

# **MDIA5021**

5Xj Yfh]g]b[ 'UbX'7fYUh]j ]hm

HYfa 'C bY''##'&\$%

## 7ci fgY'Cj Yfj ]Yk

## Ghuzz 7 cbhuWh8 Yhu]`g

### '7cbj Ybcfg'

B Ua Y	9a U]`	5j U]`UV]`]lm	@cWUh]cb	D\cbY
B]WXc`Ug	b]Wkc`Ug"f]WkUfXgcb4 i bgk "YXi"	5ddc]bha Ybhgʻa Um	Fa&' %9	-',)*'))
F]WkUfXgcb	Ui	VY a UXY VmYa U]`	KYVghYf <sup>.</sup> 6`X[	

#### GWkcc~7cbhJWh~abZcfa Uh]cb

Fcca " &ž Yj Y`" FcVYfhK YVghYf 6i ]X]b[

D\cbY. f\$&L'-',) '(,) \*

9a U]`. 'gUa 4 i bgk "YXi "Ui

K YVg]hY. \hdg.##gUa "Ufhg"i bgk "YXi "Ui

 $\label{eq:hamiltonian} $$HY'GWCC``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck`YX[Y'h\Y'HfUX]tjcbU``7igtcX]Ubgžh\Y'6YXY[U'`fPYbg]b[tcb'WJadigŁZ'; UX][U'`fP]tmUbX'5ft\'v'8Yg][b'7UadigYgŁ'UbX't\Y'B[ibbUkU`dYcd'Y'fbigtfU']Ub'8YZYbW': cfW'5WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`cWJhYX''$ 

Hi fb]h]b gYh]b[. H\]g ]g bchU Hi fb]h]b Ugg][ ba Ybh

5ggYgga Ybh (. D]h/X

GhUfh'XUhY.

 $8YHJ]^*g. DfYdUfY^UbX^ii bXYfHJ_Y^U'' a ]bi HY^*d]hWX^icZcbY^idcfhZc^]c^id]YWY \pm bX]j ]Xi U^iHJg_Z^i]b!WUgg dfYgYbHJh]cb^idUgg#JJ]^''$ 

5XX]h]cbU`XYhU]`g.

FYZYf'hc'a ccX`Y'Zcf'XYhU]`g"

Hi fb]h]b gYh]b[ . 'H\]g ]g bch'U Hi fb]h]b Ugg][ ba Ybh

## FYgci fWyg

## DfYgWf]VYX F Ygci fWfg

6UffmžD"'f&\$%\* Ł"'H\Y'5Xj Yfnjg]b[ '7cb\Wdh6cc\_ž' fX'9X]njcbž@cbXcbž'H\Ua Yg'/ '<i Xgcb"

## FYWca a YbXYX FYgci fW/g

5]hW.]gcbž'>"f&\$\$(Ł"'7i h]b['9X[Y'5Xj Yfh]g]b['ž&bX'9X]h]cb"'G]b['UdcfY. DYUfgcb'<U``"

5'rgh]Y'ž'Hca / ; fck ž'>YUbž'f&\$%\$£"5Xj Yfh]g]b['7 fYUh]j Y. 'GhfUhY[mž'7 cdmž'UbX'8 Yg]['bž' fX'YX]h]cbž ......@cg'5b[Y'Yg. 'GU[Y'Di V']WUh]cbg"

<Y[Ufhmž'>"'f&\$%%£"'<Y[Ufhmcb'5Xj Yfh]g]b["'@cbXcb. 'H\Ua Yg'UbX'<i Xgcb"

F ca Ubž'? "/ 'A UUgž'>"'f&\$\$' Ł"<ck 'hc'5Xj Yfh]gY. 'K \Uhk cf\_gžk \UhXcYgb'h! 'UbX'k \mž' fX'9X]h]cb" ......@cbXcb. '<c[Ub

Gi ``]j Ubž'@"'f&\$\$, Ł"<Ymž'K \]dd`Yž'Gei YYnY'H\]g. '5'; i ]XY'hc'7 fYUh]b['; fYUh'5Xj Yfh]g]b['ž' fX .......9X]h]cb"'<cVc\_Ybž'B>.'>c\b'K]'YmV' Gcbgž'=bW'

## 7ci fgY 9j U`i Uh]cb UbX 8Yj Y`cda Ybh

DZcfa U`ZYYXVUW\_`UVci hih.Y`Wci fgY`]g`k Y`Wca YX`UbX`YbWci fU[YX`h\fci [\ci hih.Y`gYa YghYf`Vmih.Y`Wci fgY Wcbj YbYf`UbX`hi hcfg": YYXVUW\_`UbX`Yj U`i Uh]cb`]g`i gYX`hc`]a dfcj Y`h\Y`Wci fgY`YUW\`gYa YghYf`': cf Yl Ua d`Yž`U`[fci d`dfc YWh`Ug`VYYb`fYa cj YX`Zfca 'h\Y`UggYggga YbhihUg\_g`]b`&\$% '`VUgYX`cb`ghi XYbh ZYXVUW\_`]b`&\$% ''`Ghi XYbhg`UfY`YbWci fU[YX`hc`dUfh]W]dUhY`]b`cb`]bY`gi fj Ymg``UhYf`]b`h\Y`gYa YghYf"`5b Ya U]``k ]``VY`gYbhhc`U```ghi XYbhg`UXj ]g]b[`k \Ybžk\YfY`UbX`\ck 'hc`dfcj ]XY`ZYYXVUW\_"

