100	Peoria	NA	1940--1944	specialty	8
## 101	Peoria	NA	1920--1929	specialty	5
## 102	Peoria	NA	1945+	specialty	5
## 103	Peoria	NA	1940--1944	none	3
## 104	Peoria	NA	1940--1944	general	6
## 105	Peoria	7	1935--1939	none	5
## 106	Peoria	NA	1920--1929	specialty	5
## 107	Peoria	NA	1919-	general	2
## 108	Peoria	Inf	1919-	general	4
## 109	Peoria	NA	1920--1929	<NA>	NA
## 110	Peoria	NA	<NA>	<NA>	NA
## 111	Peoria	NA	<NA>	<NA>	NA
## 112	Peoria	NA	<NA>	<NA>	NA
## 113	Peoria	NA	<NA>	<NA>	NA
## 114	Peoria	NA	<NA>	<NA>	NA
## 115	Peoria	NA	<NA>	<NA>	NA
## 116	Peoria	NA	<NA>	<NA>	NA
## 117	Peoria	NA	<NA>	<NA>	NA
## 118	Bloomington	NA	1930--1934	specialty	8
## 119	Bloomington	1	1945+	general	3
## 120	Bloomington	NA	1930--1934	specialty	4
## 121	Bloomington	7	1945+	none	3
## 122	Bloomington	6	1935--1939	general	9
## 123	Bloomington	1	1935--1939	specialty	5
## 124	Bloomington	Inf	1919-	none	2
## 125	Bloomington	7	1920--1929	specialty	4
## 126	Bloomington	6	1940--1944	specialty	4
## 127	Bloomington	1	1930--1934	specialty	6
## 128	Bloomington	2	1919-	general	4

## 129	Bloomington	5	1945+	specialty	4
## 130	Bloomington	1	1930--1934	none	3
## 131	Bloomington	1	1940--1944	general	5
## 132	Bloomington	2	1930--1934	specialty	3
## 133	Bloomington	2	1945+	specialty	9
## 134	Bloomington	11	1920--1929	none	5
## 135	Bloomington	5	1940--1944	none	6
## 136	Bloomington	17	1935--1939	general	3
## 137	Bloomington	7	1945+	general	3
## 138	Bloomington	NA	1940--1944	specialty	4
## 139	Bloomington	NA	1920--1929	specialty	6
## 140	Bloomington	NA	1945+	specialty	9
## 141	Bloomington	NA	1935--1939	specialty	8
## 142	Bloomington	NA	1930--1934	specialty	5
## 143	Bloomington	NA	1940--1944	specialty	4
## 144	Bloomington	NA	1945+	specialty	6
## 145	Bloomington	NA	1920--1929	specialty	6
## 146	Bloomington	NA	1945+	general	4
## 147	Bloomington	NA	1935--1939	specialty	5
## 148	Bloomington	NA	1935--1939	specialty	9
## 149	Bloomington	NA	1945+	general	3
## 150	Bloomington	NA	1940--1944	specialty	5
## 151	Bloomington	1	1930--1934	specialty	5
## 152	Bloomington	Inf	1920--1929	specialty	9
## 153	Bloomington	9	1945+	general	9
## 154	Bloomington	9	1930--1934	general	6
## 155	Bloomington	Inf	1940--1944	general	6
## 156	Bloomington	7	1940--1944	none	3
## 157	Bloomington	NA	1920--1929	specialty	8
## 158	Bloomington	NA	1935--1939	general	4
## 159	Bloomington	NA	1920--1929	specialty	7
## 160	Bloomington	NA	1945+	specialty	4
## 161	Bloomington	NA	1930--1934	specialty	3
## 162	Bloomington	NA	1935--1939	<NA>	NA
## 163	Bloomington	NA	<NA>	<NA>	NA
## 164	Bloomington	NA	1920--1929	none	NA
## 165	Bloomington	NA	1919-	general	NA
## 166	Bloomington	NA	<NA>	<NA>	NA
## 167	Bloomington	NA	<NA>	<NA>	NA
## 168	Quincy	2	1935--1939	none	6
## 169	Quincy	Inf	1920--1929	general	3
## 170	Quincy	Inf	1945+	none	5
## 171	Quincy	4	1930--1934	general	3
## 172	Quincy	Inf	1935--1939	specialty	4
## 173	Quincy	5	1919-	general	5
## 174	Quincy	7	1935--1939	specialty	6
## 175	Quincy	Inf	1919-	general	6
## 176	Quincy	3	1940--1944	general	4
## 177	Quincy	15	1930--1934	specialty	3
## 178	Quincy	16	1919-	specialty	4
## 179	Quincy	7	1940--1944	general	3
## 180	Quincy	6	1935--1939	general	4
## 181	Quincy	6	1940--1944	none	4
## 182	Quincy	5	1935--1939	specialty	8

## 183	Quincy	NA	1930--1934	specialty	5
## 184	Quincy	NA	1935--1939	none	4
## 185	Quincy	NA	1930--1934	specialty	5
## 186	Quincy	NA	1945+	specialty	6
## 187	Quincy	NA	1935--1939	specialty	4
## 188	Quincy	NA	1945+	specialty	4
## 189	Quincy	NA	1930--1934	none	4
## 190	Quincy	NA	1935--1939	specialty	8
## 191	Quincy	NA	1920--1929	specialty	7
## 192	Quincy	NA	1935--1939	specialty	4
## 193	Quincy	NA	1935--1939	specialty	3
## 194	Quincy	NA	1930--1934	specialty	4
## 195	Quincy	3	1935--1939	none	4
## 196	Quincy	13	1940--1944	general	6
## 197	Quincy	11	1930--1934	none	4
## 198	Quincy	8	1920--1929	specialty	9
## 199	Quincy	3	1930--1934	general	5
## 200	Quincy	2	1920--1929	none	4
## 201	Quincy	NA	1919-	none	4
## 202	Quincy	NA	1919-	<NA>	NA
## 203	Quincy	NA	<NA>	<NA>	NA
## 204	Quincy	NA	1920--1929	<NA>	NA
## 205	Quincy	NA	<NA>	specialty	NA
## 206	Quincy	NA	<NA>	<NA>	NA
## 207	Quincy	NA	<NA>	<NA>	NA
## 208	Quincy	NA	<NA>	<NA>	NA
## 209	Quincy	NA	<NA>	<NA>	NA
## 210	Quincy	NA	<NA>	<NA>	NA
## 211	Quincy	NA	<NA>	<NA>	NA
## 212	Galesburg	Inf	1935--1939	general	4
## 213	Galesburg	Inf	1935--1939	none	4
## 214	Galesburg	4	1945+	general	6
## 215	Galesburg	5	1935--1939	none	4
## 216	Galesburg	8	1935--1939	general	6
## 217	Galesburg	4	1919-	specialty	8
## 218	Galesburg	3	1945+	none	4
## 219	Galesburg	8	1930--1934	general	2
## 220	Galesburg	13	1935--1939	none	3
## 221	Galesburg	6	1935--1939	none	6
## 222	Galesburg	3	1945+	none	5
## 223	Galesburg	6	1930--1934	specialty	7
## 224	Galesburg	14	1945+	general	5
## 225	Galesburg	7	1935--1939	general	3
## 226	Galesburg	4	1935--1939	general	6
## 227	Galesburg	14	1945+	general	7
## 228	Galesburg	NA	1919-	specialty	3
## 229	Galesburg	7	1940--1944	specialty	5
## 230	Galesburg	NA	1935--1939	general	8
## 231	Galesburg	NA	1920--1929	specialty	9
## 232	Galesburg	NA	1940--1944	specialty	6
## 233	Galesburg	NA	1940--1944	specialty	5
## 234	Galesburg	NA	1930--1934	specialty	4
## 235	Galesburg	NA	1930--1934	specialty	8
## 236	Galesburg	NA	1940--1944	specialty	5

