004630 **Program Description 1**

Program Title GAME OF LIFE (9X9)

Contributor's Name JOHN RAUSCH

Address 402 VIRGINIA AVE

City FRANKLIN **State** OHIO **Zip Code** 45005

Program Description, Equations, Variables THE GAME OF LIFE WAS ORIGINALLY DESCRIBED IN SCIENTIFIC AMERICAN, OCTOBER 1970, IN AN ARTICAL BY MARTIN GARDNER. THE GAME ITSELF WAS ORIGINATED BY JOHN CONWAY OF GONVILLE AND CAIUS COLLEGE, UNIVERSITY OF CAMBRIDGE, ENGLAND.

IN THE GAME, ORGANISMS EXIST IN THE FORM OF COUNTERS ON A LARGE CHECKERBOARD (9X9 IN THIS VERSION) AND DIE OR REPRODUCE ACCORDING TO SOME SIMPLE GENETIC RULES. CONWAY'S CRITERIA FOR CHOOSING HIS GENETIC LAWS WERE CAREFULLY DELINEATED AS FOLLOWS:

1) THERE SHOULD BE NO INITIAL PATTERN FOR WHICH THERE IS A SIMPLE PROOF THAT THE POPULATION CAN GROW WITHOUT LIMIT.

2) THERE SHOULD BE INITIAL PATTERNS THAT APPARENTLY DO GROW WITHOUT LIMIT.

3) THERE SHOULD BE SIMPLE INITIAL PATTERNS THAT GROW AND CHANGE FOR A CONSIDERABLE PERIOD OF TIME BEFORE COMING TO AN END IN THREE POSSIBLE WAYS: FADING AWAY COMPLETELY (FROM OVERCROWDING OR ISOLATION), SETTLING INTO A STABLE CONFIGURATION THAT REMAINS UNCHANGED THEREAFTER, OR ENTERING INTO AN OSCILLATING PHASE IN WHICH THEY REPEAT AN ENDLESS CYCLE OF TWO OR MORE PERIODS.

(CONTINUED)

Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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00463D

Program Description I

Program Title

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Program Description, Equations, Variables IN BRIEF, THE RULES SHOULD BE SUCH AS TO MAKE THE BEHAVIOR OF THE POPULATION UNPREDICTABLE. CONWAY'S GENETIC LAWS ARE DELIGHTFULLY SIMPLE. FIRST NOTE THAT EACH CELL OF THE CHECKERBOARD (ASSUMED TO BE AN INFINITE PLANE OF WHICH YOU ARE VIEWING ONLY A SMALL SECTION) HAS EIGHT NEIGHBORING CELLS, FOUR ADJACENT ORTHOGANALLY, AND FOUR ADJACENT DIAGONALLY. THE RULES ARE:

1) SURVIVALS. EVERY COUNTER (ORGANISM) WITH TWO OR THREE NEIGHBORING COUNTERS SURVIVES THROUGH THE NEXT GENERATION.

2) DEATHS. EVERY COUNTER WITH MORE THAN THREE NEIGHBORING COUNTERS DIES FROM OVERCROWDING. EVERY COUNTER WITH LESS THAN TWO NEIGHBORING COUNTERS DIES FROM ISOLATION.

3) BIRTHS. EVERY EMPTY CELL WITH EXACTLY THREE NEIGHBORING COUNTERS GIVES BIRTH.

IT IS IMPORTANT TO REMEMBER THAT ALL BIRTHS AND DEATHS OCCUR SIMULTANEOUSLY. TOGETHER THEY CONSTITUTE A SINGLE GENERATION IN THE LIFE HISTORY OF THE INITIAL CONFIGURATION.