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

Hi fb]h]b Gi Va ]gg]cb

Image: Ybwb: bh/f'u'dfcv'ya k \yb'uhh/a dh/b[ 'hc'gi va ]hmci f'ugg][ ba Ybhh\fci [ \ 'Hi fb]h/bž'd'YugY

HY'Yd\cbY'9| h/fbu''Gi ddcfhcb'-', ) '' ' ' %cf'Ya U] 'h\Ya 'cb'Yl h/fbu'h/hgi ddcfh4 i bgk "YXi "Ui "'Gi ddcfh
\ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY\_XUmg'UbX'-.\$\$Ua '-') .\$\$da 'cb'k YY\_YbXg'fl \*) 'XUmg'U'mYUfŁ" Image: UfY'i bUV'Y'hc'gi va ]hmci f'Ugg][ ba YbhXi Y'hc'U'ZJi 'hk ]h\ 'Hi fb]h/b'mci 'a UmUdd'mZcf'Ub'Yl h/bg]cbž'Vi hmci
a i ghfYhJ]b'mci f'h/w\_Yhbi a VYf'Zfca '9| h/fbu''Gi ddcfhfU'cb[ 'k ]h\ 'Ubmch\Yf'YY] UbhXcW a YbhgŁ'hc
]bWi XY'Ug'Yj ]XYbW'hc'gi ddcfhmci f'Yl h/bg]cb'Udd']WJh/cb" Image: Ya U]''9| h/fbu''Gi ddcfhmci 'k ]'`
Ui hca Uh/WJ'mfYW'] Y'U'h/w\_Yhbi a VYfž'Vi h]Zmci 'hY'Yd\cbY'mci 'k ]'`'bYYX'hc'gdYW/ZWJ'`mUg\_'Zcf'cbY''
Hi fb]h/b'U'gc'dfcj ]XYg'i dXUh/g'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk ]hYf"

; YbYfU``mž'UggYgga YbhiHug\_g'a i ghVY'gi Va ]hhYX'Y`YVWfcb]\W)``mj ]U'Y]h\Yf'Hi fb]hjb'cf'U'A ccX`Y Ugg][ ba Ybh'' =b']bgHJb\W'g'k \YfY'h\]g']g'bchdcgg]V`Yž']hk ]``'VY'gHJhYX'cb'mci f'\\circ i fgY'g'A ccX`Y'g]hY'k ]h\ U`hYfbUhj Y'gi Va ]gg]cb'XYHJ]`g''

cfi]bZcfa Uh]cbicbi\ckihcigi Va ]hUgg][ ba Ybhgicbi]bYij ]UiA ccXiY.i\hdg.#gh XYbh'i bgk "YXi "Ui #\ck! qi Va ]hUgq][ ba Ybha ccXiY

## 5 WUXYa ]W<cbYghmUbX D`U[ ]Uf]ga

D`U[]Uf]ga `]g`i g]b[ 'h\Y`k cfXg`cf`]XYUg`cZch\Yfg`UbX`dfYgYbh]b[ 'h\Ya `Ug`mci f`ck b"'=hWJb'hU\_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b[ 'hc`UWW]XYbhU`mWcdm]b[ 'Zfca `U`gci fWY'k ]h\ci hUW\_bck `YX[ Ya Ybh'

IBGK [fcidgdu[]uf]ga ]bhch\YZc``ck]b[ WuhY[cf]Yg.

7 cdm]b[.'i g]b['h\Y'gUa Y'cf'j Yfmg]a]`Uf'k cfXg'hc'h\Y'cf][]bU`hYl h'cf']XYU'k]h\ci h'UW\_bck `YX[]b['h\Y gci fW'cf'i g]b['ei chUh]cb'a Uf\_g"'H\]g'U`gc'Udd`]Yg'hc']a U[Ygž'Ufh'UbX'XYg][b'dfcYWgž'Ug'k Y``'Ug dfYgYbhUh]cbg'k \YfY'gca YcbY'dfYgYbhg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci h'WfX]h'