## 237	Galesburg	NA	1935--1939	specialty	5
## 238	Galesburg	NA	1920--1929	specialty	7
## 239	Galesburg	NA	1919-	specialty	6
## 240	Galesburg	NA	1930--1934	specialty	NA
## 241	Galesburg	16	1920--1929	general	5
## 242	Galesburg	NA	1935--1939	general	6
## 243	Galesburg	NA	1935--1939	specialty	5
## 244	Galesburg	NA	<NA>	<NA>	NA
## 245	Galesburg	NA	<NA>	<NA>	NA
## 246	Galesburg	NA	<NA>	<NA>	NA
##	free_time_with	discuss_medicine_socially	club_with_drs		
## 1	non-doctors		no	no	
## 2	doctors		yes	no	
## 3	doctors		no	no	
## 4	non-doctors		no	no	
## 5	non-doctors		yes	no	
## 6	split		yes	no	
## 7	non-doctors		yes	no	
## 8	split		yes	no	
## 9	non-doctors		no	no	
## 10	split		no	no	
## 11	split		yes	no	
## 12	non-doctors		yes	no	
## 13	non-doctors		no	no	
## 14	doctors		yes	no	
## 15	split		yes	no	
## 16	non-doctors		no	no	
## 17	non-doctors		no	no	
## 18	non-doctors		yes	no	
## 19	split	don't care		no	
## 20	non-doctors		no	no	
## 21	doctors		yes	no	
## 22	split		yes	yes	
## 23	doctors		yes	no	
## 24	non-doctors		yes	no	
## 25	split		yes	yes	
## 26	split		yes	no	
## 27	split		yes	yes	
## 28	doctors		no	no	
## 29	non-doctors		yes	no	
## 30	doctors		no	no	
## 31	doctors		no	no	
## 32	non-doctors		no	no	
## 33	non-doctors		yes	no	
## 34	non-doctors		yes	no	
## 35	doctors		no	no	
## 36	doctors		no	no	
## 37	non-doctors		no	no	
## 38	non-doctors	don't care		no	
## 39	non-doctors		no	no	
## 40	doctors		yes	<NA>	
## 41	non-doctors		yes	no	
## 42	split		yes	no	
## 43	split		no	no	

## 44	split	no	no
## 45	non-doctors	yes	no
## 46	non-doctors	no	no
## 47	non-doctors	no	no
## 48	doctors	no	no
## 49	non-doctors	no	no
## 50	split	yes	no
## 51	non-doctors	yes	no
## 52	non-doctors	don't care	<NA>
## 53	doctors	yes	no
## 54	doctors	no	no
## 55	non-doctors	no	yes
## 56	non-doctors	no	no
## 57	non-doctors	yes	no
## 58	doctors	yes	no
## 59	non-doctors	yes	no
## 60	doctors	yes	no
## 61	doctors	yes	yes
## 62	non-doctors	yes	no
## 63	non-doctors	no	no
## 64	split	don't care	no
## 65	doctors	yes	no
## 66	doctors	yes	yes
## 67	non-doctors	no	no
## 68	non-doctors	no	no
## 69	non-doctors	no	no
## 70	non-doctors	yes	no
## 71	non-doctors	yes	no
## 72	split	yes	no
## 73	<NA>	<NA>	<NA>
## 74	non-doctors	yes	no
## 75	non-doctors	no	no
## 76	non-doctors	yes	no
## 77	non-doctors	no	yes
## 78	doctors	no	no
## 79	split	yes	<NA>
## 80	non-doctors	no	no
## 81	split	yes	no
## 82	non-doctors	no	no
## 83	doctors	yes	<NA>
## 84	non-doctors	no	no
## 85	non-doctors	yes	no
## 86	split	yes	no
## 87	doctors	no	no
## 88	doctors	yes	no
## 89	non-doctors	no	no
## 90	non-doctors	yes	no
## 91	<NA>	<NA>	<NA>
## 92	split	yes	no
## 93	non-doctors	no	no
## 94	non-doctors	yes	no
## 95	doctors	no	no
## 96	split	no	no
## 97	non-doctors	yes	no