YOU WILL FIND THE POPULATION CONSTANTLY UNDERGOING UNUSUAL, SOMETIMES BEAUTIFUL, AND ALWAYS UNEXPECTED CHANGE. IN A FEW

(CONTINUED)

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004630 **Program Description I**

Program Title _____

_____

Contributor's Name _____

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City _____ **State** _____ **Zip Code** _____

Program Description, Equations, Variables CASES THE POPULATION EVENTUALLY DIES OUT, ALTHOUGH THIS MAY NOT HAPPEN UNTIL AFTER A GREAT MANY GENERATIONS. MOST STARTING PATTERNS EITHER REACH STABLE CONFIGURATIONS (CONWAY CALLS THEM "STILL LIFES") THAT CANNOT CHANGE OR CONFIGURATIONS THAT OSCILLATE FOREVER. CONFIGURATIONS WITH NO INITIAL SYMMETRY TEND TO BECOME SYMMETRICAL. ONCE THIS HAPPENS THE SYMMETY CANNOT BE LOST, ALTHOUGH IT MAY INCREASE IN RICHNESS.

THIS PROGRAM RUNS BEST ON AN HP-97 SINCE IT CAN RUN IN A CONTINUOUS MODE PRINTING EACH GENERATION IN AN ESPECIALLY NICE FORM. HOWEVER, SATISFACTORY RESULTS CAN BE OBTAINED ON AN HP-67. THE CONFIGURATIONS ARE EASILY COPIED ONTO GRIDDED PAPER. IT TAKES LESS THAN THREE MINUTES TO RUN A GENERATION. THIS SEEMS FAST WHEN COMPARED TO THE FIFTY MINUTES REQUIRED BY A 10X10 LIFE GAME ALSO IN THE LIBRARY. THE DIFFERENCE IS NOT SIZE. THE 9X9 WAS CHOSEN FOR NEAT PRINT OUT APPEARANCE, NOT SPEED. IN ADDITION, THIS PROGRAM CAN OPTIONALLY CHECK FOR "STILL LIFES" AND TERMINATE WHEN TWO CONSECUTIVE GENERATIONS ARE IDENTICAL. OSCILLATIONS CANNOT BE CHECKED WITH A COMPUTER OF ANY SIZE EASILY! EVEN WHEN RUNNING IN THE CONTINUOUS MODE,

(CONTINUED)

Operating Limits and Warnings _____

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00463D Program Description I

Program Title

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Program Description, Equations, Variables EXECUTION CAN BE INTERUPTED AFTER EACH GENERATION. IMMEDIATELY AFTER THE GENERATION IS PRINTED, A ONE SECOND PAUSE WINDOW (DISPLAY WILL BE 0.000000000) WILL APPEAR. YOU CAN CAUSE THE PROGRAM TO STOP BY PRESSING ANY DIGIT KEY (OR R/S OF COURSE). TO RESUME EXECUTION OF THE NEXT GENERATION, JUST PRESS R/S. YOU CAN ALSO CAUSE THE CURRENT GENERATION TO BE REPRINTED BY PRESSING C (TAKE NOTE HP-67 USERS). IN AN EMERGENCY, YOU CAN STOP THE PROGRAM EVEN AFTER IT HAS STARTED EXECUTION (BUT NOT AFTER IT STARTS PRINTING THE NEXT GENERATION) AND REPRINT THE CURRENT GENERATION BY PRESSING C. THE ONLY THING THAT WILL HAVE CHANGED IS THE GENERATION NUMBER STORED IN REGISTER E, SO YOU MAY WANT TO SUBTRACT ONE FROM IT BEFORE PRESSING C.

MANY THANKS TO MORDECAI SCHWARTZ WHOSE 10X10 GAME OF LIFE POINTED OUT THE FEASABILITY OF PROGRAMMING THIS VERY UNUSUAL AND WELL KNOWN (AMONG RECREATIONAL MATH FANS) GAME ON THE HP-67 AND HP-97.

ANYONE THAT CAN PROVIDE A SIGNIFICANT IMPROVEMENT TO THE EXECUTION TIME IS URGED TO CONTACT ME DIRECTLY.

Operating Limits and Warnings NO EDIT IS MADE ON THE INITIAL GRID COORDINATES TO BE SURE THEY ARE IN THE RANGE OF 1 TO 9. NO ATTEMPT WILL BE MADE TO DESCRIBE (OR EVEN FIGURE OUT) WHAT MIGHT HAPPEN IF ILLEGAL ENTRIES ARE MADE.