=\uddfcdf]UhY 'dUfUd\fUg]b[ .'7\Ub[ ]b[ 'U'ZYk 'k cfXg'UbX'd\fUgYg'k \]'Y 'a cghmfYhJ]b]b[ 'h\Y'cf][ ]bU`
ghfi Whi fY 'UbX#cf'dfc[ fYgg]cb'cZ]XYUg'cZh\Y'cf][ ]bU`ž'UbX']bZcfa Uh]cb'k ]h\ci h\UW\_bck `YX[ Ya Ybh''H\]g'U`gc
Udd`]Yg']b'dfYgYbhUh]cbg'k \YfY 'gca YcbY'dUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'k cfXg'k ]h\ci h\UhYX]hUbX'hc
d]YW]b[ 'hc[ Yh\Yf'ei chYg'UbX'dUfUd\fUgYg']bhc'U'bYk 'k \c`Yž'k ]h\ci h\Uddfcdf]UhY'fYZYfYbW]b[ "

7 c``i g]cb.'k cf\_jb['k]h\ch\Yfg'Vi hdUgg]b['cZZh\Y'k cf\_'Ug'U'dYfgcb'g']bX]j ]Xi U``k cf\_"'7 c``i g]cb'U`gc ]bWi XYg'dfcj ]X]b['mci f'k cf\_'hc'Ubch\Yf'ghi XYbhVYZcfY'h\Y'Xi Y'XUhYžcf'Zcf'h\Y'di fdcgY'cZh\Ya d`U[]Uf]g]b['UhiUbmh]a Yž'dUm]b['Ubch\Yf'dYfgcb'hc'dYfZcfa 'Ub'UWUXYa ]WhUg\_ž'ghYU']b['cf'UWei]f]b[ Ubch\Yf'dYfgcb'g'UWUXYa ]Wk cf\_'UbX'Wcdm]b[']hz'cZYf]b['hc'Wca d'YhY'Ubch\Yf'dYfgcb'g'k cf\_'cf'gYY\_]b[ dUma YbhZcf'Wca d'Yh]b['UWUXYa ]Wk cf\_"

±bUddfcdf]UhY`W]hUh]cb.`7]h]b[`gcifWrg`k\]W\`\UjY`bchVYYb`fYUXžk]h\cihUW\_bck`YX[]b[`h\Y`´gYWcbXUfm´gcifWrZfca`k\]W\`\_bck`YX[Y`cZh\Ya`\Ug`VYYb`cVhU]bYX"

8 i d`]\W\n]cb`ffgY`Z\d`U[]\Uf]ga "Ł`gi Va]\n]b[`mci f`ck b`k cf\_z`]b`k \c`Y`cf`]b`dUffz`k \YfY`]h\Ug`dfYj]ci g`m VYYb`dfYdUfYX`cf`gi Va]\nYX`Zcf`Ubch\Yf`UggYgga Ybhcf`\\cf\\text{i fgY`UhI\_BGK\_`cf`Ubch\Yf`i b]j Yfg]\m'

7 cffYWnfYZYfYbWlb[ 'dfUWnWyg.

- DUfUd\fUg]b[žgi a a Uf]g]b[žYggUmk f]h]b[ 'UbX h]a Y a UbU[Ya Ybh
- 5ddfcdf]UhY'i gY'cZUbX'Uhtf]Vi h]cb'Zcf'U'fUb[Y'cZa UhYf]U`g']bWi X]b['hYl hž']a U[Ygž'Zcfa i `UY'UbX WbWYdhg"

±0X]j ]Xi U``Ugg]ghUbWr`]g`Uj U]`UV`Y`cb`fYei YghZfca `H\Y`@YUfb]b[ `7 YbhY`f\hd.#k k k "`Wi bgk "YXi "Ui #£" Gh XYbhg`UfY`U`gc`fYa ]bXYX`h\UhWUfYZ ``hja Y`a UbU[ Ya Ybh]g`Ub`]a dcfhUbhdUfhcZgh XmUbX`cbY`cZh\Y ]XYbh]Z]YX`WUi gYg`cZd`U[ ]Uf]ga `]g`dccf`hja Y`a UbU[ Ya Ybh'`Gh XYbhg`g\ci `X`U``ck `gi Z]W]Ybh'hja Y`Zcf fYgYUfW\žXfUZh]b[ `UbX`dfcdYf`fYZ/fYbW]b[ `cZgci fWfg`]b`dfYdUf]b[ `U``UggYgga Ybh']hYa g"

IBGK @]VfUfmU`gc`\Ugʻh\Y`9@G9`hcc``UjU]`UV`Y`hc`Ugg]ghmci`k]h\`mcif`ghiXmUhIBGK "'9@G9`]gXYg][bYX`hc`]bhfcXiVW`bYk`ghiXYbhg`hc`ghiXm]b[`UhIBGK`Vih]hWUb`U`gc`VY`U`[fYUhfYZfYg\Yf`Xif]b[`mcifqhiXm"

7 ca d'Yhlb[ 'h\Y'9@&9'hi hcf]U`'UbX'ei ]n'k ]`'YbUV'Y'mci 'hc.

 UbU`mgY`hcd]\Mgž'd`Ub`fYgdcbgYg`UbX`cf[Ub]gY`fYgYUf\W\`Zcf'U\WXYa]\Wk f]hjb[`UbX`ch\Yf UggYgga YbhhUg\_g