## 98	non-doctors	yes	no
## 99	non-doctors	no	no
## 100	non-doctors	yes	no
## 101	split	no	no
## 102	non-doctors	yes	no
## 103	split	yes	no
## 104	non-doctors	no	no
## 105	non-doctors	yes	no
## 106	split	don't care	<NA>
## 107	non-doctors	no	<NA>
## 108	non-doctors	no	no
## 109	doctors	<NA>	no
## 110	<NA>	<NA>	<NA>
## 111	<NA>	<NA>	<NA>
## 112	<NA>	<NA>	<NA>
## 113	<NA>	<NA>	<NA>
## 114	<NA>	<NA>	<NA>
## 115	<NA>	<NA>	<NA>
## 116	<NA>	<NA>	<NA>
## 117	<NA>	<NA>	<NA>
## 118	non-doctors	yes	no
## 119	non-doctors	yes	no
## 120	non-doctors	no	no
## 121	non-doctors	yes	no
## 122	non-doctors	yes	no
## 123	doctors	yes	no
## 124	non-doctors	yes	no
## 125	non-doctors	yes	no
## 126	doctors	yes	no
## 127	non-doctors	no	no
## 128	non-doctors	no	no
## 129	doctors	no	no
## 130	split	no	yes
## 131	non-doctors	no	no
## 132	non-doctors	yes	no
## 133	doctors	yes	no
## 134	non-doctors	yes	no
## 135	split	no	no
## 136	non-doctors	don't care	no
## 137	non-doctors	no	no
## 138	split	yes	no
## 139	non-doctors	yes	no
## 140	split	yes	no
## 141	non-doctors	yes	no
## 142	non-doctors	no	no
## 143	doctors	yes	no
## 144	split	don't care	no
## 145	split	yes	yes
## 146	doctors	no	no
## 147	non-doctors	<NA>	no
## 148	non-doctors	yes	no
## 149	doctors	yes	no
## 150	split	yes	no
## 151	non-doctors	no	no



## 152	non-doctors	no	no
## 153	non-doctors	yes	no
## 154	non-doctors	yes	no
## 155	non-doctors	don't care	no
## 156	non-doctors	no	no
## 157	non-doctors	no	no
## 158	doctors	no	no
## 159	non-doctors	no	no
## 160	non-doctors	no	no
## 161	<NA>	<NA>	<NA>
## 162	<NA>	<NA>	<NA>
## 163	<NA>	<NA>	<NA>
## 164	<NA>	<NA>	<NA>
## 165	non-doctors	<NA>	<NA>
## 166	<NA>	<NA>	<NA>
## 167	<NA>	<NA>	<NA>
## 168	split	yes	no
## 169	non-doctors	no	no
## 170	doctors	yes	no
## 171	non-doctors	no	no
## 172	non-doctors	yes	no
## 173	non-doctors	no	no
## 174	doctors	yes	no
## 175	non-doctors	no	no
## 176	non-doctors	yes	no
## 177	non-doctors	no	no
## 178	doctors	no	no
## 179	non-doctors	no	no
## 180	non-doctors	yes	yes
## 181	doctors	no	no
## 182	non-doctors	yes	yes
## 183	doctors	yes	no
## 184	non-doctors	yes	no
## 185	split	no	no
## 186	non-doctors	no	no
## 187	doctors	yes	no
## 188	non-doctors	no	no
## 189	non-doctors	no	no
## 190	non-doctors	no	no
## 191	non-doctors	no	no
## 192	non-doctors	no	no
## 193	doctors	no	no
## 194	split	yes	no
## 195	non-doctors	no	no
## 196	doctors	no	no
## 197	non-doctors	yes	no
## 198	non-doctors	yes	no
## 199	non-doctors	yes	yes
## 200	non-doctors	yes	no
## 201	non-doctors	no	no
## 202	<NA>	<NA>	<NA>
## 203	<NA>	<NA>	<NA>
## 204	<NA>	<NA>	<NA>
## 205	<NA>	<NA>	<NA>

## 206	<NA>	<NA>	<NA>
## 207	<NA>	<NA>	<NA>
## 208	<NA>	<NA>	<NA>
## 209	<NA>	<NA>	<NA>
## 210	<NA>	<NA>	<NA>
## 211	<NA>	<NA>	<NA>
## 212	non-doctors	no	no
## 213	non-doctors	no	no
## 214	split	yes	yes
## 215	non-doctors	no	yes
## 216	doctors	yes	no
## 217	non-doctors	yes	no
## 218	doctors	no	yes
## 219	non-doctors	no	no
## 220	non-doctors	no	no
## 221	doctors	yes	no
## 222	split	no	no
## 223	non-doctors	no	no
## 224	non-doctors	no	no
## 225	split	no	yes
## 226	doctors	<NA>	yes
## 227	split	yes	no
## 228	split	no	no
## 229	non-doctors	yes	no
## 230	doctors	no	yes
## 231	non-doctors	no	no
## 232	doctors	yes	yes
## 233	doctors	no	yes
## 234	non-doctors	yes	no
## 235	non-doctors	no	no
## 236	non-doctors	no	no
## 237	non-doctors	yes	yes
## 238	non-doctors	no	no
## 239	doctors	yes	no
## 240	non-doctors	no	yes
## 241	<NA>	<NA>	<NA>
## 242	non-doctors	yes	no
## 243	non-doctors	no	no
## 244	<NA>	<NA>	<NA>
## 245	<NA>	<NA>	<NA>
## 246	<NA>	<NA>	<NA>
##	drs_among_three_best_friends	practicing_here	office_visits_per_week
## 1	0	20+ years	101--150
## 2	3	1- year	76--100
## 3	2	10--20 years	76--100
## 4	0	5--10 years	51--75
## 5	1	10--20 years	51--75
## 6	0	10--20 years	101--150
## 7	0	20+ years	151+
## 8	0	10--20 years	151+
## 9	0	20+ years	25-
## 10	3	10--20 years	151+
## 11	1	20+ years	101--150
## 12	0	5--10 years	151+

## 13	0	1--2 years	26--50
## 14	3	5--10 years	101--150
## 15	0	10--20 years	151+
## 16	0	2--5 years	25-
## 17	1	5--10 years	101--150
## 18	1	10--20 years	151+
## 19	1	20+ years	<NA>
## 20	1	5--10 years	51--75
## 21	1	5--10 years	101--150
## 22	2	2--5 years	76--100
## 23	2	10--20 years	76--100
## 24	1	1- year	76--100
## 25	3	2--5 years	76--100
## 26	0	10--20 years	101--150
## 27	1	10--20 years	76--100
## 28	0	5--10 years	51--75
## 29	1	5--10 years	101--150
## 30	3	2--5 years	76--100
## 31	2	5--10 years	151+
## 32	1	20+ years	51--75
## 33	2	5--10 years	101--150
## 34	NA	20+ years	26--50
## 35	2	10--20 years	76--100
## 36	2	10--20 years	101--150
## 37	3	5--10 years	51--75
## 38	0	20+ years	26--50
## 39	2	20+ years	76--100
## 40	2	2--5 years	<NA>
## 41	0	10--20 years	25-
## 42	2	20+ years	101--150
## 43	NA	10--20 years	101--150
## 44	2	2--5 years	26--50
## 45	1	20+ years	151+
## 46	0	10--20 years	26--50
## 47	0	20+ years	26--50
## 48	1	10--20 years	76--100
## 49	0	20+ years	51--75
## 50	0	10--20 years	76--100
## 51	1	5--10 years	151+
## 52	0	10--20 years	151+
## 53	2	20+ years	151+
## 54	1	2--5 years	51--75
## 55	0	10--20 years	<NA>
## 56	0	20+ years	<NA>
## 57	0	10--20 years	151+
## 58	3	20+ years	76--100
## 59	2	1- year	25-
## 60	2	1- year	26--50
## 61	3	10--20 years	76--100
## 62	1	2--5 years	51--75
## 63	0	2--5 years	76--100
## 64	2	1- year	25-
## 65	3	1--2 years	76--100
## 66	2	2--5 years	101--150