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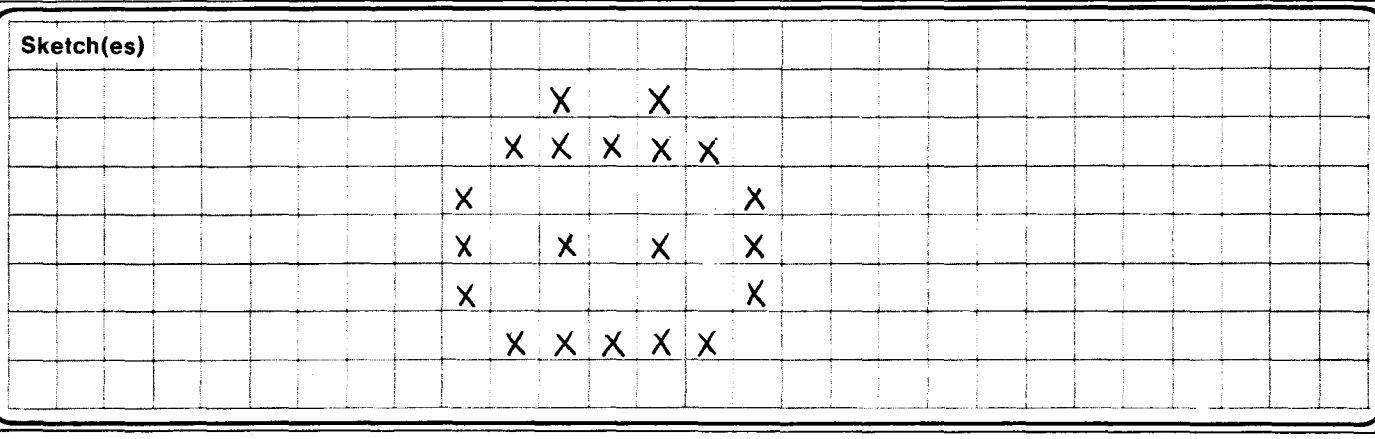
00463D Program Description II

Sketch(es)



Sample Problem(s) THE CONFIGURATION SHOWN IN THE ABOVE SKETCH IS INPUT AND THE FIRST SIX GENERATIONS (INCLUDING ZERO) ARE INCLUDED.

```
      GSBA
2.4   GSBB
2.6   GSBB
3.3   GSBB
3.4   GSBB
3.5   GSBB
3.6   GSBB
3.7   GSBB
4.2   GSBB
4.6   GSBB
5.2   GSBB
5.4   GSBB
5.6   GSBB
5.8   GSBB
6.2   GSBB
6.8   GSBB
7.3   GSBB
7.4   GSBB
7.5   GSBB
7.6   GSBB
7.7   GSBB
      GSBC
```

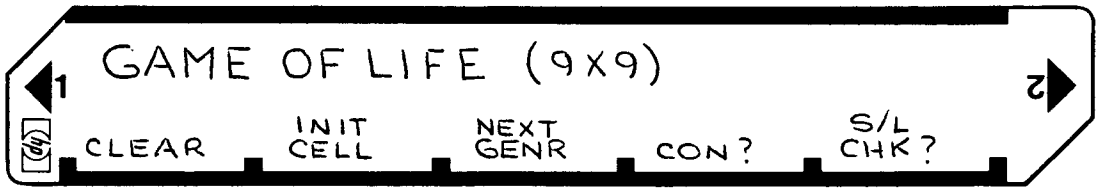
Solution(s)

```
        0.          1.          2.          3.          4.          5.          6.
0.123456789 0.123456789 0.123456789 0.123456789 0.123456789 0.123456789 0.123456789
1.000000000 1.000000000 1.000000000 1.000000000 1.000000000 1.001000100 1.001000100
2.000101000 2.001101100 2.001101100 2.001101100 2.011101110 2.010101010 2.010000010
3.001111100 3.001101100 3.010101010 3.110101011 3.010101010 3.010000010 3.000000000
4.010000010 4.010000010 4.110000011 4.000000000 4.001101100 4.000101000 4.001000100
5.010101010 5.110000011 5.111000111 5.000111000 5.000101000 5.000101000 5.000101000
6.010000010 6.010000010 6.110111011 6.100111001 6.001000100 6.001101100 6.001000100
7.001111100 7.001111100 7.001000100 7.001010100 7.001000100 7.001010100 7.001000100
8.000000000 8.000111000 8.001000100 8.000101000 8.000111000 8.000111000 8.000000000
9.000000000 9.000000000 9.000010000 9.000000000 9.000000000 9.000010000 9.000111000
```

Reference(s) SCIENTIFIC AMERICAN, OCT 1970, NOV 1970, JAN 1971, FEB 1971, AND APR 1971. MATHEMATICAL GAMES FEATURE. INTERESTED READERS ARE URGED TO OBTAIN COPIES OF THESE ARTICALS. THE GAME OF LIFE RESULTED IN MORE RESPONSE TO MARTIN GARDNER THAN ANY OTHER TOPIC COVERED IN HIS MONTHLY FEATURE.

00463D

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE 2.			
2	CLEAR. (DOES NOT AFFECT EXECTION MODES)		A	0.
3	SELECT CONTINUOUS (1) OR STOP (0) MODE OF EXECUTION. DEFAULTS TO 1.		D	ALTERNATELY 0 & 1
4	SELECT "STILL LIFE" CHECK. ON (1), OFF (0) WHEN ON, REQUIRES A LITTLE MORE RUN TIME PER GENERATION. DEFAULTS TO 0.		E	ALTERNATELY 1 & 0
5	SPECIFY INITIAL CELL CONFIGURATION. INDICATE THE ROW (1-9) AND COLUMN (1-9) OF THE CELL THAT IS TO CONTAIN LIFE IN GENERATION 0. REPEAT AS REQUIRED.	ROW, COL	B	0.
6	NEXT GENERATION. GENERATION 0 IS PRINTED BEFORE ACTUAL GENERATION IS COMPUTED. AFTER THE PRINTING OF A GENERATION IS COMPLETED, THE FOLLOWING WILL OCCUR: A) IF STOP MODE WAS SELECTED, CALCULATOR WILL STOP. THIS IS YOUR FIRST CHANCE TO CORRECT AN INITIAL CONFIGURATION. PRESS R/S TO CONTINUE OR GO TO STEP 5 TO ADD ANY CELLS YOU FORGOT. IF YOU PUT ANY IN THE WRONG PLACE YOU WILL HAVE TO START OVER AT STEP 2. YOU CAN ALSO PRESS C TO REPRINT THE INITIAL CONFIGURATION. B) YOU WILL SEE A ONE SECOND PAUSE WINDOW (EVEN IN CONTINUOUS MODE) WHERE YOU CAN STOP EXECUTION BY PRESSING ANY DIGIT KEY OR R/S. YOUR OPTIONS ARE THE SAME AS IN A ABOVE. C) NEXT GENERATION WILL BE COMPUTED AND PRINTED. A ZERO IS PRINTED IF A "STILL LIFE" IS DETECTED AND CHECK IS ON.		C	SEE TEXT