## 67	0	1--2 years	26--50
## 68	0	1- year	51--75
## 69	0	1--2 years	151+
## 70	NA	20+ years	<NA>
## 71	0	20+ years	26--50
## 72	2	20+ years	101--150
## 73	0	10--20 years	51--75
## 74	1	2--5 years	101--150
## 75	0	10--20 years	101--150
## 76	NA	5--10 years	151+
## 77	0	10--20 years	101--150
## 78	1	10--20 years	51--75
## 79	0	10--20 years	101--150
## 80	0	20+ years	76--100
## 81	0	5--10 years	76--100
## 82	0	20+ years	51--75
## 83	2	5--10 years	151+
## 84	2	5--10 years	51--75
## 85	0	2--5 years	25-
## 86	2	1--2 years	<NA>
## 87	2	1--2 years	<NA>
## 88	1	2--5 years	<NA>
## 89	NA	10--20 years	<NA>
## 90	0	2--5 years	<NA>
## 91	NA	20+ years	<NA>
## 92	0	20+ years	26--50
## 93	0	20+ years	26--50
## 94	0	10--20 years	51--75
## 95	3	5--10 years	51--75
## 96	1	10--20 years	25-
## 97	1	2--5 years	51--75
## 98	NA	2--5 years	26--50
## 99	0	5--10 years	151+
## 100	0	2--5 years	25-
## 101	1	20+ years	51--75
## 102	1	2--5 years	26--50
## 103	3	2--5 years	26--50
## 104	0	2--5 years	151+
## 105	0	5--10 years	101--150
## 106	1	20+ years	<NA>
## 107	NA	20+ years	76--100
## 108	0	20+ years	101--150
## 109	2	20+ years	<NA>
## 110	NA	1--2 years	<NA>
## 111	NA	<NA>	<NA>
## 112	NA	<NA>	<NA>
## 113	NA	<NA>	<NA>
## 114	NA	<NA>	<NA>
## 115	NA	<NA>	<NA>
## 116	NA	<NA>	<NA>
## 117	NA	<NA>	<NA>
## 118	1	10--20 years	101--150
## 119	0	5--10 years	76--100
## 120	0	10--20 years	101--150

## 121	0	1- year	26--50
## 122	1	5--10 years	76--100
## 123	0	10--20 years	101--150
## 124	NA	10--20 years	101--150
## 125	0	20+ years	101--150
## 126	3	2--5 years	76--100
## 127	0	20+ years	76--100
## 128	1	20+ years	101--150
## 129	1	1--2 years	51--75
## 130	3	5--10 years	151+
## 131	0	1- year	76--100
## 132	0	10--20 years	101--150
## 133	2	5--10 years	151+
## 134	NA	5--10 years	51--75
## 135	1	5--10 years	26--50
## 136	0	5--10 years	151+
## 137	0	2--5 years	76--100
## 138	2	2--5 years	26--50
## 139	0	20+ years	51--75
## 140	1	2--5 years	26--50
## 141	0	5--10 years	51--75
## 142	0	10--20 years	101--150
## 143	1	2--5 years	<NA>
## 144	1	2--5 years	26--50
## 145	1	20+ years	151+
## 146	1	1- year	<NA>
## 147	2	5--10 years	76--100
## 148	0	10--20 years	101--150
## 149	0	1- year	25-
## 150	1	2--5 years	51--75
## 151	1	5--10 years	101--150
## 152	NA	20+ years	101--150
## 153	0	2--5 years	101--150
## 154	NA	2--5 years	<NA>
## 155	0	10--20 years	151+
## 156	0	2--5 years	51--75
## 157	0	20+ years	151+
## 158	0	10--20 years	101--150
## 159	2	20+ years	101--150
## 160	0	1- year	26--50
## 161	NA	10--20 years	76--100
## 162	NA	5--10 years	<NA>
## 163	NA	<NA>	<NA>
## 164	NA	20+ years	<NA>
## 165	2	20+ years	<NA>
## 166	NA	<NA>	<NA>
## 167	NA	<NA>	<NA>
## 168	1	10--20 years	151+
## 169	0	20+ years	151+
## 170	1	1- year	25-
## 171	0	20+ years	151+
## 172	1	10--20 years	151+
## 173	0	20+ years	51--75
## 174	2	1--2 years	101--150

## 175	1	20+ years	76--100
## 176	0	2--5 years	76--100
## 177	1	10--20 years	151+
## 178	0	20+ years	151+
## 179	0	5--10 years	101--150
## 180	NA	5--10 years	76--100
## 181	2	5--10 years	101--150
## 182	0	10--20 years	51--75
## 183	1	5--10 years	151+
## 184	2	1--2 years	25-
## 185	2	5--10 years	151+
## 186	0	1--2 years	25-
## 187	2	5--10 years	76--100
## 188	0	2--5 years	151+
## 189	0	20+ years	151+
## 190	0	10--20 years	151+
## 191	0	10--20 years	<NA>
## 192	1	5--10 years	<NA>
## 193	1	2--5 years	26--50
## 194	1	5--10 years	51--75
## 195	NA	10--20 years	<NA>
## 196	NA	1- year	76--100
## 197	0	1--2 years	151+
## 198	1	20+ years	151+
## 199	0	10--20 years	151+
## 200	0	1--2 years	26--50
## 201	0	20+ years	101--150
## 202	2	20+ years	<NA>
## 203	NA	2--5 years	<NA>
## 204	0	1--2 years	<NA>
## 205	NA	1- year	<NA>
## 206	NA	<NA>	<NA>
## 207	NA	<NA>	<NA>
## 208	NA	<NA>	<NA>
## 209	NA	<NA>	<NA>
## 210	NA	<NA>	<NA>
## 211	NA	<NA>	<NA>
## 212	0	5--10 years	101--150
## 213	0	1- year	151+
## 214	0	2--5 years	51--75
## 215	0	10--20 years	101--150
## 216	0	5--10 years	151+
## 217	1	20+ years	76--100
## 218	3	2--5 years	51--75
## 219	0	20+ years	151+
## 220	0	5--10 years	101--150
## 221	1	5--10 years	76--100
## 222	1	1--2 years	76--100
## 223	1	5--10 years	101--150
## 224	0	2--5 years	76--100
## 225	1	5--10 years	101--150
## 226	1	10--20 years	151+
## 227	3	1- year	<NA>
## 228	2	20+ years	101--150

## 229	0	5--10 years	76--100
## 230	3	5--10 years	51--75
## 231	1	10--20 years	<NA>
## 232	2	2--5 years	151+
## 233	3	2--5 years	151+
## 234	2	5--10 years	26--50
## 235	0	10--20 years	101--150
## 236	1	5--10 years	<NA>
## 237	0	5--10 years	51--75
## 238	2	5--10 years	51--75
## 239	1	20+ years	26--50
## 240	0	20+ years	51--75
## 241	NA	20+ years	<NA>
## 242	2	10--20 years	<NA>
## 243	2	5--10 years	26--50
## 244	NA	<NA>	<NA>
## 245	NA	<NA>	<NA>
## 246	NA	<NA>	<NA>
##	proximity_to_other_drs	specialty	
## 1	in_building_and_office	pediatrician	
## 2	in_building_and_office	GP	
## 3	in_building_but_not_office	internist	
## 4	in_building_and_office	GP	
## 5	in_building_but_not_office	GP	
## 6	in_building_and_office	internist	
## 7	in_building_but_not_office	GP	
## 8	not_in_building	GP	
## 9	in_building_but_not_office	pediatrician	
## 10	in_building_and_office	GP	
## 11	in_building_perhaps_in_office	internist	
## 12	not_in_building	GP	
## 13	in_building_and_office	GP	
## 14	in_building_and_office	GP	
## 15	<NA>	GP	
## 16	in_building_but_not_office	internist	
## 17	in_building_but_not_office	GP	
## 18	in_building_and_office	GP	
## 19	in_building_and_office	internist	
## 20	in_building_and_office	internist	
## 21	<NA>	pediatrician	
## 22	in_building_but_not_office	pediatrician	
## 23	in_building_but_not_office	pediatrician	
## 24	in_building_but_not_office	internist	
## 25	not_in_building	GP	
## 26	not_in_building	GP	
## 27	in_building_and_office	pediatrician	
## 28	in_building_but_not_office	internist	
## 29	in_building_but_not_office	internist	
## 30	not_in_building	GP	
## 31	in_building_but_not_office	internist	
## 32	in_building_and_office	internist	
## 33	not_in_building	GP	
## 34	in_building_but_not_office	GP	
## 35	in_building_and_office	GP	

## 36	in_building_but_not_office	internist
## 37	in_building_and_office	internist
## 38	not_in_building	GP
## 39	<NA>	GP
## 40	in_building_and_office	other
## 41	in_building_and_office	other
## 42	in_building_perhaps_in_office	other
## 43	in_building_and_office	other
## 44	in_building_and_office	other
## 45	in_building_and_office	other
## 46	in_building_and_office	other
## 47	in_building_and_office	other
## 48	in_building_but_not_office	other
## 49	in_building_perhaps_in_office	other
## 50	in_building_and_office	other
## 51	in_building_perhaps_in_office	other
## 52	in_building_but_not_office	other
## 53	in_building_but_not_office	other
## 54	in_building_but_not_office	other
## 55	in_building_and_office	other
## 56	in_building_and_office	other
## 57	in_building_but_not_office	other
## 58	not_in_building	other
## 59	in_building_but_not_office	other
## 60	in_building_and_office	other
## 61	in_building_but_not_office	other
## 62	in_building_but_not_office	other
## 63	in_building_and_office	other
## 64	in_building_but_not_office	other
## 65	in_building_but_not_office	other
## 66	in_building_and_office	other
## 67	in_building_but_not_office	other
## 68	in_building_and_office	other
## 69	in_building_and_office	other
## 70	in_building_and_office	internist
## 71	<NA>	internist
## 72	in_building_but_not_office	internist
## 73	not_in_building	GP
## 74	not_in_building	GP
## 75	<NA>	GP
## 76	in_building_but_not_office	GP
## 77	in_building_but_not_office	pediatrician
## 78	in_building_but_not_office	pediatrician
## 79	in_building_and_office	GP
## 80	in_building_but_not_office	GP
## 81	not_in_building	internist
## 82	in_building_and_office	internist
## 83	in_building_but_not_office	other
## 84	in_building_and_office	other
## 85	in_building_and_office	other
## 86	in_building_perhaps_in_office	other
## 87	<NA>	other
## 88	in_building_and_office	other
## 89	<NA>	other



## 90	<NA>	other
## 91	<NA>	pediatrician
## 92	in_building_and_office	pediatrician
## 93	not_in_building	internist
## 94	in_building_and_office	internist
## 95	in_building_perhaps_in_office	internist
## 96	<NA>	internist
## 97	not_in_building	GP
## 98	in_building_and_office	internist
## 99	in_building_but_not_office	other
## 100	in_building_and_office	other
## 101	in_building_and_office	other
## 102	in_building_and_office	other
## 103	in_building_but_not_office	other
## 104	in_building_and_office	other
## 105	in_building_and_office	GP
## 106	in_building_and_office	other
## 107	not_in_building	GP
## 108	not_in_building	GP
## 109	<NA>	other
## 110	<NA>	other
## 111	<NA>	<NA>
## 112	<NA>	<NA>
## 113	<NA>	<NA>
## 114	<NA>	<NA>
## 115	<NA>	<NA>
## 116	<NA>	<NA>
## 117	<NA>	<NA>
## 118	in_building_but_not_office	internist
## 119	in_building_and_office	GP
## 120	in_building_but_not_office	GP
## 121	in_building_and_office	internist
## 122	in_building_but_not_office	internist
## 123	in_building_and_office	GP
## 124	not_in_building	internist
## 125	not_in_building	GP
## 126	in_building_and_office	pediatrician
## 127	not_in_building	GP
## 128	in_building_and_office	GP
## 129	in_building_and_office	pediatrician
## 130	in_building_but_not_office	GP
## 131	not_in_building	GP
## 132	in_building_and_office	GP
## 133	in_building_and_office	GP
## 134	<NA>	GP
## 135	in_building_but_not_office	internist
## 136	not_in_building	GP
## 137	in_building_but_not_office	GP
## 138	in_building_and_office	other
## 139	in_building_and_office	other
## 140	in_building_and_office	other
## 141	in_building_but_not_office	other
## 142	in_building_and_office	other
## 143	in_building_and_office	other