00463 D

Program Listing I

REVISED 12-19-76

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	CLEAR.
002	DSP0	-63 00	
003	CLRG	16-53	
004	F?S	16-51	
005	CLRG	16-53	
006	CLX	-51	
007	RTN	24	
008	*LBLB	21 12	INITIALIZE CELL. COORDINATE IS CONVERTED TO A FRACTIONAL VALUE WITH A 1 IN PROPER POSITION AND ADDED TO ROW.
009	STOI	35 46	
010	INT	16 34	
011	X?I	16-41	
012	FRC	16 44	
013	1	01	
014	0	00	
015	X	-35	
016	10^x	16 33	
017	1/X	52	
018	ST+i	35-55 45	
019	CLX	-51	
020	RTN	24	
021	*LBLC	21 13	NEXT GENERATION. CURRENT GENERATION IS PRINTED BEFORE COMPUTATION OF NEXT GENERATION IS STARTED.
022	RCLE	36 15	
023	DSP0	-63 00	
024	PRTX	-14	
025	.	-62	
026	1	01	
027	2	02	
028	3	03	
029	4	04	
030	5	05	
031	6	06	
032	7	07	
033	8	08	
034	9	09	
035	DSPS	-63 09	
036	PRTX	-14	
037	CLX	-51	
038	STOI	35 46	
039	*LBL0	21 00	LOOP TO PRINT OUT ALL NINE ROWS.
040	ISZI	16 26 46	
041	RCLi	36 45	
042	RCLI	36 46	
043	+	-55	
044	PRTX	-14	
045	RCLI	36 46	
046	9	09	
047	X≠Y?	16-32	
048	GTO0	22 00	
049	CLX	-51	
050	SFC	16-11	
051	F0?	16 23 00	STOP IF NOT IN CONTINUOUS MODE. PAUSE TO PERMIT INTERRUPTION BY R/S OR DIGIT ENTRY.
052	R/S	51	
053	CF3	16 22 03	
054	PSE	16 51	
055	F3?	16 23 03	
056	R/S	51	
057	RCLE	36 15	ADD 1 TO GENERATION NUMBER.
058	1	01	
059	+	-55	
060	STOE	35 15	
061	1	01	
062	STOI	35 46	
063	0	00	
064	RCL2	36 02	COMPUTE NEXT GENERATION. SUBROUTINE AT LABEL 1 IS CALLED FOR ALL NINE ROWS AFTER PUTTING THE ROWS BEFORE AND AFTER IN Z AND Y AND PUTTING THE ROW TO BE COMPUTED IN X.
065	RCL1	36 01	
066	GSB1	23 01	
067	RCL1	36 01	
068	RCL3	36 03	
069	RCL2	36 02	
070	GSB1	23 01	
071	RCL2	36 02	
072	RCL4	36 04	
073	RCL3	36 03	
074	GSB1	23 01	
075	RCL3	36 03	
076	RCL5	36 05	
077	RCL4	36 04	
078	GSB1	23 01	
079	RCL4	36 04	
080	RCL6	36 06	
081	RCL5	36 05	
082	GSB1	23 01	
083	RCL5	36 05	
084	RCL7	36 07	
085	RCL6	36 06	
086	GSB1	23 01	
087	RCL6	36 06	
088	RCL8	36 08	
089	RCL7	36 07	
090	GSB1	23 01	
091	RCL7	36 07	
092	RCL9	36 09	
093	RCL8	36 08	
094	GSB1	23 01	
095	RCL8	36 08	
096	0	00	
097	RCL9	36 09	
098	GSB1	23 01	
099	F1?	16 23 01	CHECK FOR STILL LIFE IF SELECTED. PUT NEXT GENERATION IN P REGISTERS AFTER CLEARING THEM EXCEPT FOR E. THEN GO TO PRINT GENERATION. COMPUTE NEXT GENERATION FOR ONE ROW. ROW BEING WORKED ON IS STORED IN A. THEN ROWS BEFORE AND AFTER ARE ADDED AS START FOR
100	GSB4	23 04	
101	RCLE	36 15	
102	CLRG	16-53	
103	P?S	16-51	
104	STOE	35 15	
105	GTOC	22 13	
106	*LBL1	21 01	
107	STOA	35 11	
108	R↓	-31	
109	+	-55	
110	ENT↑	-21	
111	R↑	16-31	
112	+	-55	