## 144	in_building_but_not_office	other
## 145	in_building_and_office	other
## 146	in_building_but_not_office	other
## 147	in_building_and_office	other
## 148	in_building_and_office	other
## 149	not_in_building	other
## 150	in_building_but_not_office	other
## 151	in_building_but_not_office	pediatrician
## 152	not_in_building	GP
## 153	in_building_but_not_office	internist
## 154	not_in_building	GP
## 155	in_building_but_not_office	other
## 156	<NA>	GP
## 157	in_building_but_not_office	other
## 158	in_building_and_office	other
## 159	<NA>	other
## 160	in_building_but_not_office	other
## 161	<NA>	other
## 162	<NA>	other
## 163	<NA>	other
## 164	<NA>	other
## 165	<NA>	other
## 166	<NA>	<NA>
## 167	<NA>	<NA>
## 168	in_building_and_office	internist
## 169	not_in_building	GP
## 170	in_building_and_office	internist
## 171	in_building_and_office	GP
## 172	not_in_building	GP
## 173	in_building_and_office	internist
## 174	in_building_and_office	GP
## 175	in_building_and_office	internist
## 176	in_building_and_office	internist
## 177	in_building_and_office	GP
## 178	in_building_but_not_office	other
## 179	in_building_but_not_office	GP
## 180	in_building_and_office	internist
## 181	in_building_perhaps_in_office	pediatrician
## 182	in_building_and_office	other
## 183	in_building_and_office	other
## 184	in_building_and_office	other
## 185	in_building_and_office	other
## 186	in_building_and_office	other
## 187	in_building_and_office	other
## 188	in_building_but_not_office	other
## 189	in_building_and_office	other
## 190	in_building_and_office	other
## 191	in_building_and_office	other
## 192	in_building_and_office	other
## 193	in_building_and_office	other
## 194	in_building_and_office	other
## 195	in_building_and_office	GP
## 196	in_building_and_office	internist
## 197	not_in_building	GP

```

## 198      in_building_and_office pediatrician
## 199      not_in_building          GP
## 200  in_building_but_not_office          GP
## 201      <NA>          other
## 202      <NA>          other
## 203      not_in_building          other
## 204      <NA>          other
## 205      <NA>          other
## 206      <NA>          <NA>
## 207      <NA>          <NA>
## 208      <NA>          <NA>
## 209      <NA>          <NA>
## 210      <NA>          <NA>
## 211      <NA>          <NA>
## 212  in_building_but_not_office          GP
## 213  in_building_but_not_office          GP
## 214      in_building_and_office          GP
## 215  in_building_but_not_office          GP
## 216      <NA>          internist
## 217      in_building_and_office          internist
## 218      in_building_and_office          internist
## 219  in_building_but_not_office          GP
## 220  in_building_but_not_office          GP
## 221  in_building_but_not_office pediatrician
## 222      in_building_and_office          internist
## 223      in_building_and_office          GP
## 224      in_building_and_office          GP
## 225      not_in_building          GP
## 226      not_in_building          GP
## 227      in_building_and_office pediatrician
## 228      not_in_building          GP
## 229      in_building_and_office pediatrician
## 230      in_building_and_office          other
## 231      in_building_and_office          other
## 232      in_building_and_office          other
## 233      in_building_and_office          other
## 234  in_building_but_not_office          other
## 235      in_building_and_office          other
## 236      in_building_and_office          other
## 237      in_building_and_office          other
## 238      in_building_and_office          other
## 239      in_building_and_office          other
## 240      in_building_and_office          other
## 241      in_building_and_office          GP
## 242  in_building_but_not_office          other
## 243  in_building_but_not_office          other
## 244      <NA>          <NA>
## 245      <NA>          <NA>
## 246      <NA>          <NA>

```

1. The Model.

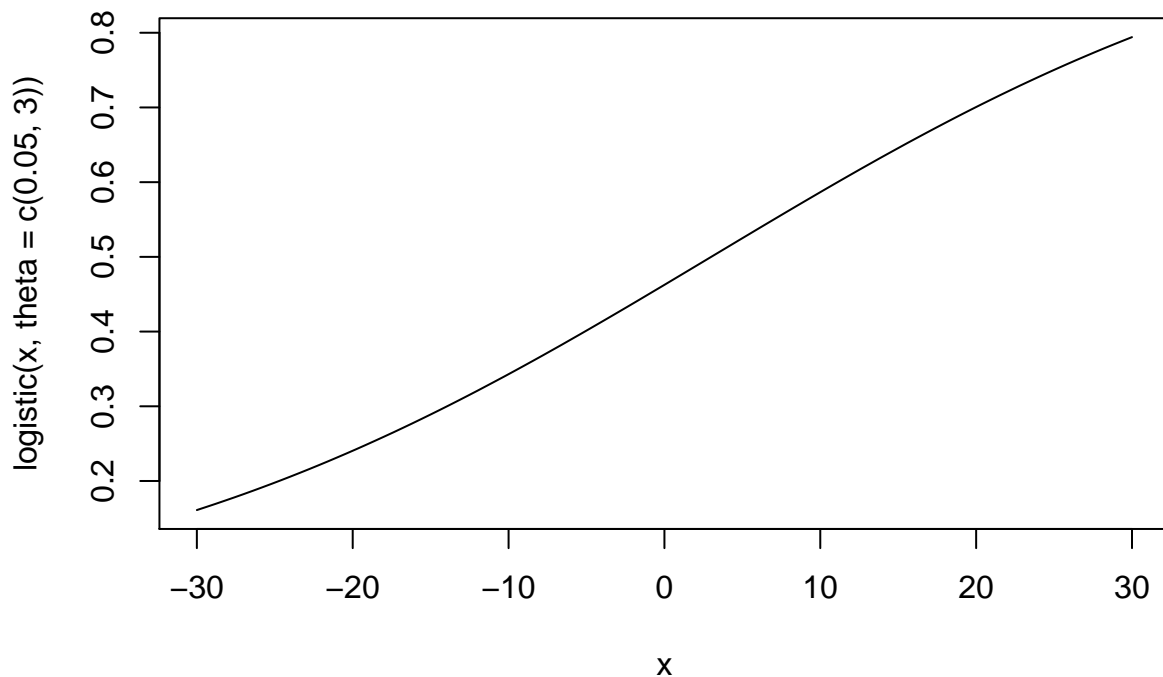
- a. Write a function, `logistic`, which calculates the logistic function. It should take two arguments, `t` and `theta`. The `theta` argument should be a vector of length two, the first component being the parameter  $b$  and the second component being  $t_0$ . Your function may not use any loops. Plot

- the curve of the logistic function with  $b = 0.05$ ,  $t_0 = 3$ , from  $t = -30$  to  $t = 30$ .
- b. Explain why  $p(t_0) = 0.5$ , no matter what  $b$  is. Use this to check your logistic function at multiple combinations of  $b$  and  $t_0$ .

```
logistic<-function(t,theta)
{
  b=theta[1]
  t0=theta[2]
  p<- exp(1)^(b*(t-t0))/(1+exp(1)^(b*(t-t0)))
  return (p)
}
logistic(t=-30:30, theta=c(0.05,3))
```

```
## [1] 0.1611089 0.1679816 0.1750863 0.1824255 0.1900016 0.1978161 0.2058704
## [8] 0.2141650 0.2227001 0.2314752 0.2404891 0.2497399 0.2592251 0.2689414
## [15] 0.2788848 0.2890505 0.2994329 0.3100255 0.3208213 0.3318122 0.3429895
## [22] 0.3543437 0.3658644 0.3775407 0.3893608 0.4013123 0.4133824 0.4255575
## [29] 0.4378235 0.4501660 0.4625702 0.4750208 0.4875026 0.5000000 0.5124974
## [36] 0.5249792 0.5374298 0.5498340 0.5621765 0.5744425 0.5866176 0.5986877
## [43] 0.6106392 0.6224593 0.6341356 0.6456563 0.6570105 0.6681878 0.6791787
## [50] 0.6899745 0.7005671 0.7109495 0.7211152 0.7310586 0.7407749 0.7502601
## [57] 0.7595109 0.7685248 0.7772999 0.7858350 0.7941296
```

```
curve(logistic(x,theta=c(0.05,3)), from=-30, to=30)
```



```
logistic(t=3, c(b=0.05, t0=3))
```

```
## b
## 0.5
```

```
logistic(t=3, c(b=0.5, t0=3))
```

```
## b
## 0.5
```

```
logistic(t=3, c(b=5, t0=3))
```

```
## b
## 0.5
```

Because if  $t_0=0.5$ ,  $t-t_0=0$ ,  $p(t_0) = e^{(1+e^0)} = 1/1+1 = .5$

c. Explain why the slope of  $p(t)$  at  $t = t_0$  is  $b/4$ . (Hint: calculus.) Use this to check your `logistic` function at multiple combinations of  $b$  and  $t_0$ .

```
logistic(t=3, c(b=0.05, t0=3))
```

```
## b
## 0.5
```

```
logistic(t=4, c(b=0.5, t0=4))
```

```
## b
## 0.5
```

```
logistic(t=5, c(b=5, t0=5))
```

```
## b
## 0.5
```

```
deriv1<-deriv(~exp(5*(t-5))/(1+exp(5*(t-5))), "t")
deriv1
```

```
## expression({
##   .expr3 <- exp(5 * (t - 5))
##   .expr4 <- 1 + .expr3
##   .expr6 <- .expr3 * 5
##   .value <- .expr3/.expr4
##   .grad <- array(0, c(length(.value), 1L), list(NULL, c("t")))
##   .grad[, "t"] <- .expr6/.expr4 - .expr3 * .expr6/.expr4^2
##   attr(.value, "gradient") <- .grad
##   .value
## })
```

```
t<-5
eval(deriv1)
```

```
## [1] 0.5
## attr(,"gradient")
##      t
## [1,] 1.25
```

```
deriv2<-deriv(~exp(2*(t-1))/(1+exp(2*(t-1))), "t")
mode(deriv2)
```

```
## [1] "expression"
```

```
t<-1
eval(deriv2)
```

```
## [1] 0.5
## attr(,"gradient")
##      t
## [1,] 0.5
```

2. The Data.

- a. How many doctors in the survey had adopted tetracycline by month 5? Hint: Use `na.omit` carefully.

```
ckk<-na.omit(ckm[,2])
ckk1<-ckk[is.infinite(ckk)==FALSE]
```

```
ckm1<-ckk1[ckk1<=5]
length(ckm1)
```

```
## [1] 51
```

There are 51 doctors in the survey had adopted tetracycline by month 5. b. What proportion of doctors, for whom adoption dates are available, had adopted tetracycline by month 5?

```
length(ckm1)/length(ckk)
```

```
## [1] 0.408
```

40.8% of doctors for whom adoption dates are available, had adopted tetracycline by month 5.