REGISTERS

USED	1	2	3	4 CURRENT GENERATION	5	6	7	8	9
S0 ZERO	S1	S2	S3	S4 NEXT GENERATION	S5	S6	S7	S8	S9

A USED	B USED	C	D	E GENERATION NUMBER	I USED

Program Listing II

REVISED 12-19-76

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	1	01	
114	0	00	
115	X	-35	
116	I	01	
117	%	55	
118	+	-55	
119	+	-55	
120	FRC	16 44	NEIGHBOR COUNT. ROW BEING WORKED ON IS THEN ADDED AND SHIFTED LEFT AND RIGHT AND ADDED TO STARTING POINT TO OBTAIN TOTAL NEIGHBOR COUNT. NEXT ROW IS STARTED AT ZERO IN REG 0. SUBROUTINE AT LABEL 2 IS CALLED NINE TIMES FOR EACH DIGIT (COLUMN) IN ROW.
121	STOB	35 12	
122	CLX	-51	
123	STO0	35 00	
124	GSB2	23 02	
125	GSB2	23 02	
126	GSB2	23 02	
127	GSB2	23 02	
128	GSB2	23 02	
129	GSB2	23 02	
130	GSB2	23 02	
131	GSB2	23 02	
132	GSB2	23 02	
133	RCL0	36 00	
134	EEX	-23	
135	9	09	
136	÷	-24	
137	P↕S	16-51	NEW ROW IS CHANGED TO A FRACTION. P AND S REGISTERS ARE SWITCHED AND NEW ROW IS STORED. THEN P AND S ARE SWITCHED BACK AND I IS INCREMENTED
138	STOi	35 45	
139	P↕S	16-51	
140	ISZI	16 26 46	
141	RTN	24	
142	*LBL2	21 02	EACH DIGIT IN ROW IS CHECKED AGAINST ITS CORRESPONDING NEIGHBOR COUNT IN REG B. EACH TIME CALLED, DIGIT AND COUNT IS EXTRACTED AND REMAINING PART IS PUT BACK IN REG.
143	I	01	
144	0	00	
145	STx0	35-35 00	
146	RCLA	36 11	
147	x	-35	
148	FRC	16 44	
149	STOA	35 11	
150	LSTX	16-63	
151	INT	16 34	
152	RCLB	36 12	
153	I	01	
154	0	00	
155	x	-35	
156	FRC	16 44	
157	STOB	35 12	
158	CLX	-51	
159	LSTX	16-63	AT STEP 160, X CONTAINS NEIGHBOR COUNT AND Y CONTAINS CURRENT CELL VALUE (0 OR 1). THREE IS SUBTRACTED FROM COUNT. IF RESULT IS ZERO, NEW CELL WILL BE LIVE REGARDLESS OF Y. IF X IS EQUAL
160	INT	16 34	
161	3	03	
162	-	-45	
163	X=0?	16-43	
164	GTO3	22 03	
165	CHS	-22	
166	X≠Y?	16-32	
167	RTN	24	
168	*LBL3	21 03	
169	1	01	
170	ST+0	35-55 00	TO Y AFTER CHS, NEW CELL IS LIVE.
171	RTN	24	
172	*LBL0	21 14	ALTERNATELY TURN CONTINUOUS MODE OFF AND ON.
173	CLX	-51	
174	F0?	16 23 00	
175	1	01	
176	SF0	16 21 00	
177	X≠0?	16-42	
178	CF0	16 22 00	
179	PRTX	-14	
180	RTN	24	
181	*LBLE	21 15	ALTERNATELY TURN STILL LIFE CHECK ON AND OFF.
182	1	01	
183	F1?	16 23 01	
184	CLX	-51	
185	SF1	16 21 01	
186	X=0?	16-43	
187	CF1	16 22 01	
188	PRTX	-14	
189	RTN	24	
190	*LBL4	21 04	CHECK FOR STILL LIFE. EACH ROW OF CURRENT GENERATION IS COMPARED TO CORRESPONDING ROW OF NEW GENERATION. IF ANY ARE NOT EQUAL THE GENERATION WILL CONTINUE. IF ALL ARE EQUAL THE GENERATION NUMBER IS PRINTED FOLLOWED BY A ZERO AND THE PROGRAM STOPS.
191	CLX	-51	
192	STOI	35 46	
193	*LBL5	21 05	
194	ISZI	16 26 46	
195	RCLi	36 45	
196	P↕S	16-51	
197	RCLi	36 45	
198	P↕S	16-51	
199	X≠Y?	16-32	
200	RTN	24	
201	RCLI	36 46	
202	9	09	
203	X≠Y?	16-32	
204	GTO5	22 05	
205	RCLE	36 15	
206	DSP0	-63 00	
207	PRTX	-14	
208	CLX	-51	
209	PRTX	-14	
210	R/S	51	

LABELS

A CLEAR	B INITIALIZE CELL	C NEXT GENERATION	D CONTINUOUS MODE?	E STILL LIFE CHECK?
a	b	c	d	e
0 PRINT LOOP	1 COMPUTE NEIGHBOR COUNT	2 GENERATE CELL CHECK	3 CREATE LIFE	4 STILL LIFE CHECK
5 STILL LIFE CHECK LOOP	6	7	8	9

FLAGS

0 CONTINUOUS IF OFF	1 STILL LIFE CHECK IF ON	2	3

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	0