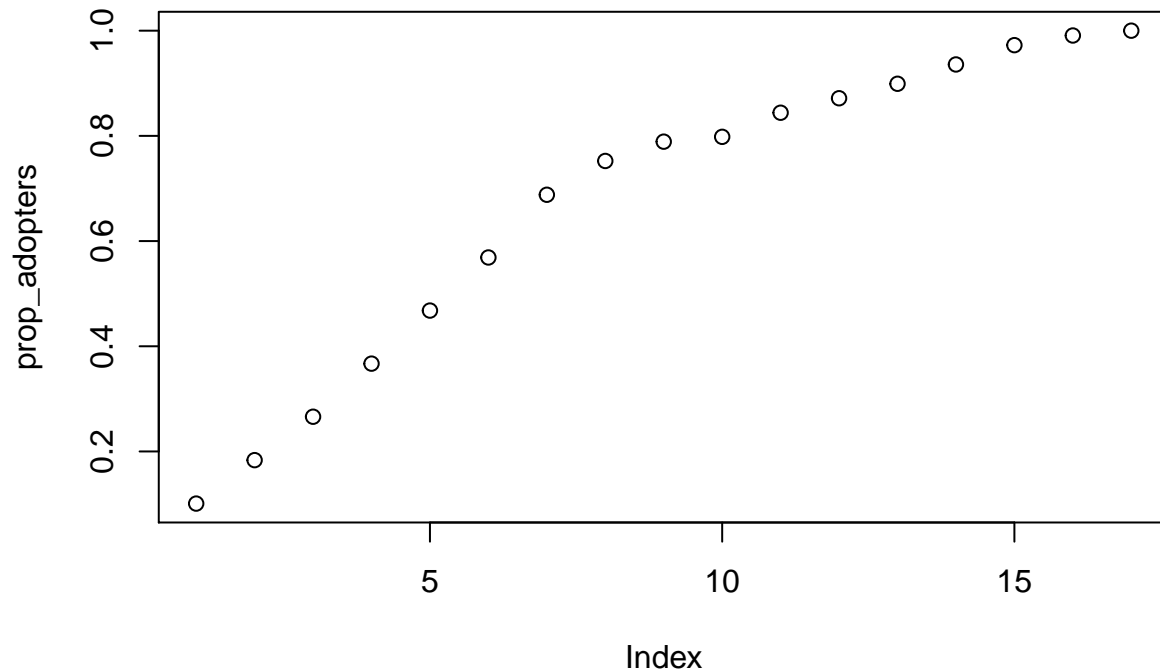
- c. Create a vector, `prop_adopters`, storing the proportion of doctors who have adopted by each month. (Be careful about Inf and NA.)

```
prop_adopters<-vector("numeric", 17)
for (i in 1:17)
{
  n<- ckk1[ckk1<=i]
  n3<-length(n)
  n2<-length(ckk1)
  prop_adopters[i]<-n3/n2
}
prop_adopters
```

```
## [1] 0.1009174 0.1834862 0.2660550 0.3669725 0.4678899 0.5688073 0.6880734
## [8] 0.7522936 0.7889908 0.7981651 0.8440367 0.8715596 0.8990826 0.9357798
## [15] 0.9724771 0.9908257 1.0000000
```

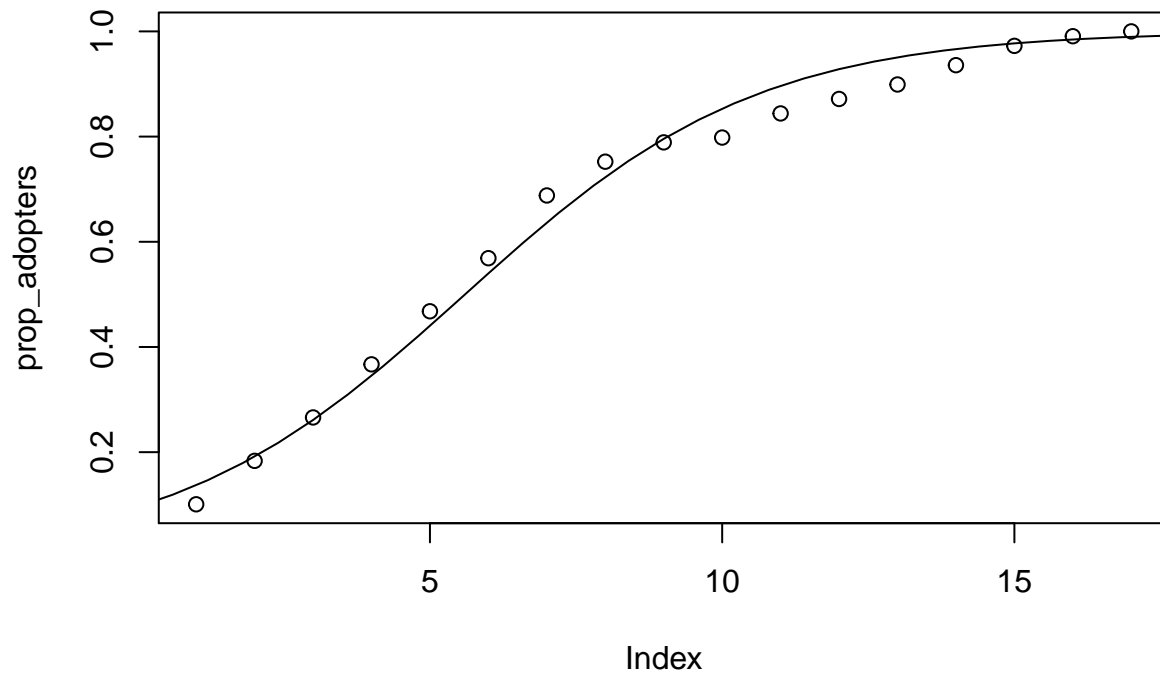
- d. Make a scatter-plot of the proportion of adopters over time.

```
plot(prop_adopters)
```



e. Make rough guesses about  $t_0$  and  $b$  from the plot, and from your answers in problem 1.

```
plot(prop_adopters)
curve(logistic(x,theta=c(b=0.4, t0=5.6)), from=-30, to=30, add=TRUE)
```



### 3. The Fit.

- Write a function, `logistic_mse`, which calculates the mean squared error of the logistic model on this data set. It should take a single vector, `theta`, and return a single number. This function cannot contain any loops, and must use your `logistic` function.

```
logistic_mse <-function(theta)
{
```

```
x<-c(1:17)
ex<- logistic(x,theta)
mse<-mean((prop_adopters-ex)^2)
return(mse)
}
logistic_mse(c(0.4,5.6))
```

```
## [1] 0.001165075
```

b. Use `optim` to minimize `logistic_mse`, starting from your rough guess in problem 2e. Report the local

```
theta<-c(0.37,5.5)
optim(theta, logistic_mse)
```

```
## $par
## [1] 0.3738456 5.5196051
##
## $value
## [1] 0.001037297
##
## $counts
## function gradient
##      63      NA
##
## $convergence
## [1] 0
##
## $message
## NULL
```

c. Add a curve of the fitted logistic function to your scatterplot from Problem 2d. Does it seem like a

```
plot(prop_adopters)
curve(logistic(x,theta=c(b=0.3738436, t0= 5.5195559)), from=-30, to=30, add=TRUE)
```

